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(54) **Title:** METHODS AND APPARATUS FOR REPAIRING INOPERATIVE PIXELS IN A DISPLAY
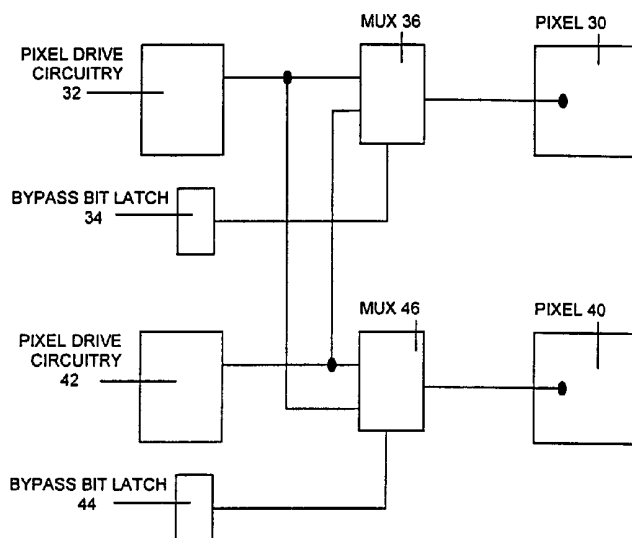
(57) **Abstract:** Methods and apparatus for repairing inoperative pixels in a display (10) are provided. In particular, the present invention provides methods and apparatus for improving the effective yield rates of displays, such as liquid crystal micro-displays, by disconnecting inoperative pixels (30) from their defective drive circuitry (32) and tying such pixels to the working drive circuit (42) of a nearby pixel. A display can be repaired without the need to provide redundant drive circuitry underneath each pixel (30, 40).

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METHODS AND APPARATUS FOR REPAIRING INOPERATIVE PIXELS IN A DISPLAY

BACKGROUND OF THE INVENTION

The present invention provides methods and apparatus for repairing inoperative

5   pixels in a display. In particular, the present invention provides methods and apparatus

for improving the effective yield rates of displays, such as liquid crystal micro-displays,

by disconnecting inoperative pixels from their defective drive circuitry and tying such

pixels to the working drive circuit of a nearby pixel.

Manufacturing of displays, such as liquid crystal (LC) micro-displays, with very

10   large numbers of pixels is hampered by low yield rates due to the large area of

semiconductor material (e.g., Complementary Metal Oxide Semiconductor (CMOS))

required for each device. Nevertheless, displays can actually tolerate a certain level of

various types of defects and still be considered acceptable. Additionally, there are

various techniques that have been developed and successfully applied to other display

15   technologies that can reduce the visibility of some types of defects and dramatically

increase the yield of acceptable displays.

For example, on a device size suitable to hold 8 million pixels (approximately 32

x 58 mm), without any repair strategy, the yield of "perfect" display devices is estimated

at less than 2% (assumed defect rate of $0.2 / cm^2$).

20   Defects in the microelectronic circuitry can cause a variety of types of

malfunctions in the resulting display, such as:

Stuck-ON Pixel   These pixels are always ON. In a three-chip RGB (red,

green, blue) system, they would be visible as a constant

red, green, or blue dot in the display. Such stuck-ON

25   pixels are much more visible in dark areas of the display

than bright areas.

| Stuck-OFF Pixel | These pixels are always OFF. In a three-chip RGB system, they would be visible as a constant cyan, magenta, or yellow dot in the display. Such stuck-OFF pixels are much more visible in the bright areas of the display than the dark areas. |

| Stuck-Intermediate | Some pixels can get stuck in an intermediate state. Depending on the intended color of the pixel and the surrounding area of the display, they will sometimes appear as red, green, or blue, and at other times will appear as the complement of the color channel affected. |

| Partial Response | Some pixels may have a portion of their circuitry affected such that they partially respond to the intended color. Perhaps they are of reduced intensity or contrast, but they still track the intended value to some degree. |

| Defective Clump | A significant portion of the circuitry in the visible area may be shared between clumps of pixels. A defect in this area may effect the entire clump of pixels and may take any of the above forms. |

| Dead Column / Row | Defects in signals generated by the drive circuitry which are fed to every pixel in a column or row will manifest themselves in the entire column or row. The manifestation may take a variety of forms. |

Although a display having any of the foregoing defects may still be useable, all such defects are significant enough that once noticed, the user will be unhappy. The only exception being perhaps a few isolated stuck-OFF pixels in the display used for the blue channel, due to the low contrast sensitivity of human vision to blue light.

5   A previously known method for dealing with such defects is to provide redundant circuitry in the display that can be selected to drive a pixel or column of pixels in the event of a defect in the primary circuitry. As it is already difficult to fit all required circuitry in the space available in such micro—displays, the inclusion of redundant circuitry becomes problematic.

