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(84) Designated Contracting States: AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR Designated Extension States: AL LT LV MK RO SI	(72) Inventor: JÄRVENTÖ, Jussi 33100 Tampere (FI) (74) Representative: Pursiainen, Timo Pekka Tampereen Patenttitoimisto Oy, Hermiankatu 12B 33720 Tampere (FI)
(71) Applicant: Mitron OY 30100 Forssa (FI)	

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System and method for controlling a liquid crystal display and a liquid crystal display

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The invention relates to a system and method for controlling a liquid crystal display (1) comprising at least one pixel (p). The system comprises means (3) for providing control information for said at least one pixel (p) according to a desired brightness for the pixel. The system comprises means (6, 7, 8, 10, 12) for forming at least a first control signal (COM) and a second control

signal (SIG) for said at least one pixel having a phase shift respective to the desired brightness. The first control signal (COM) is connected to the first electrode of said at least one pixel and the second control signal (SIG) is connected to the second electrode of said at least one pixel (p). The invention further relates to a liquid crystal display (1).

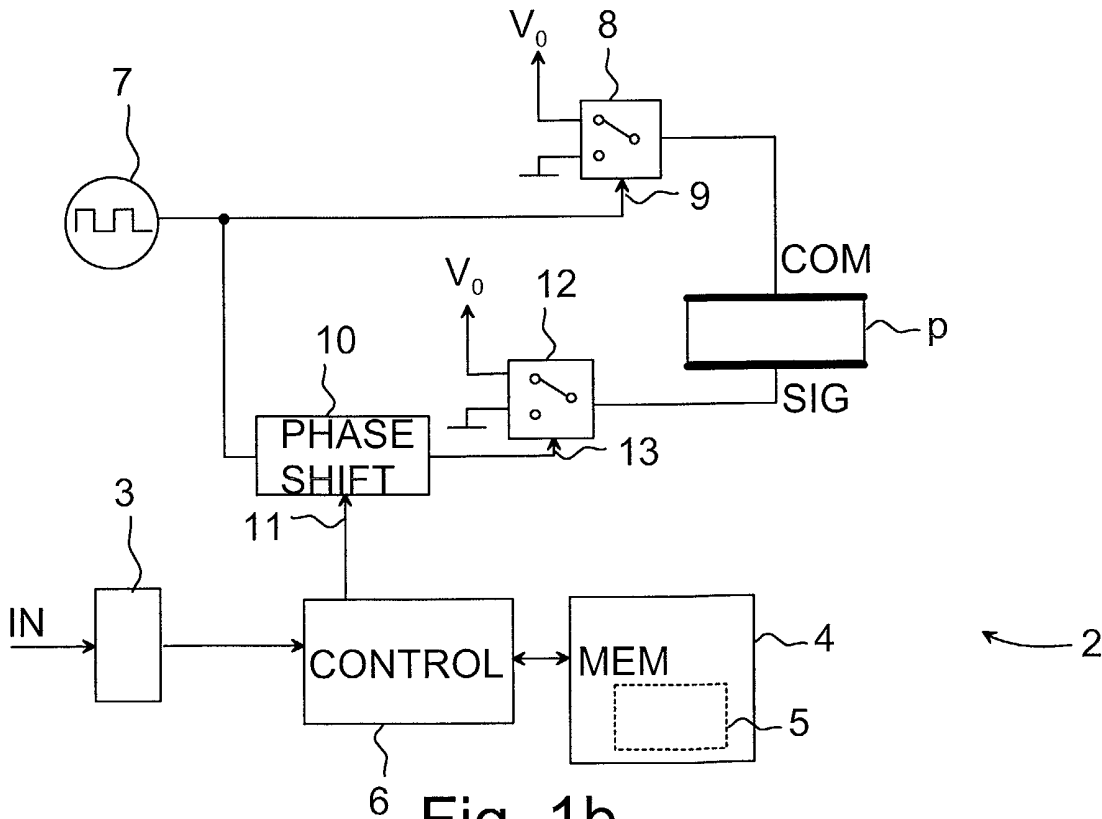


Fig. 1b

Description**Technical field**

[0001] The present invention relates to a system for controlling a liquid crystal display comprising at least one pixel, the system comprising means for providing control information for said at least one pixel according to a desired brightness for the pixel. The invention further relates to a method for controlling a liquid crystal display comprising at least one pixel, in which control information is provided for said at least one pixel according to a desired brightness for the pixel. The invention also relates to a liquid crystal display comprising at least one pixel, and means for providing control information for said at least one pixel according to a desired brightness for the pixel.

Discussion of the related art

[0002] Liquid crystal displays (LCD) are known in which more than two alternatives for the pixel brightness are available. This kind of liquid crystal displays can be used either to illustrate grey scale images or colour images. The liquid crystal displays for illustrating colour images actually comprise three different pixels (subpixels) and colour filters for each subpixel of the image. The colour filters form red, green and blue colours, respectively. The combination of the three subpixels can be seen as one colour pixel. The ratio of the brightness of the three subpixels define the colour of the pixel, which a human eye sees. In fact, the colour displays can be imagined to comprise three separate grey scale displays. In the present application, therefore, only grey scale liquid crystal displays (liquid crystal displays for short) are handled but the same principles can be broadened to cover colour liquid crystal displays, too.

