

COLOR DISPLAY HAVING HORIZONTAL SUB-PIXEL ARRANGEMENTS AND LAYOUTS

BACKGROUND

[001] The present application relates to improvements to display layouts, and, more particularly, to improved color pixel arrangements.

[002] Full color perception is produced in the eye by three-color receptor nerve cell types called cones. The three types of cones are sensitive to different wavelengths of light: long, medium, and short ("red", "green", and "blue", respectively). The relative density of the three differs significantly from one another. There are slightly more red receptors than green receptors. There are very few blue receptors compared to red or green receptors.

[003] The human vision system processes the information detected by the eye in several perceptual channels: luminance, chrominance, and motion. Motion is only important for flicker threshold to the imaging system designer. The luminance channel takes the input from only the red and green receptors. In other words, the luminance channel is "color blind." It processes the information in such a manner that the contrast of edges is enhanced. The chrominance channel does not have edge contrast enhancement. Since the luminance channel uses and enhances every red and green receptor, the resolution of the luminance channel is several times higher than the chrominance channels. Consequently, the blue receptor contribution to luminance perception is negligible. The luminance channel thus acts as a resolution band pass filter. Its peak response is at 35 cycles per degree (cycles/°). It limits the response at 0 cycles/° and at 50 cycles/° in the horizontal and vertical axis. This means that the luminance channel can only tell the relative brightness between two areas within the field of view. It cannot tell the absolute brightness. Further, if any detail is finer than 50 cycles/°, it simply blends together. The limit in the horizontal axis is slightly higher than the vertical axis. The limit in the diagonal axes is significantly lower.

[004] The chrominance channel is further subdivided into two sub-channels, to allow us to see full color. These channels are quite different from the luminance channel, acting as low pass filters. One can always tell what color an object is, no matter how big it is in our field of view. The red/green chrominance sub-channel resolution limit is at 8 cycles/°, while the yellow/blue chrominance sub-channel resolution limit is at 4 cycles/°. Thus, the error introduced by lowering the red/green resolution or the yellow/blue resolution by one octave will be barely noticeable by the most perceptive viewer, if at all, as experiments at Xerox and NASA, Ames Research Center (see, e.g., R. Martin, J. Gille, J. Larimer, Detectability of Reduced Blue Pixel Count in Projection Displays, SID Digest 1993) have demonstrated.

[005] The luminance channel determines image details by analyzing the spatial frequency Fourier transform components. From signal theory, any given signal can be represented as the summation of a series of sine waves of varying amplitude and frequency. The process of teasing out, mathematically, these sine-wave-components of a given signal is called a Fourier Transform. The human vision system responds to these sine-wave-components in the two-dimensional image signal.

[006] Color perception is influenced by a process called “assimilation” or the Von Bezold color blending effect. This is what allows separate color pixels (also known as sub-pixels or emitters) of a display to be perceived as a mixed color. This blending effect happens over a given angular distance in the field of view. Because of the relatively scarce blue receptors, this blending happens over a greater angle for blue than for red or green. This distance is approximately 0.25° for blue, while for red or green it is approximately 0.12°. At a viewing distance of twelve inches, 0.25° subtends 50 mils (1,270 μ) on a display. Thus, if the blue pixel pitch is less than half (625 μ) of this blending pitch, the colors will blend without loss of picture quality. This blending effect is directly related to the chrominance sub-channel resolution limits described above. Below the resolution limit, one sees separate colors, above the resolution limit, one sees the combined color.

BRIEF DESCRIPTION OF THE DRAWINGS

[007] The accompanying drawings, which are incorporated in, and constitute a part of this specification illustrate implementations and embodiments of the invention and, together with the description, serve to explain principles of the invention.

[008] Figure 1 shows a repeat cell of six sub-pixels wherein the sub-pixels are laid out length-wise horizontally.

[009] Figure 2A through 2F depicts various embodiments of sub-pixel arrangements laid out in a horizontal fashion.

[010] Figure 3 shows a novel six sub-pixel repeat cell arrangement for a panel display.