10   It would be advantageous to provide a method of repairing inoperative pixels in a display without requiring redundant circuitry in order to increase the yield rate of such displays.

The methods and apparatus of the present invention provide the aforementioned and other advantages.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for repairing inoperative pixels in a display. In particular, the present invention provides methods and apparatus for improving the effective yield rates of displays, such as liquid crystal micro-displays, by disconnecting inoperative pixels from their defective drive circuitry and connecting such pixels to the working drive circuit of a nearby pixel.

The "repaired" pixel will then display the same value as the nearby pixel that it is connected to. However, since in most images, neighboring pixels are highly likely to be displaying similar values, the resulting slight error in the image is very well below acceptable limits for almost all applications. Most viewers find it difficult to detect such an artifact at all even when it is pointed out to them. As the display resolution goes higher, this type of repair becomes even more difficult to detect.

In an illustrated embodiment of the present invention, an electronic display is provided which is capable of repairing inoperative pixels. The display comprises a plurality of pixels with drive circuitry for controlling the pixels. Means for disconnecting an inoperative pixel from its defective drive circuitry are provided. The inoperative pixel is then provided with a connection to a working drive circuit of a nearby pixel.

The means for connecting the inoperative pixel to a working drive circuit may comprise additional circuitry associated with each pixel in the display. This additional circuitry connects the inoperative pixel to the working drive circuit of a nearby pixel.

In one embodiment, the additional circuitry may comprise a bypass bit latch. When the bypass bit is set, the defective drive circuitry is bypassed and the inoperative pixel is driven from the working drive circuit of a nearby pixel. The bypass bit may be loaded from an external memory after the display is turned ON. In addition, multiplexing circuitry associated with the bypass bit latch may be provided.

Alternatively, the additional circuitry may further comprise a tri-state transistor associated with each pixel connected to the bypass bit latch and a resistor coupling

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neighboring pixels. When the bypass bit is set, the transistor is switched to bypass the defective drive circuitry so that the inoperative pixel is driven from the working drive circuit of a nearby pixel through the resistor.

In a further embodiment, the additional circuitry may comprise a resistive connection between neighboring pixel metal layers. The defective drive circuitry can be disconnected from the inoperative by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the resistive connection.

Alternatively, the additional circuitry may comprise a capacitive connection between neighboring pixel metal layers. The defective drive circuitry can be disconnected from the inoperative pixel by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the capacitive connection.

The via may be severed, for example, by laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other electro-magnetic beam, electro-ionic erosion, physical cutting or removal of the metal using a sharp or abrasive implement or probe, or by any other suitable technique.

The pixels may be repaired individually or in groups (i.e., groups of up to 8 adjacent inoperative pixels may be repaired without significantly impacting the quality of the display).

In a further embodiment, the display may also comprise test circuitry to identify the defective drive circuitry.

The pixel drive circuitry associated with each pixel may be located adjacent to each pixel or located separately from each pixel.

The display may be a liquid crystal micro-display or a similar display device.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an embodiment of a liquid crystal micro-display assembly in accordance with the present invention;

5   Figure 2 shows a schematic representation of an embodiment of repair circuitry in accordance with the present invention;

Figure 3 shows a schematic representation of a further embodiment of repair circuitry in accordance with the present invention;

Figure 4 shows an alternate embodiment of repair circuitry in accordance with the present invention;

10   Figure 5 shows another alternate embodiment of repair circuitry in accordance with the present invention; and

Figure 6 shows examples of various pixel repair configurations.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to methods and apparatus for repairing inoperative pixels in a display. In particular, the present invention provides methods and apparatus for improving the effective yield rates of displays, such as liquid crystal micro-displays,

5   by disconnecting inoperative pixels from their defective drive circuitry and connecting such pixels to the working drive circuit of a nearby pixel.

The invention is particularly adapted for use with a traditional reflective liquid crystal on complimentary metal oxide semiconductor (FLC-on-CMOS) micro-display assembly with the LC material being placed on top of a CMOS control chip. Pads on the

10   top layer of the CMOS chip provide both electrical control of the LC material as well as the optical mirror for the light.

Such a display may have 8.3 million pixels arranged as 3840 pixels by 2160 pixels. The pixels may be on a 15μm pitch. The size of the active area of this exemplary display is thus 57.6 x 32.4mm. Additional control circuitry and frame buffer memory

15   (e.g., Dynamic Random Access Memory (DRAM)) along the two long sides of the circuit may be 61.4 x 3mm. Input/output (I/O) pads and an LCD seal ring would add another couple few millimeters to the overall dimensions of the chip, but these areas would be relatively immune from the very small defects typical of the CMOS process. The invention is also applicable to displays of varying sizes and types.