[0003] Liquid crystal displays comprise normally a large number of pixels arranged in matrix form. The pixels are controlled according to the details of the image to be displayed on the liquid crystal display. Each pixel can be controlled separately but not necessarily simultaneously. Typically the electrodes of the pixels are connected in series in such a way that one electrode of each pixel within one row of the display are connected together, and the other electrode of each pixel within one column of the display are connected together. The pixels of this kind of liquid crystal display can be controlled one row at a time or one columns at a time. Therefore, each pixel within one row (or column) produces a brightness information substantially simultaneously. If all the rows (or columns) of the display are scanned fast enough, a human eye cannot notice the multiplexed control method of the liquid crystal display but sees the image as a whole.

[0004] There are certain requirements the control systems for the grey scale liquid crystal displays have to fulfil. A brightness of a pixel of the liquid crystal display is controlled by providing an adjustable voltage between a first electrode and a second electrode of the pixel. The driving voltage has to be alternating voltage (AC) because a direct voltage (DC) connected between the electrodes of a pixel causes chemical reactions in the liquid and significantly decreases the life time of the pixel. Therefore the duty cycle of the driving voltage is normally very small. In prior art systems the brightness control is achieved by *e.g.* adjusting the voltage level between the electrodes of the pixel according to the control information, which contains information about the desired brightness for the pixel in question.

[0005] The patent US-4,427,978 presents a field effect liquid crystal display wherein a composite alternating voltage is successively produced across a matrix of pixels formed by crossed arrays of row and column electrodes of the display. The composite alternating voltage consists of a row driving alternating voltage component and a column driving alternating component voltage. The phases of the row and column alternating voltage components are relatively phased so as to produce the composite alternating voltage across the individual pixels. The column alternating voltage component includes a grey scale component having an root mean square (RMS) value variable in accordance with the grey scale of the image to be displayed on the liquid crystal display. The system is very complicated and forms an alternating voltage, which in fact consists of two different components. The first component is the basic alternating voltage having 50 % duty cycle, and the second component provides variable width pulses which are added to the first component. The width of the pulses of the second component varies in accordance with the desired grey scale.

[0006] Another patent US-5,587,721 presents a liquid crystal driving apparatus for colour liquid crystal displays. The apparatus comprises a converter which converts the grey scale information to a grey scale pulse signal having width modulated signal. The frequency of the pulses is substantially constant but the width of the pulses vary according to the desired grey scale of the pixel in question. Furthermore, the pulse width modulated voltage is only connected to one electrode of the pixel the other electrode being in constant potential *e.g.* in ground potential.

[0007] Prior art arrangements are primarily designed for small sized liquid crystal displays, *e.g.* for PC displays, but they are not suitable for large sized liquid crystal displays, which are, for example, designed for outdoor use. The size of each pixel is quite large (even 20 mm x 20 mm) in the large sized displays. If usual driving systems were used with these displays some visual artefacts could be seen.

[0008] Information displays for outdoor use are typically based on LED-displays or mechanical displays in which a matrix of two-coloured flaps form the display area. The flaps can be turned around to change the colour of the display

(split-flap display) to form the desired image. There are some disadvantages in these kind of displays. The LED-displays emit light and the brightness of the light is limited. This means that, for example, in direct sunlight the LED-displays are useless without special arrangements, because the brightness of the sunlight is multifold compared with the brightness of the LEDs. The split-flap displays comprise mechanical parts which move during operation. Therefore they need regular maintenance and the lifetime of the mechanics is limited.

Objectives and summary of the invention

[0009] It is thus an object of this invention to provide a system and a method for controlling a liquid crystal display, and a liquid crystal display which comprises an improved control method. The present invention is based on the idea that two separate control voltages are formed having a variable phase shift according to the grey scale information, wherein the first control voltage is connected to the first electrode of a pixel and the second control voltage is connected to the second electrode of the pixel. By changing the phase shift of said two control voltages the true RMS-voltage of the pixel can be varied, which can be seen as variations in the brightness of the pixel. A system according to a first embodiment of the present invention is primarily characterized by that the system comprises means for forming at least a first control signal and a second control signal for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal is connected to the first electrode of said at least one pixel and the second control signal is connected to the second electrode of said at least one pixel.

[0010] A method according to the present invention is primarily characterized by that at least a first control signal and a second control signal are formed for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal is connected to the first electrode of said at least one pixel and the second control signal is connected to the second electrode of said at least one pixel.

[0011] A liquid crystal display according to the present invention is primarily characterized by that the liquid crystal display comprises means for forming at least a first control signal and a second control signal for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal is connected to the first electrode of said at least one pixel and the second control signal is connected to the second electrode of said at least one pixel.

[0012] The present invention provides significant advantages over prior art systems and methods. The invention is especially applicable with large sized liquid crystal displays especially for outdoor use and also in large lounges, sheds, etc. The driving system according to the invention needs less circuitry and no moving parts and is cheaper compared with prior art systems. The adjustment of the brightness of each individual pixel of the liquid crystal display is also easier than with prior art systems. The information presented on displays of the present invention is readable also in direct sunlight, hence no special arrangements are needed to prevent direct sunlight to access the display.