[011] Figure 4 shows one embodiment of an arrangement of sub-pixels laid out in a horizontal fashion connected to column and row drivers.

[012] Figure 5 shows one embodiment of a set of TFT connections to a sub-pixel arrangement.

[013] Figures 6A and 6B show two separate embodiments of an arrangement of sub-pixels comprising unique connections of its TFTs to the column drivers.

[014] Figures 7 and 8 show two separate embodiments of a TFT connection for a novel eight sub-pixel repeat cell arrangement.

[015] Figure 9 shows one possible dot inversion scheme for one embodiment of an arrangement laid out in a horizontal fashion.

[016] Figures 10 and 11 depict two different embodiments of TFT connections to driver without use of crossovers for the novel eight sub-pixel repeat cell arrangement.

[017] Figures 12A, 12B, and 12C depict various embodiments of a system architecture for panels comprising arrangements of sub-pixels laid out in a horizontal fashion.

DETAILED DESCRIPTION

[018] Reference will now be made in detail to implementations and embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

Sub-Pixel Arrangements

[019] In Figure 1, an arrangement of sub-pixel emitters 100 is shown, comprising a six sub-pixel repeat cell comprised of three colors. This six sub-pixel repeat cell was substantially shown in the '232 application – however, the sub-pixels in Figure 1 are laid out lengthwise along the horizontal axis. For example, the horizontal width of the sub-pixels can be greater in length than the vertical height of the sub-pixels. In one embodiment, sub-pixels 106 are blue colored, while sub-pixels 102 and 104 could be assigned either red or green colored, respectively. In another embodiment, sub-pixels 106 could be assigned the color green, while sub-pixels 102 and 104 are either red or blue colored, respectively. In yet another embodiment, sub-pixels 106 could be assigned the color red, while sub-pixels 102 and 104 are either green or blue colored, respectively. Other color variations can be implemented as well, which are different from red, green and blue, such that the color gamut of the resulting arrangement creates a useable display from a user's standpoint.

[020] As shown in Figure 1, sub-pixels 102 and 104 are displayed in a “checkerboard” fashion – whereby the red and green sub-pixel subplanes are displayed 180 degrees out of phase. Such a checkerboard pattern has been previously disclosed in the '232 application and in U.S. Patent Application No. 09/628,122 (“the '122 application”), entitled “ARRANGEMENT OF COLOR PIXELS FOR FULL COLOR IMAGING DEVICES WITH SIMPLIFIED ADDRESSING,” filed on July 28, 2000, which is hereby incorporated herein by reference and is commonly owned by the same assignee of this application – and such a checkerboard arrangement is similarly advantageous with the sub-pixels laid out in the horizontal axis as in the vertical axis.

[021] As was disclosed in the '394 application, an entire panel constructed with the sub-pixels lengthwise in the vertical axis (e.g., the vertical height having a greater length than the horizontal width) could be enabled in software to perform sub-pixel rendering when the panel is physically rotated 90 degrees from the vertical – in essence, running the panel with all sub-pixels in the horizontal axis. This feature enabled a single panel to perform sub-pixel rendering while displaying images in either the landscape or portrait mode of operation.

[022] It may be advantageous, however, to physically construct a panel with all sub-pixels laid out length-wise along the horizontal axis (e.g., the vertical height having a smaller length than the horizontal width). In particular, with sub-pixels 106 assigned with the color blue, one advantage is that the blue stripe is moved from the vertical to horizontal axis – thus, de-emphasizing the presence of a contiguous blue structure, which is more apparent to the human eye along the vertical axis than it is along the horizontal axis. A vertical blue stripe, thus, tends to interfere with text readability and uniformity as text is comprised mostly of vertical strokes. A similar advantage is also possible with sub-pixels 106 assigned the color green.