20   A significant amount of functionality in the circuitry under each pixel is desired. The basic modulation for each pixel may be, for example, a 10-bit counter running on a chirped clock to produce a log or gamma-corrected response. Generation of the pulse timing required by the LC material is also required under each pixel. Diagnostic capabilities may be included to verify correct operation of the control circuit for each

25   pixel. Finally, an additional 10 bits of storage may be desired to allow loading of the data for a next frame to be distributed over the entire frame time.

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Fitting this circuitry in the available space has proven challenging and drives the design towards a larger pixel pitch compared to existing designs. The smallest feasible CMOS feature sizes are also utilized. Even still, for the desired complex pixel control functionality, typical prior art redundant repair circuitry is problematic to provide in the

5   available space.

Figure 1 illustrates the arrangement of a liquid crystal-micro display in accordance with the present invention. Display area 10 is divided into several sections due to the differing impacts that defects in each section will have on the display yield. Pixel drive and repair circuitry 12 covers the majority of the device area (e.g., the pixel

10   drive circuitry comprises 92% of the active area or approximately 17.2 cm^2 and the pixel repair circuitry comprises 4% of the active area or approximately 0.07 cm^2). By providing the repair mechanisms described herein, most types of defects in this circuitry can be tolerated and still result in acceptable devices.

Signal distribution buffer circuitry 14 may comprise 4% of the active area of the

15   display or approximately 0.07 cm^2. Signals in the display are routed to every pixel in a column. Distribution buffer circuitry 14 will be required to fan these signals out over the large number of loads and distances and still meet timing requirements. Defects in these buffers will render large portions of the display inoperable and render the display unusable.

20   Column signal generation logic (1.2 cm^2) and Buffer DRAM (1.8 cm^2) are provided at 16. Column signal generation logic generates the signals for each column. Defects in this area are highly likely to render the entire display unusable since the error is likely to impact a large area of the display such as an entire column or more. Buffer DRAM is similar to conventional DRAM. If yield is a problem in this area, traditional

25   DRAM techniques of including spare rows and columns can be employed.

Input/output (I/O) pads 18 are provided. These features typically do not contribute to low yield. Cover Glass Glue-Down Area 20 also consumes a portion of the wafer, but typically does not have any features that would contribute to low yield.

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In an illustrated embodiment of the present invention as shown in Figure 1, an
electronic display 10 is provided which is capable of repairing inoperative pixels. The
display comprises a plurality of pixels with drive circuitry 12 for controlling the pixels.
Means for disconnecting an inoperative pixel from its defective drive circuitry are

5   provided. The inoperative pixel is then provided with a connection to a working drive
circuit of a nearby pixel.

Using the drive circuitry 12 of a neighboring pixel to drive an otherwise
inoperative pixel will result in the two pixels displaying the same intensity. Visual
artifacts will typically be visible in the case of high contrast textures and edges moving

10   across the two tied-together pixels at a slow rate.

The means for connecting the inoperative pixel to a working drive circuit may
comprise additional circuitry associated with each pixel in the display that connects the
inoperative pixel to the working drive circuit of a nearby pixel. The additional circuitry
may comprise discrete or integrated circuitry.

15   In one embodiment as shown in Figure 2, the additional circuitry may comprise
bypass bit latches 34, 44 which can select the source of the drive signal for pixels 30,
40. When a bypass bit is set, the defective drive circuitry is bypassed and the inoperative
pixel is driven from the working drive circuit of a nearby pixel. The bypass bit may be
loaded from an external memory after the display is turned ON. For example, in Figure

20   2, assume that pixel 30 is inoperative due to defective drive circuitry 32. After the
display is turned ON, bypass bit 34 associated with the inoperative pixel 30 is set such
that defective drive circuitry 32 is bypassed and inoperative pixel 30 is driven by
working drive circuitry 42 of a nearby pixel 40. In addition, multiplexing circuitry 36,
46 associated with bypass bit latches 34, 44 may be provided. An advantage of such an

25   arrangement is that testing and repair can be accomplished at any time in the
manufacturing process, even after assembly of the LCD.

As shown in Figure 3, the additional circuitry may alternatively comprise tri-
state transistors 38, 48 associated with each respective pixel 30, 40. Transistors 38, 48
are connected to respective bypass bit latches 34, 44 and resistor 50 couples neighboring

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pixels 30, 40. Resistor 50 may be any suitable resistor, such as a discrete resistor, an integrated circuit resistor fabricated in metal, polysilicon, or any other suitable resistive material. As an example, assume that pixel 30 is inoperative due to defective drive circuitry 32. When bypass bit 34 is set, the transistor 38 is switched to bypass defective

5   drive circuitry 32 so that inoperative pixel 30 is driven from working drive circuit 42 of nearby pixel 40 through the resistor 50. An advantage of such an arrangement is that testing and repair can be accomplished at any time in the manufacturing process, even after assembly of the LCD.