Brief discussion of the drawings

[0013] The invention will now be described in more detail in the following with reference to the appended figures, in which

- Fig. 1a shows a display according to an advantageous embodiment of the present invention,
- Fig. 1b shows as a simplified block diagram a control system for the display of Fig 1a according to an advantageous embodiment of the present invention,
- Figs. 1c to 1e show examples of the waveforms driven to a pixel of the display of Fig 1a,
- Fig. 1f shows as a simplified block diagram another control system for the display of Fig 1a,
- Figs. 2a and 2b shows the arrangement of the electrodes for the pixels of a display according to another advantageous embodiment of the present invention,
- Figs. 2c to 2g show examples of driving voltages for the display of Fig 2a according to an advantageous embodiment of the present invention,
- Fig. 3a shows the arrangement of the electrodes for the pixels of a display according to yet another advantageous embodiment of the present invention, and
- Figs. 3b to 3e show examples of driving voltages for the display of Fig 3a according to an advantageous embodiment of the present invention.

iment of the present invention.

Detailed description of the invention

[0014] In the following the first advantageous embodiment of the present invention will be described with reference to Fig. 1. The liquid crystal display 1 is a so called directly controlled display, which means that it comprises separate control lines for each pixel p (some of them are marked with references p(1,1),..., p(N,M) in Fig. 1a) of the liquid crystal display 1. Therefore the brightness of each pixel p(1,1),..., p(N,M) can be controlled simultaneously and independently by using these separate control lines. The first electrode of each pixel p is connected to the first control line, e.g. a common electrode (COM), and the second electrode of a pixel is connected to a second control line for the pixel, e.g. a signal electrode SIG, respectively. Hence, there is a separate signal electrode SIG for each pixel. For clarity, all the signal electrodes are not shown in Fig. 1a.

[0015] The operation of the pixels is based on a polarization effect known as such. Between the electrodes of the pixels there is a certain kind of crystallized liquid the polarization of which can be changed by changing the voltage between the electrodes. The changes of the polarization affect to the optical properties of the pixel, which can be seen as changes in the brightness of the pixel. The pixels of the liquid crystal display do not emit light. Therefore the liquid crystal display always needs a separate light source if the liquid crystal display is to be used in dark or in dim conditions. The liquid crystal display normally comprise a backlight as a light source, but the backlight is not shown in the figures.

[0016] In Fig. 1b a control system 2 for the liquid crystal display 1 of Fig. 1a according to an advantageous embodiment of the present invention is shown as a simplified block diagram. It comprises input means 3 for inputting the information to be displayed on the liquid crystal display 1. It is assumed here that the information is in digital form and that there are certain number of bits reserved for each pixel to represent the grey scale information for the pixel. Preferably, the grey scale information is inputted pixel by pixel to the input means 3. The inputted information can also comprise synchronization information or some other address information so that the input means 3 can allocate the incoming information to respective pixels of the liquid crystal display 1. The control system 2 advantageously comprises a memory 4 to store the information to be displayed. In an advantageous embodiment of the present invention the grey scale information contains 8 bits (one byte), wherein 256 different levels can be represented by each pixel. The memory contains an area reserved for all the pixels. This part of the memory 4 is called as a display memory in this description and it is illustrated with reference 5 in the figures. The incoming information can be continuous, wherein the pixel values in the display memory 5 are updated every time new information is inputted, or the information is inputted only when where is a change in at least one pixel value.

[0017] The pixel information of the display memory 5 is fed to the liquid crystal display 1 e.g. in the following way. The controller 6 of the control system 1 reads pixel values from the display memory pixel by pixel. It is assumed here that the liquid crystal display 1 is updated rows by rows so that the pixels of the first row p(1,1),..., p(1,M) are updated first, then the pixels of the second row p(1,1),..., p(1,M) are updated, and the pixels of the last row p(1,1),..., p(1,M) are last updated, and the operation is repeated at least when any pixel value changes. In the beginning of the update process the controller 6 reads from the display memory 5 the value of the first pixel to be updated. Based on this value a correct control signal value is calculated by e.g. the controller 6.

[0018] To calculate the control signal value some terms are defined here. A phase angle θ between the voltages of the common electrode and the signal electrode is defined as $\theta = \alpha \cdot 180^\circ$, where α illustrates the proportional ratio of said voltages being at different levels. For example, if α equals 0, then also θ equals 0. This means that the voltages are the same i.e. they have the same amplitude and the same phase. Respectively, if α equals 1, then θ equals 180° . This means that one of the voltages is the inverse of the other one i.e. they have the opposite phase. The RMS voltage (Root Mean Square) which the pixel undergoes can be calculated by the following formula (1):

$$V_{RMS} = \sqrt{\frac{1}{T} \left(\int (V_{SIG} - V_{COM})^2 dt \right)} = \sqrt{\frac{1}{T} \left(\int_0^{\alpha T} V_0^2 dt \right)} = \sqrt{\alpha} V_0 = \frac{\sqrt{5\theta}}{30} V_0 \quad (1)$$

in which T is the cycle time of the voltages of the common electrode and the signal electrodes, and the V_0 is the peak amplitude value of the voltages. Although the voltages can be in different phase they have substantially the same cycle time and peak amplitude value. Hence, the RMS voltage of a pixel can be given as a function of the phase angle θ and the pixel can be driven by any voltage value between 0 to V_0 by setting the phase angle to a value between 0 to 180° . The inputted information contain pixel values as grey scales between black and white. The minimum value

represents black (minimum brightness) and the maximum value represents white (full brightness), or vice versa. It is also assumed here that the pixel brightness is substantially proportional to the RMS voltage driven to the pixel, and that the driving voltage of 0 V means minimum brightness and the driving voltage V_0 means full brightness. Therefore, an equation in which the driving voltage (V_{RMS}) is a variable, is needed. This can be defined by solving the equation (1) with respect to the voltage V_{RMS} . The equation then becomes to equation (2):

$$\theta = 180 \cdot \left(\frac{V_{RMS}}{V_0} \right)^2 = 180 \cdot x^2 \quad (2)$$

in which x is the desired grey scale value.