[023] Figures 2A-2F depict several alternative embodiments of sub-pixel arrangements laid out in the horizontal axis. Figure 2A show that the sub-pixels 106 are effectively twice the length along the horizontal axis of sub-pixels 102 and 104. Such a choice of length for sub-pixel 106 was previously disclosed in the '232 application along the vertical axis. Also shown, sub-pixels 106 could be of smaller width along the vertical axis than sub-pixels 102 and 104. Such a choice for length along the vertical axis is also disclosed in the related co-pending applications noted above.

[024] Figure 2C and 2D depict the addition of a “black” pixel 108 that is disclosed in the co-pending and commonly assigned U.S. Patent Application No. 10/278,328, entitled “IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS WITH REDUCED BLUE LUMINANCE WELL VISIBILITY,” filed on Oct. 22, 2002. Black pixel 108 could

also be deployed in a staggered fashion, as shown in Figure 2D. Figures 2E and 2F depict the addition of a fourth color pixel 110 as was previously disclosed in U.S. Patent Application No. 10/243,094, entitled "IMPROVED FOUR COLOR ARRANGEMENTS OF EMITTERS FOR SUB-PIXEL RENDERING," filed on September 13, 2002, which is hereby incorporated herein by reference and commonly owned by the same assignee of this application.

[025] Figure 3 depicts an alternative arrangement 300 of sub-pixels comprising a 3x2 column/row repeat cell 302. One possible color assignment for arrangement 300 has sub-pixels 106 as blue, sub-pixels 102 as red, and sub-pixels 104 as green. This arrangement may be considered somewhat as placing the blue sub-pixel stripes on the horizontal axis, even though each sub-pixel has its lengthwise edge on the vertical axis. This arrangement further disperses the blue stripe by staggering the placement of blue sub-pixels; while slightly altering the red/green checkerboard pattern somewhat by placing the red and green subplanes partially 45 degrees out of phase thereby staggering the red and the green sub-pixels in a novel manner.

Circuit Architecture

[026] Figure 4 depicts a high level architecture diagram whereby one exemplary sub-pixel arrangement 400 is laid out in the horizontal fashion described above and column drivers 402 and row drivers 404 are electrically mated to arrangement 400.

[027] For panels employing thin film transistors (TFTs) to actuate or drive sub-pixels, Figure 5 depicts one embodiment of a TFT layout for the basic arrangement of Figure 1. Each sub-pixel is connected to a column line 502 and a row line 504. TFT 506, located at each sub-pixel, actuates or drives a sub-pixel according to signals that are resident on its connected row and column line.

[028] Figures 6A and 6B depict two alternative embodiments of TFT layouts 602 and 604 respectively. Each layout alters the location of the third column line differently from that of Figure 5. In Figures 6A and 6B, the third column line is on

the right or left of the second column of sub-pixels respectively. In Figure 6A, there is a crossover of the third column line by the blue data going to the blue sub-pixel in the second row. In Figure 6B, there are no data crossovers, which may minimize crosstalk. In either case, aperture ratio may decrease to allow for the extra column line.

[029] Figures 7 and 8 depict a layout for an arrangement 700 of sub-pixels comprising a repeat cell 702 of eight sub-pixels. This repeat cell -- with its various color assignments for sub-pixels 102, 104 and 106 -- is further disclosed in co-pending and commonly assigned U.S. Patent Applications: U.S. Patent Application No.10/278,352, entitled "IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH SPLIT BLUE SUB-PIXELS," filed on Oct. 22, 2002, and U.S. Patent Application No.10/278,353, entitled "IMPROVEMENTS TO COLOR FLAT PANEL DISPLAY SUB-PIXEL ARRANGEMENTS AND LAYOUTS FOR SUB-PIXEL RENDERING WITH INCREASED MODULATION TRANSFER FUNCTION RESPONSE," filed on Oct. 22, 2002, respectively. Figure 7 shows this arrangement as laid out in a horizontal fashion. This octal grouping is unique in that it presents an extra stripe of sub-pixels 102. The TFT layout for this arrangement may be constructed without adding TFTs (704) or without adding extra drivers (706), as shown in Figures 7 and 8 respectively.