     In a further embodiment as shown in Figure 4, the additional circuitry may

10   comprise a resistor 52 coupled between pixel metal layers of nearby pixels 31, 41. Resistor 52 may comprise a discrete or integrated circuit resistor fabricated in metal, polysilicon, or any other suitable resistive material. Assuming that pixel 31 is inoperative due to defective drive circuitry 32, defective drive circuitry 32 can be disconnected from the inoperative pixel 31 by severing a via 55 connecting defective

15   drive circuitry 32 to inoperative pixel 31, such that inoperative pixel 31 is driven by a nearby pixel 41 through the resistor 52. Because the pixel drive waveform typically consists of pulses of very low duty cycle, resistor 52 typically will not contribute significantly to the power dissipation of the device.

     Additionally, since the current flowing for each pixel typically is very small,

20   resistor 52 typically will be sufficient to drive the pixel 31 with essentially the same waveform as pixel 41.

     As shown in Figure 5, the additional circuitry may alternatively comprise a capacitor 54 coupled between pixel metal layers of nearby pixels 31, 41. Assuming pixel 31 is inoperative due to defective drive circuitry 32, the defective drive circuitry 32 can

25   be disconnected from the inoperative pixel by severing a via 55 connecting the defective drive circuitry 32 to the inoperative pixel 31, such that the inoperative pixel 31 is driven by a nearby pixel 41 through the capacitor 54. Capacitor 54 may be formed from a pixel metal layer normally used for light-blocking or may comprise any other suitable capacitive connection.

The via 55 may be severed, for example, by laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other electro-magnetic beam, electro-ionic

5   erosion, physical cutting or removal of the metal using a sharp or abrasive implement or probe, or by any other suitable technique. The via 55 may comprise a fuseable link between the drive circuitry and the pixel, and the link may be "blown", e.g., by applying a suitable short circuit voltage across the link, or by any other suitable technique.

The pixels may be repaired individually or in groups. In one embodiment of the

10   invention, the amount of circuitry per pixel is reduced by sharing the bypass bit latch amongst a group of pixels. If the drive circuit for any pixel in the group fails, the bypass bit is set for that group, and each pixel in the group is then driven by the circuitry of a nearby pixel. The drive circuit used for each repaired pixel may be different or the same for each pixel in the group. Even though some working pixels are bypassed in the group,

15   the overall quality of the display is still improved by removing the stuck-ON or stuck-OFF defect(s). Groups may be any size depending on the demands of the application, but typically groups larger than 8 pixels begin to have diminishing returns in terms of space saved in relation to quality of the repair.

Figure 6 shows examples of various pixel repair configurations, including

20   examples of individual pixel repair and examples of various pixel repair groupings. In the repair example 100, the defective pixels 101 may be driven by an adjacent pixel located either to the left or the right of the defective pixel (e.g., pixels 102 and 103). In repair example 200, a 4 pixel group (2 X 2) of defective pixels is repaired by driving the defective pixels 201 using the drive circuitry of pixels located to the left (202, 203) or

25   the right (204, 205) of the 4 pixel group. In repair example 300, an 8 pixel group (4 X 2) of defective pixels 301 is repaired using pixels located above (302, 303), below (304, 305), to the left (306, 307) and to the right (308, 309). In repair example 400, a 16 pixel group (4 X 4) of defective pixels 401 is repaired using pixels above (402, 403), below

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(404, 405), to the left (406, 407, 408, 409), and to the right (410, 411, 412, 413). Pixels
402, 403, 404, and 405 are shown as driving a respective adjacent pixel as well as a
respective pixel located in the interior of the 4 X 4 defective pixel block 401. It will be
appreciated that any of the other pixels (406-413) can be used to drive an adjacent pixel
5   and an interior pixel.

The repair examples shown in Figure 6 are illustrative examples, and it will be
appreciated that a defective pixel may be driven by any of the adjacent pixels (including
for example, pixels located above, below, or diagonally from the defective pixels).
Further, it will be appreciated that defective pixels may be repaired by connecting the
10   defective pixels to the drive circuitry of non-adjacent pixels (as shown, for example, in
repair example 400).

In a further embodiment, the display may also comprise test circuitry to identify
the defective drive circuitry. For example, all the pixels in a row may be tested in
parallel using wired-OR and wired-AND circuitry. Rows with an inoperative pixel will
15   then be subject to an additional series of tests to identify the exact pixel in the row that
is inoperative.