[0019] For each pixel the controller 6 reads the pixel value from the display memory 5, scales the pixel value between 0 to 1, and calculates the correct phase angle value θ by using the formula (2). For example, if the grey scale value is 8 bits in length, values from 0 to 255 can be defined. The controller then divides the value read from the display memory 5 by 256 and uses the result as the variable x . The calculated phase angle value is then used to set the phase shift between the common electrode voltage and the signal electrode voltage to the correct value. This can be performed e.g. in the following way.

[0020] The clock generator 7 forms a square wave signal having a first value (e.g. 0 V) and a second value (e.g. 5 V). The duty cycle of the square wave is preferably substantially 50 %. The phase shift value is fed to the first switch 8 and to the phase shift block 10. The first switch 8 selects to the output of the first switch either 0 V or V_0 depending on the value of the control input 9 of the first switch. At the output of the first switch there is hence a square wave varying between 0 V and V_0 . The phase of the square wave is substantially the same as the phase of the clock generator 7.

[0021] To form the signal electrode voltage the controller 6 outputs the calculated phase shift value to the control input 11 of the phase shift block 10. The phase shift block 10 changes the phase of the inputted square wave according to the control input 11. The output of the phase shift block 7 is connected to a second switch 12. The second switch selects to the output of the second switch either a first voltage (e.g. 0 V) or a second voltage V_0 depending on the value of the control input 13 of the second switch. At the output of the second switch there is hence a square wave varying between 0 V and V_0 . The phase of the square wave is shifted from the phase of the output of the clock generator 7 according to the calculated phase shift value θ . Figs. 1c to 1e illustrate examples of the waveforms driven to a pixel of the display of Fig 1a.

[0022] It is obvious that the square wave voltages for the common electrode and the signal electrode can be formed in a different way than presented above. For example, if the clock generator 7 directly forms a square wave signal varying between 0 V and V_0 the first switch 8 is not needed. Respectively, if the phase shift block 10 directly forms a square wave signal varying between 0 V and V_0 the phase shift block 10 is not needed. The phase shift block 10 and the clock generator 7 can also be implemented in the controller 6.

[0023] The operations to form the necessary signal electrode voltages for the pixels of the direct controlled liquid crystal display 1 can also be implemented by using so called multiplexing technique. Fig. 1f shows as a simplified block diagram one embodiment of the control system in which multiplexing is used. The operation of the control system is basically as follows. The controller 6 reads the brightness value for a pixel from the display memory 5, scales the value between 0 to 1, calculates the correct phase angle value θ by using the formula (2) and stores the value to a data buffer 14. A grey scale generator 15 forms a set of square waves which have different phases. The different square waves represent different grey scale values of all possible values (e.g. 256 values). The grey scale generator 16 can also form the square wave for the common electrode COM of pixels of the liquid crystal display 1. The square waves are connected to a multiplexing block 16. The data buffer 14 is also connected to the multiplexing block 16. For each pixel of the liquid crystal display 1 the multiplexing block 16 examines the desired grey scale value for the pixel and connects that output of the grey scale generator 15 to the signal electrode of the pixel in question, which has the correct phase shift. With this kind of multiplexed control system it is possible to drive large liquid crystal displays 1 having a great number of pixels.

[0024] The invention can also be used in connection with multiplexed liquid crystal displays. The operation is slightly modified from the steps presented above. Fig. 2a illustrates the arrangement of the common electrodes and Fig. 2b illustrates the arrangement of the signal electrodes for the pixels of a liquid crystal display 1 according to another advantageous embodiment of the present invention. The liquid crystal display 1 is a dot matrix display, which can be used to display all the numbers from 0 to 9, the letters, and also some graphical symbols. The pixels are arranged in the form presented in Figs. 2a and 2b. The multiplication ratio used is 1:2 in this embodiment, wherein two pixels share one signal electrode. In the figures 2a and 2b only four signal electrodes SIG1 to SIG4 are shown but it is obvious that the liquid crystal display 1 of Figs. 2a and 2b have more signal electrodes for providing necessary second signals for all the pixels. There is also two common electrodes COM1, COM2 for providing the first signals for the pixels. The

connections are made so that the pixels which are connected to the same common electrode are connected to different signal electrodes. This is illustrated with dots in Figs. 2a and 2b. For example, the pixels p(1,1) and p(5,1) are connected to the same signal electrode, the first signal electrode SIG1, but the pixels p(1,1) is on the other side connected to the first common electrode COM1 and the pixels p(5,1) is connected to the second common electrode COM2.