[030] With a color assignment of blue sub-pixels 106, red sub-pixels 102 and green sub-pixels 104, it can be seen in Figure 7 that the blue data is sent to two blue sub-pixels through one TFT. There is a crossover of the red/green data line which may lead to some crosstalk. In Figure 8, there are additional TFTs, but there are no crossovers.

[031] In the various arrangements above embodied in an AMLCD panel, a "dot inversion" scheme may be employed to operate the panel. Both a 1x1 and 2x1 dot inversion scheme have been previously discussed as suitable. In particular, a 2x1 dot inversion scheme may reduce crosstalk in some of these embodiments. In cases

where there are two column lines adjacent, there may be two pixels that have the same polarity next to each other. However, the intervening data line is of opposite polarity, so low crosstalk may still be achieved. As one example, Figure 9 depicts a dot inversion scheme for AMLCD panels having the arrangement of Figures 6A and 6B.

[032] To achieve substantially the same number of drivers with the display utilizing octal repeat cell 702 as a display with a repeat cell shown in Figure 1, it is possible to interconnect the two blue columns 106. In a TFT array, this could be achieved with row or column metal lines. In a passive display, on the other hand, there is typically only the titanium tin oxide ITO line and no easy way to add a crossover. Therefore, the crossover is made in the column driver or on the TAB. This might add some cost and complexity to the display.

[033] To achieve a similar result without crossovers, Figures 10 and 11 depict two layouts – 1000 and 1100 respectively -- for an arrangement similarly comprising the octal repeat cell of 702. The connections are made on alternate sides in such a manner as to eliminate the crossover. In Figure 10, the number of leads on right and left are in the ratio of 2:1. The advantage of this connection is that the organization of data in column drivers is less complex. The connection pattern may be repeated to the bottom of the LCD.

[034] In Figure 11, the number of leads on each side is balanced. The order of data may be more complicated though. Left side data can proceed as follows: G1/R1, B3/4, R4/G4, etc., and the right side data can proceed as follows: B1/2, R2/G2, G3/R3, etc. This pattern may be repeated to the bottom of the display.

[035] Thus, in displays where there are electrode connections on both sides of the display, the number of connections to the column driver is reduced and the number of column drivers required is the same as for a display based on the repeat cell shown in Figure 1. For mobile phone STN displays, which do not have any crossover metal capability, this can lead to cost reduction for displays incorporating octal repeat group 702.

System Architecture

[036] Figures 12A, 12B and 12C depict various system architectures 1210, 1220, and 1230, respectively, that may vary depending upon the driving scheme. As may be seen, these various embodiments differ in the location of the sub-pixel rendering (SPR) logic location within the system. The system architectures 1210, 1220, and 1230 of Figures 12A, 12B, and 12C, respectively, may apply to the various layouts shown in Figures 6-8. The components described in Figures 12A, 12B, and 12C can operate in a manner described in U.S. Patent Application No. 10/150,355, entitled "METHODS AND SYSTEMS FOR SUB-PIXEL RENDERING WITH GAMMA ADJUSTMENT," filed on May 17, 2002, which is hereby incorporated herein by reference and commonly owned by the same assignee of this application, to perform sub-pixel rendering techniques with the sub-pixel arrangements disclosed herein.

[037] While the invention has been described with reference to exemplary embodiments, various modifications or changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings without departing from the essential scope thereof. For example, some of the embodiments above may be implemented in other display technologies such as Organic Light Emitting Diode (OLED), ElectroLumenscent (EL), Electrophoretic, Active Matrix Liquid Crystal Display (AMLCD), Passive Matrix Liquid Crystal display (AMLCD), Incandescent, solid state Light Emitting Diode (LED), Plasma Display Panel (PDP), and Iridescent. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed herein as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

What is claimed is:

1 A display comprising:

a plurality of a sub-pixel group; said sub-pixel group comprising a plurality of sub-pixels wherein each sub-pixel having a height along a vertical axis and a width along a horizontal axis, the width being greater in length than the height;

a column driver coupled to each said sub-pixel in a column of the sub-pixel group;

a row driver coupled to each said sub-pixel in a row of the sub-pixel group;
and

wherein each said sub-pixel of the sub-pixel group is coupled to said row driver along said width of said sub-pixel.