The pixel drive circuitry associated with each pixel may be located adjacent to
each pixel or located separately from each pixel. Moving the drive circuitry for each
pixel so it is not necessarily physically located under the pixel that it drives allows for
20   nearby repair partner pixels with non-adjacent drive circuitry. Depending on the size of
defects that may occur, the drive circuitry for repair partners can be located one, two, or
more pixels away from the pixels that they drive. Since the total number of defects
typically is small, the probability of two independent defects damaging any given pair of
repair partner pixels becomes negligible.

25   The display may be a liquid crystal micro-display or other suitable displays that
comprise integrated circuit manufacturing techniques.

It should now be appreciated that the present invention provides an improved
method and apparatus for repairing inoperative pixels in a display. In particular, the
invention provides an improved method and apparatus for repairing defective pixels in a

liquid crystal micro-display without the need to provide redundant drive circuitry underneath each pixel.

Although the invention has been described in connection with various preferred embodiments, it should be appreciated that numerous adaptations and modifications can be made thereto without departing from the scope of the invention as set forth in the claims. In particular, the invention is not limited to liquid crystal micro displays, and can be used in connection with the many different types of display technology.

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What is claimed is:

1.   A method for repairing inoperative pixels in a display, comprising:
        identifying defective drive circuitry for the inoperative pixel;
        disconnecting the defective drive circuitry from the inoperative pixel; and
        connecting the inoperative pixel to a working drive circuit of a nearby pixel.

2.   A method in accordance with claim 1, wherein the step of connecting the
inoperative pixel to a working drive circuit of a nearby pixel further comprises:
        providing additional circuitry associated with each pixel in the display, which
circuitry connects the inoperative pixel to the working drive circuit of a nearby pixel.

3.   A method in accordance with claim 2, wherein the additional circuitry comprises
a bypass bit latch, such that when the bypass bit is set, the defective drive circuitry is
bypassed and the inoperative pixel is driven from the working drive circuit of a nearby
pixel.

4.   A method in accordance with claim 3, wherein the bypass bit is loaded from an
external memory after the display is turned on.

5.   A method in accordance with claim 3, wherein the step of providing additional
circuitry further comprises:
        multiplexing the drive circuits of each pixel with the drive circuit of a nearby
pixel.

6.   A method in accordance with claim 3, wherein the additional circuitry further
comprises:
        a tri-state transistor associated with each pixel connected to the bypass bit latch;
and

a resistor coupling neighboring pixels;

such that when the bypass bit is set, the transistor is switched to bypass the defective drive circuitry so that the inoperative pixel is driven from the working drive circuit of a nearby pixel through the resistor.

7.   A method in accordance with claim 2, wherein the additional circuitry comprises:

a resistive connection between neighboring pixel metal layers;

wherein disconnecting the defective drive circuitry is accomplished by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the resistive connection.

8.   A method in accordance with claim 7, wherein the via is severed by one of laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other electro-magnetic beam, electro-ionic erosion, or physical cutting or removal of the metal using a sharp or abrasive implement or probe.

9. A method in accordance with claim 2, wherein the additional circuitry comprises:

a capacitive connection between neighboring pixel metal layers;

wherein disconnecting the defective drive circuitry is accomplished by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the capacitive connection.

10.   A method in accordance with claim 9, wherein the via is severed by one of laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other

electro-magnetic beam, electro-ionic erosion, or physical cutting or removal of the metal using a sharp or abrasive implement or probe.

11.   A method in accordance with claim 1, wherein the pixels are repaired in groups.

12.   A method in accordance with claim 1, wherein identifying defective drive circuitry comprises the further step of providing test circuitry associated with the display.

13.   A method in accordance with claim 1, wherein the pixel drive circuitry associated with each pixel is located separately from each pixel.

14.   A method in accordance with claim 1, wherein the display is a liquid crystal micro-display.

15.   An electronic display apparatus capable of repairing inoperative pixels, comprising:
    a plurality of pixels;
    drive circuitry for controlling the pixels;
    means for disconnecting defective drive circuitry from an inoperative pixel; and
    means for connecting the inoperative pixel to a working drive circuit of a nearby pixel.

16.   Apparatus in accordance with claim 15, wherein the means for connecting the inoperative pixel to a working drive circuit comprises:
    additional circuitry associated with each pixel in the display, which circuitry connects the inoperative pixel to the working drive circuit of a nearby pixel.

17.   Apparatus in accordance with claim 16, wherein the additional circuitry comprises a bypass bit latch, such that when the bypass bit is set, the defective drive circuitry is bypassed and the inoperative pixel is driven from the working drive circuit of a nearby pixel.

18.   Apparatus in accordance with claim 17, wherein the bypass bit is loaded from an external memory after the display is turned on.