[0025] In the following, the operation of the second embodiment of the present invention is described by using the pixels p(1,1) and p(5,1) of the liquid crystal display 1 of Figs. 2a and 2b as examples of the pixels. The waveforms of the voltages of the common electrodes COM1, COM2 and the signal electrode SIG1 differ slightly from the previous example. Now, a two-part square wave is formed to the first and the second common electrodes. The first part is similar in both of these common electrodes, but the second part of the second common electrode COM2 is inverted version of the waveform of the first common electrode COM1. These waveforms are illustrated in Figs. 2c and 2d. Still, the duty cycle of both parts is preferably substantially 50 %. Also, in this embodiment the signal lines SIG1 to SIG 4 are used to affect to the brightness of the pixels of the first column of the liquid crystal display 1. Other signal lines which are not shown are used to affect to the brightness of the pixels of the other columns of the liquid crystal display 1. The voltage of the first signal line SIG1 consists of two parts, wherein the first part is used to affect to the brightness of the pixel p(1,1) and the second part is used to affect to the brightness of the pixel p(5,1) in the following way. The waveform of the voltage of the first signal electrode SIG1 is a square wave having substantially the same amplitude, cycle time and duty cycle as the voltages of the common electrodes COM1, COM2. Let us now mark as $\theta_1 = \beta \cdot 180^\circ$ the phase difference between the first part of the voltage of the first common electrode COM1 and the first part of the voltage of the first signal electrode SIG1. Respectively, the phase difference between the second part of the voltage of the first common electrode COM1 and the second part of the voltage of the first signal electrode SIG1 is marked as $\theta_2 = \alpha \cdot 180^\circ$. Then, the pixel p(1,1) is affected by an RMS voltage V_{RMS1} , which can be calculated as follows:

$$V_{RMS1} = \sqrt{\frac{1}{2T} \left(\int (V_{SIG} - V_{COM1})^2 dt \right)} = \sqrt{\frac{1}{2T} \left(\int_0^{\beta T} V_0^2 dt + \int_0^{\alpha T} V_0^2 dt \right)} \quad (3a)$$

$$= \sqrt{\beta + \alpha} \cdot \frac{V_0}{\sqrt{2}} = \frac{\sqrt{10}}{60} \sqrt{\theta_1 + \theta_2} V_0$$

[0026] Respectively, the pixel p(5,1) is affected by an RMS voltage V_{RMS2} , which can be calculated as follows:

$$V_{RMS2} = \sqrt{\frac{1}{2T} \left(\int (V_{SIG} - V_{COM2})^2 dt \right)} = \sqrt{\frac{1}{2T} \left(\int_0^{\beta T} V_0^2 dt + \int_0^{(1-\alpha)T} V_0^2 dt \right)} \quad (3b)$$

$$= \sqrt{\beta + 1 - \alpha} \cdot \frac{V_0}{\sqrt{2}} = \frac{\sqrt{10}}{60} \sqrt{180 + \theta_1 - \theta_2} V_0$$

[0027] Figs. 2f and 2g illustrate examples of the voltages the pixels p(1,1) and p(5,1) undergo, if voltages of Figs. 2c, 2d and 2e are fed to the common signal electrodes COM1, COM2 and the first signal electrode SIG1, respectively. If a voltage V_1 is set to the pixel p(1,1) and a voltage V_2 is set to the pixel p(5,1), a pair of equations can be formed by using equations (3a) and (3b):

$$\begin{cases} \sqrt{\beta + \alpha} \cdot \frac{V_0}{\sqrt{2}} = V_1 \\ \sqrt{\beta + 1 - \alpha} \cdot \frac{V_0}{\sqrt{2}} = V_2 \end{cases} \quad (4)$$

[0028] The values of the variables α and β can now be solved from the pair of equations (4):

$$\begin{cases} \beta = \frac{V_1^2 + V_2^2}{V_0^2} - \frac{1}{2} \\ \alpha = \frac{V_1^2 - V_2^2}{V_0^2} + \frac{1}{2} \end{cases} \quad (5)$$

[0029] It is not possible to simultaneously set both pixels $p(1,1)$ and $p(5,1)$ of the same signal line SIG1 at, for example, the value 0 V or V_0 . Therefore, the contrast of the multiplexed liquid crystal display 1 is degraded compared with the directly controlled liquid crystal displays. The maximum achievable contrast can be evaluated by calculating the maximum voltage V_{MAX} and the minimum voltage V_{MIN} which can simultaneously be connected to both pixels $p(1,1)$ and $p(5,1)$. By setting both the voltages V_1 and V_2 equal, the following equation can be achieved:

$$\begin{cases} \sqrt{\beta + \alpha} \cdot \frac{V_0}{\sqrt{2}} = V_1 \\ \sqrt{\beta + 1 - \alpha} \cdot \frac{V_0}{\sqrt{2}} = V_2 \end{cases} \quad \xrightarrow{V_1=V_2} \quad \sqrt{\alpha + \beta} = \sqrt{\beta - \alpha + 1} \Rightarrow \alpha = \frac{1}{2} \quad (6)$$

[0030] Then, the RMS voltage values of the pixels are

$$V_1 = V_2 = \frac{V_0}{\sqrt{2}} \sqrt{\beta + \frac{1}{2}} \quad (7)$$

from which it is possible to calculate the limits for the control voltage. First, by setting $\beta=0$ in the equation (7) the minimum value $V_{MIN} = \frac{V_0}{2}$ will be achieved. By setting $\beta=1$ in the equation (7) the maximum value

$$V_{MAX} = \frac{\sqrt{3}V_0}{2}$$

will be achieved. The quotient of the maximum and minimum values gives the approximation for the contrast: $\frac{V_{MAX}}{V_{MIN}} = \sqrt{3}$. By using the above described control method it is possible to generate all RMS voltages between $V_0/2 \dots \sqrt{3}V_0/2$ to the pixels.