2. The display as recited in Claim 1 wherein said sub-pixel group comprises substantially a red sub-pixel and a green sub-pixel checkerboard pattern.

3. The display as recited in Claim 2 wherein said sub-pixel group comprises blue sub-pixels, each of said blue sub-pixels is aligned substantially along a horizontal axis on said display.

4. The display as recited in Claim 1 wherein said sub-pixel group comprises substantially a red sub-pixel and a blue sub-pixel checkerboard pattern.

5. The display as recited in Claim 4 wherein said sub-pixel group comprises green sub-pixels, each of said green sub-pixels is aligned substantially along a plurality of horizontal axes on said display.

6. The display as recited in Claim 1 wherein said display further comprises:

a plurality of row lines, and wherein

said plurality of a sub-pixel group further comprises a plurality of rows of red and green sub-pixels and a plurality of rows of blue sub-pixels, wherein said red sub-pixels and said green sub-pixels substantially comprising a checkerboard pattern and

said blue sub-pixels are aligned substantially along a plurality of horizontal axes on said display;

wherein every row of sub-pixels are connected to a row line on alternating sides of said panel; and

further wherein each two adjacent rows of blue sub-pixels are coupled to one row line.

7. The display as recited in Claim 6 wherein said each two adjacent rows of blue sub-pixels are coupled to one row line on a single side of said panel.

8. The display as recited in Claim 6 wherein said each two adjacent rows of blue sub-pixels are couple to a row line on alternating sides of said panel.

9. A display comprising:

a plurality of a sub-pixel group; said sub-pixel group comprising a plurality of sub-pixels, wherein each said sub-pixel comprises one of a group, said group comprising a first color sub-pixel, a second color sub-pixel and a third sub-pixel; and

wherein said sub-pixel group further comprises two rows and four columns; wherein a first set of two non-adjacent columns comprise four sub-pixels of a first color and a second set of two non-adjacent columns comprise two sub-pixels of a second color and two sub-pixels of a third color; and

wherein further said sub-pixels of said second color and said sub-pixels of said third color comprise a checkerboard pattern.

10. The display as recited in Claim 9 wherein said first color comprises a green color and each said second color and said third color comprise one of a group, said group comprising red and blue colors, respectively.

11. The display as recited in Claim 9 wherein said first color comprises a red color and each said second color and said third color comprise one of a group, said group comprising green and blue colors, respectively.

12. The display as recited in Claim 9 wherein said first set of two non-adjacent columns further comprise four sub-pixels of a first color wherein said four

sub-pixels of a first color comprising a smaller area than said sub-pixels of second color and said sub-pixels of said third color.

13. The display as recited in Claim 9 wherein said display comprises an AMLCD display and said display applies a dot inversion scheme for driving the sub-pixels.

14. The display as recited in Claim 13 wherein said dot inversion scheme is 1x1 dot inversion.

15. The display as recited in Claim 13 wherein said dot inversion scheme is 2x1 dot inversion.

16. A display comprising:
a plurality of sub-pixel arrangements, each sub-pixel arrangement comprising a plurality of sub-pixels such that each pixel is oriented on the display with a width along a horizontal axis greater in length than a height along a vertical axis.

17. The display of claim 16, wherein at least two of the sub-pixels in each sub-pixel arrangement receive a voltage of opposite polarity.

18. The display of claim 16, wherein each sub-pixel arrangement includes alternating red and green sub-pixels.

19. A display comprising:
a plurality of pixels, each pixel is oriented on the display with a width along a horizontal axis greater in length than a height along a vertical axis; and
a controller to process input pixel data and to sub-pixel render the pixel data for output on the plurality of pixels on the display.

20. The display of claim 19, wherein the plurality of pixels include a red and green sub-pixel checker-board pattern.