19.   Apparatus in accordance with claim 17, wherein the additional circuitry further comprises:

multiplexing circuitry associated with the bypass bit latch.

20.   Apparatus in accordance with claim 17, wherein the additional circuitry further comprises:

a tri-state transistor associated with each pixel connected to the bypass bit latch; and

a resistor coupling neighboring pixels;

such that when the bypass bit is set, the transistor is switched to bypass the defective drive circuitry so that the inoperative pixel is driven from the working drive circuit of a nearby pixel through the resistor.

21.   Apparatus in accordance with claim 16, wherein the additional circuitry comprises:

a resistive connection between neighboring pixel metal layers;

wherein the defective drive circuitry can be disconnected from the inoperative pixel by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the resistive connection.

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22.   Apparatus in accordance with claim 21, wherein the via is severed by one of laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other electro-magnetic beam, electro-ionic erosion, or physical cutting or removal of the metal using a sharp or abrasive implement or probe.

23.   Apparatus in accordance with claim 16, wherein the additional circuitry comprises:
        a capacitive connection between neighboring pixel metal layers;
        wherein the defective drive circuitry can be disconnected from the inoperative pixel using by severing a via connecting the defective drive circuitry to the inoperative pixel, such that the inoperative pixel is driven by a nearby pixel through the capacitive connection.

24.   Apparatus in accordance with claim 23, wherein the via is severed by one of laser ablation, melting or ablation of a fusible link by passing sufficient current through it, selective chemical etching using a photoresist or other selection means, melting or ablation with an electron beam, melting or ablation with a focused microwave or other electro-magnetic beam, electro-ionic erosion, or physical cutting or removal of the metal using a sharp or abrasive implement or probe.

25.   Apparatus in accordance with claim 15, wherein the pixels are repaired in groups.

26.   Apparatus in accordance with claim 15, further comprising test circuitry to   .
identify the defective drive circuitry.

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27.   Apparatus in accordance with claim 15, wherein the pixel drive circuitry associated with each pixel is located separately from each pixel.