[0031] It should be noted that although the pixels $p(1,1)$ and $p(5,1)$ were used above, the similar principles can be applied in connection with other pixels of the liquid crystal display 1. Also other multiplexing ratios than 1:2 can be used.

[0032] In the following the third advantageous embodiment of the present invention will be described with reference to Figs. 3a to 3e. The liquid crystal display 1 comprises a pixel matrix $p(1,1), \dots, p(N,M)$ in which the multiplexed control method is used. The common electrodes of pixels of each row are connected together and the signal electrodes of pixels of each column are connected together. Therefore, each pixel is in a crossing point of one signal electrode and one common electrode. Further, each pixel connected to the same common electrode is connected to a different signal

electrode. Let us express the multiplication ratio as 1:N, in which N represents the number of the common electrodes (COM1 to COMN). The driving method of the voltages consists of N equal phases. During each phase one square wave is generated on one common electrode, and an intermediate voltage value ($V_0/2$) is generated on the other common electrodes. The figures 3b, 3c and 3d illustrate the voltage waveforms of the first, second and last common electrodes, respectively.

[0033] The voltage of the signal lines SIG1 to SIGM consist of N parts, wherein each part is used to affect to the brightness of one pixel of the pixels connected to the same signal electrode. The waveform of the voltage of the signal electrode SIG1, ..., SIGM is a square wave. Each part of the voltage of the signal electrode has a certain phase difference with the voltage of the respective common line. For example, the first part consists of a square wave which has a certain phase difference between the first common line, the second part consists of a square wave which has a certain phase difference between the second common line etc. The phase difference of each part depends on the desired grey scale value for the respective pixel. Fig. 3e illustrates the waveform of the signal electrode SIG1, ..., SIGM. Let us now mark as $\theta_1 = \alpha_1 \cdot 180^\circ$ the phase difference between the first part of the voltage of the first common electrode COM1 and the first part of the voltage of the first signal electrode SIG1. Respectively, the phase difference between the second part of the voltage of the second common electrode COM2 and the second part of the voltage of the first signal electrode SIG1 is marked as $\theta_2 = \alpha_2 \cdot 180^\circ$. The phase difference between the Nth (last) part of the voltage of the Nth common electrode COMN and the Nth part of the voltage of the first signal electrode SIG1 is marked as $\theta_N = \alpha_N \cdot 180^\circ$. Then, the pixels $p(1,1)$, $p(2,1)$, ..., $p(N,1)$ of the first column are affected by an RMS voltage V_{RMS1} , which can be calculated as follows:

$$\begin{aligned}
 V_{RMS1} &= \sqrt{\frac{1}{T} \int_0^T (V_{SIG} - V_{COM1})^2 dt} = \sqrt{\frac{1}{N \cdot T} \left(\int_0^{\alpha_1 T} V_0^2 dt + \int_0^{(N-1)T} (V_0/2)^2 dt \right)} \quad (8a) \\
 &= \sqrt{\frac{4\alpha_1 + N - 1}{4N}} \cdot V_0 = \frac{\sqrt{\frac{\theta_1}{45} + N - 1}}{2\sqrt{N}} V_0
 \end{aligned}$$

$$V_{RMS2} = \sqrt{\frac{1}{T} \int (V_{SIG} - V_{COM2})^2 dt} = \sqrt{\frac{1}{N \cdot T} \left(\int_0^{\alpha_2 T} V_0^2 dt + \int_0^{(N-1)T} (V_0/2) dt \right)} \quad (8b)$$

$$= \sqrt{\frac{4\alpha_2 + N - 1}{4N}} \cdot V_0 = \frac{\sqrt{\frac{\theta_2}{45} + N - 1}}{2\sqrt{N}} V_0$$

⋮

$$V_{RMSN} = \sqrt{\frac{1}{T} \int (V_{SIG} - V_{COMN})^2 dt} = \sqrt{\frac{1}{N \cdot T} \left(\int_0^{\alpha_N T} V_0^2 dt + \int_0^{(N-1)T} (V_0/2) dt \right)} \quad (8N)$$

$$= \sqrt{\frac{4\alpha_N + N - 1}{4N}} \cdot V_0 = \frac{\sqrt{\frac{\theta_N}{45} + N - 1}}{2\sqrt{N}} V_0$$

[0034] If a voltage V_1 is set to the first pixel $p(1,1)$, a voltage V_2 is set to the second pixel $p(2,1)$, and a voltage V_N is set to the Nth pixel $p(N,1)$, a set of equations can be formed by using equations (8a), (8b) and (8c):

$$\left\{ \begin{array}{l} \sqrt{\frac{4\alpha_1 + N - 1}{4N}} \cdot V_0 = V_1 \\ \sqrt{\frac{4\alpha_2 + N - 1}{4N}} \cdot V_0 = V_2 \\ \vdots \\ \sqrt{\frac{4\alpha_N + N - 1}{4N}} \cdot V_0 = V_N \end{array} \right. \quad (9)$$

[0035] From the equation (9) the values for the variables $\alpha_1, \alpha_2, \dots, \alpha_N$ can be solved.