28.   Apparatus in accordance with claim 15, wherein the display comprises a liquid crystal micro-display.
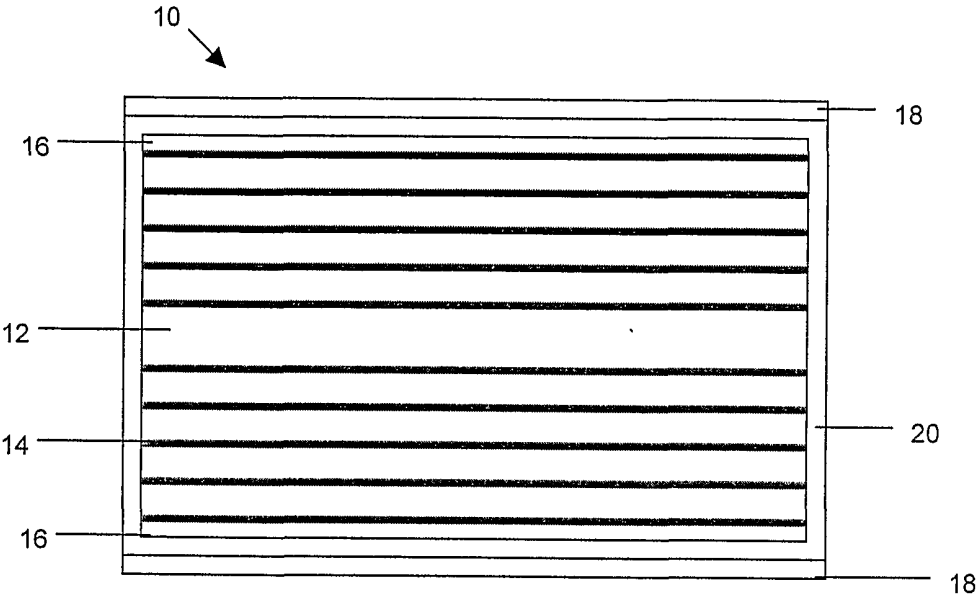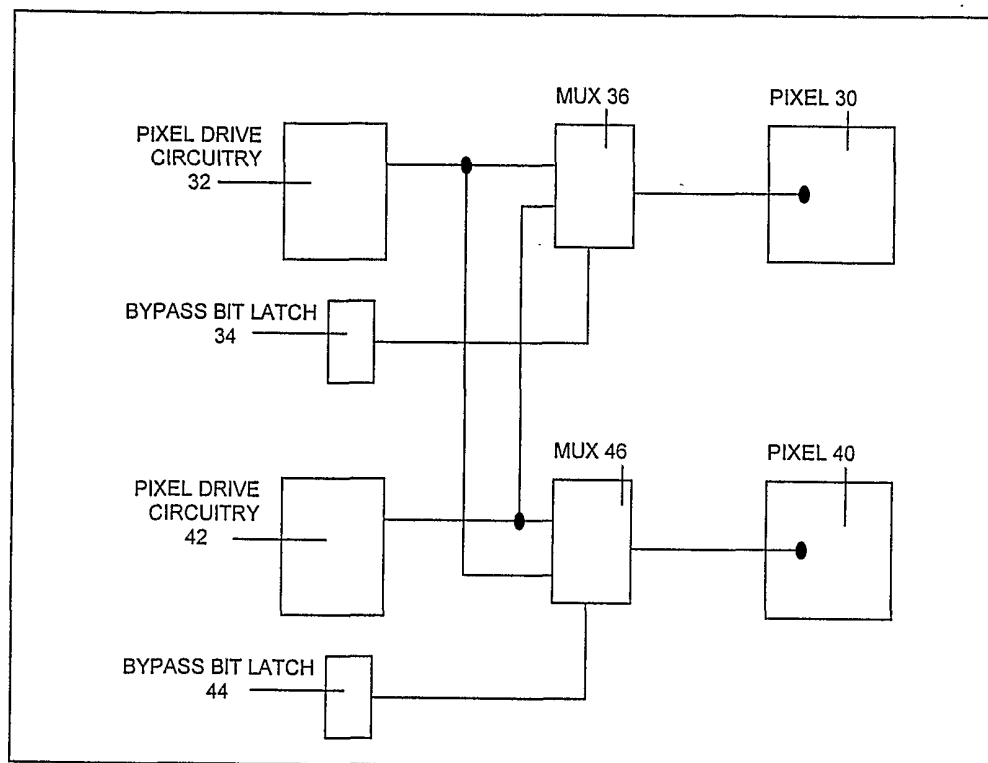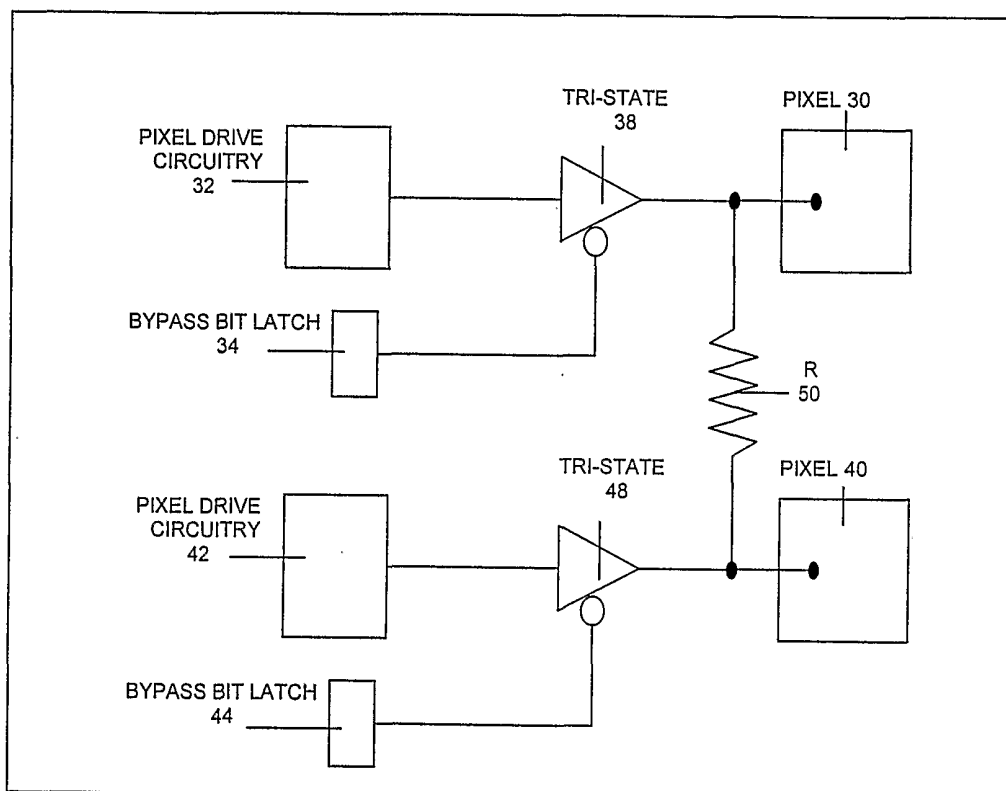
FIG. 1

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FIG. 2

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FIG. 3

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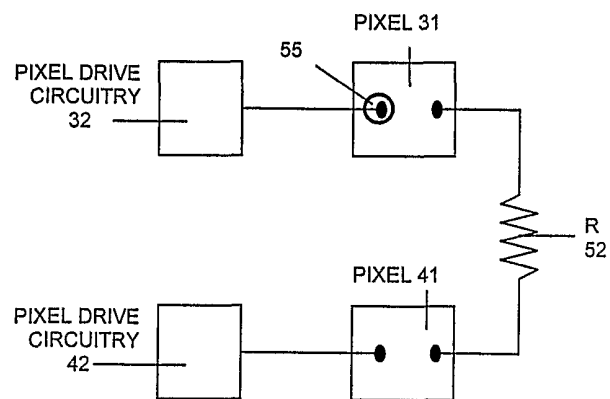VIA CUT BY LASER TO DISCONNECT PIXEL FROM DEFECTIVE DRIVE CIRCUIT

FIG. 4

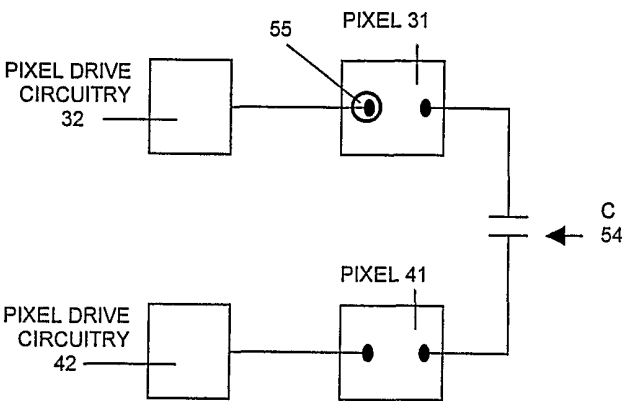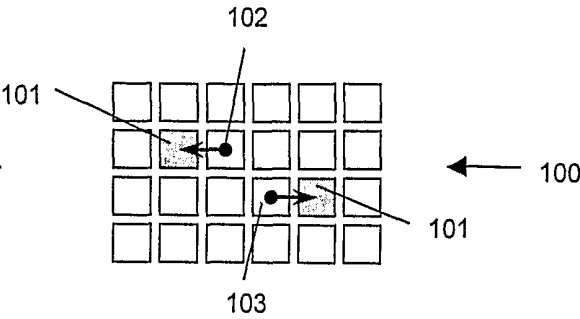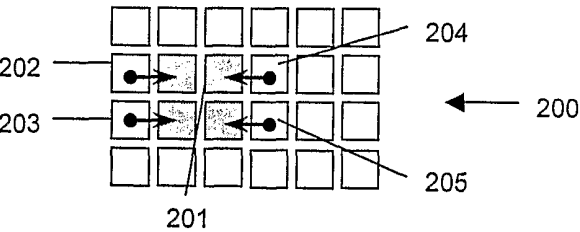VIA CUT BY LASER TO DISCONNECT PIXEL FROM DEFECTIVE DRIVE CIRCUIT
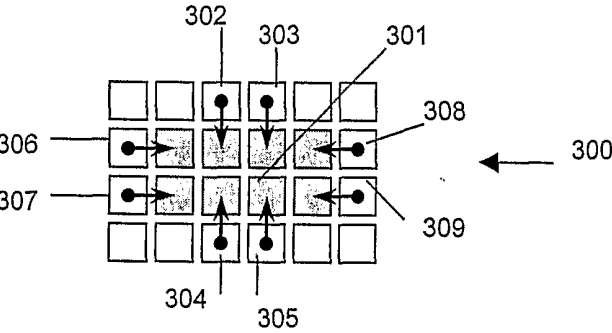

FIG. 5

SINGLE-PIXEL (1 X 1).

4-PIXEL GROUP (2 X 2).

8-PIXEL GROUP (4 X 2).

16-PIXEL GROUP (4 X 4).
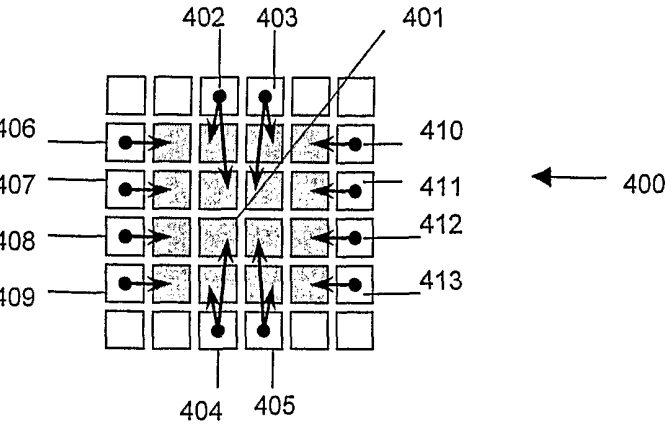

FIG. 6