$$\left\{ \begin{array}{l} \alpha_1 = \frac{NV_1^2}{V_0^2} - \frac{N-1}{4} \\ \alpha_2 = \frac{NV_2^2}{V_0^2} - \frac{N-1}{4} \\ \vdots \\ \alpha_N = \frac{NV_N^2}{V_0^2} - \frac{N-1}{4} \end{array} \right. \quad (10)$$

[0036] It is possible to solve the limits V_{MAX} , V_{MIN} for the control voltages from the equation

$$V_{RMS} = \sqrt{\frac{4\alpha + N - 1}{4N}} V_0$$

by setting the variable α to 0 and to 1:

$$\alpha = 0 \Rightarrow V_{MIN} = \sqrt{\frac{N-1}{4N}} V_0 \quad (11)$$

$$\alpha = 1 \Rightarrow V_{MAX} = \sqrt{\frac{3+N}{4N}} V_0$$

[0037] The quotient of the maximum and minimum values gives the approximation for the contrast:

$$\frac{V_{MAX}}{V_{MIN}} = \sqrt{\frac{3+N}{N-1}}.$$

By using the above described control method it is possible to generate all RMS voltages between

$$\sqrt{\frac{N-1}{4N}} \cdot V_0 \dots \sqrt{\frac{3+N}{4N}} V_0$$

to the pixels.

[0038] In this above described embodiment three voltages levels are needed: 0 V, $V_0/2$ and V_0 . The intermediate voltage level $V_0/2$ can easily be formed from the voltage level V_0 e.g. by using a simple resistor divider. The number of the different voltage levels is much smaller than what is needed with prior art systems.

[0039] The control system according to the invention is quite simple and requires only one voltage level in addition to ground. The second voltage level of the third embodiment can be formed from said one voltage level by a resistor divider. The signals needed are based on simple square waves. All the necessary control circuitry can mainly be implemented in a micro controller (MCU) and using a suitable logic circuitry, for example, an application specific integrated circuit (ASIC). The control system is hence cheaper and easier to manufacture than prior art control systems for liquid crystal displays. The phase shift between the control signals can be defined very accurately in the control system according to the present the invention. Therefore, it is quite easy to form a lot of different grey scale values in

each pixel of the liquid crystal display 1. In an advantageous embodiment of the present invention it is possible to form at least 256 different grey scale values, which means that more than 16.7 million colours can be presented on a colour liquid crystal display 1 according to the invention. With the present invention it is possible to achieve even more than the mentioned 256 grey scale values. In prior art displays only active matrix TFT-displays can present 16.7 million colours, but active matrix TFT technique is not applicable to be used in large displays. The amount of different colours which can be presented on prior art passive matrix displays is only of fraction of said 16.7 million colours

[0040] The system and method according to the invention can also be applied with colour liquid crystal displays, wherein for each colour (red, green, blue) a similar control system according to the present invention will be needed. However, it is possible that all the control systems for each colour can be implemented in the same circuitry, for example in the same micro controller and/or application specific integrated circuit.

[0041] The present invention is not limited to the above described embodiments only, but it can be varied within the scope defined by the attached claims.

Claims

1. A system for controlling a liquid crystal display (1) comprising at least one pixel (p), the system comprising means (3) for providing control information for said at least one pixel (p) according to a desired brightness for the pixel, **characterized in that** the system comprises means (6, 7, 8, 10, 12) for forming at least a first control signal (COM) and a second control signal (SIG) for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal (COM) is connected to the first electrode of said at least one pixel and the second control signal (SIG) is connected to the second electrode of said at least one pixel (p).
2. A system according to the claim 1, **characterized in that** said control signals are two-level signals having a first voltage level and a second voltage level.
3. A system according to the claim 2, **characterized in that** the waveforms of said control signals are square waves.
4. A system according to the claim 3, **characterized in that** the control signals are generated by a clock generator (7), and that said second control signal is generated by shifting the phase of the signal generated by said clock generator (7).
5. A system according to any of the claims 1 to 4, **characterized in that** the liquid crystal display (1) is a directly controlled display, wherein the first electrodes of all the pixels are connected together, and a separate second control signal (SIG1,..., SIGM) is generated for each of said pixels (p) of the liquid crystal display (1).
6. A system according to any of the claims 1 to 4, **characterized in that** the liquid crystal display (1) is a multiplexed display, the multiplication ratio used is 1:N, wherein N pixels share one signal electrode and a number of pixels share one common electrode, and that the pixels which are connected to the same common electrode are connected to different signal electrodes.
7. A system according to claim 6, **characterized in that** separate first control signals (SIG1,..., SIGM) are generated for each of said common electrodes, and that an N-part second control signal is generated for said one signal electrode which is shared by said N pixels.
8. A system according to claim 7, **characterized in that** said separate first control signals (SIG1,..., SIGM) can have a first level, a second level, or a third level, wherein a square wave is generated on only one control signal of said separate control signals varying between at said first and said third level at a time, during which the other separate first control signals are at the second level, and that N square waves are generated on said N-part second control signal, the square wave of each part having a certain phase difference with the square wave generated on the respective first control signal.
9. A method for controlling a liquid crystal display (1) comprising at least one pixel (p), in which control information is provided for said at least one pixel (p) according to a desired brightness for the pixel, **characterized in that** at least a first control signal (COM) and a second control signal (SIG) are formed for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal (COM) is connected to the first electrode of said at least one pixel and the second control signal (SIG) is connected to the second electrode of said at least one pixel (p).

10. A liquid crystal display (1) comprising at least one pixel (p), and means (3) for providing control information for said at least one pixel (p) according to a desired brightness for the pixel, **characterized in that** the liquid crystal display (1) comprises means (6, 7, 8, 10, 12) for forming at least a first control signal (COM) and a second control signal (SIG) for said at least one pixel having a phase shift respective to the desired brightness, wherein the first control signal (COM) is connected to the first electrode of said at least one pixel and the second control signal (SIG) is connected to the second electrode of said at least one pixel (p).

11. A liquid crystal display (1) according to the claim 10, **characterized in that** it is a colour liquid crystal display (1), wherein it comprises means for generating said two separate control signals for each of the different colours of the liquid crystal display (1).

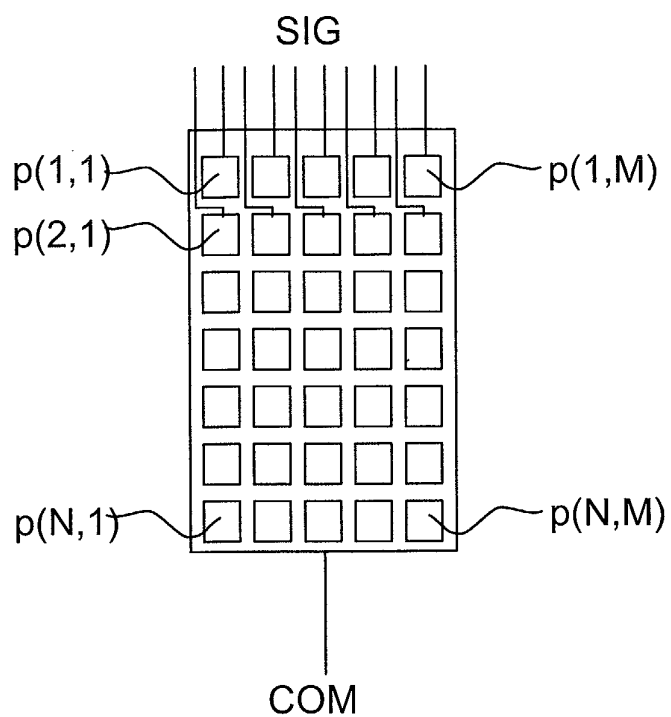


Fig. 1a

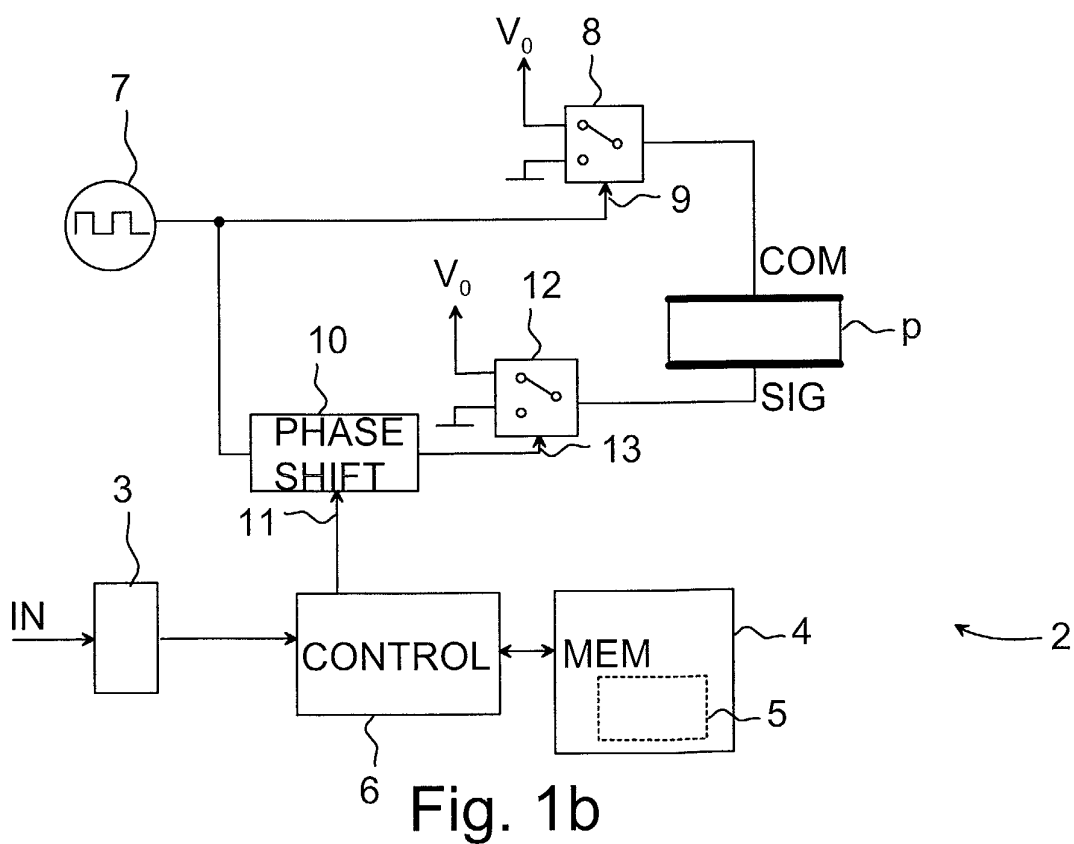


Fig. 1b

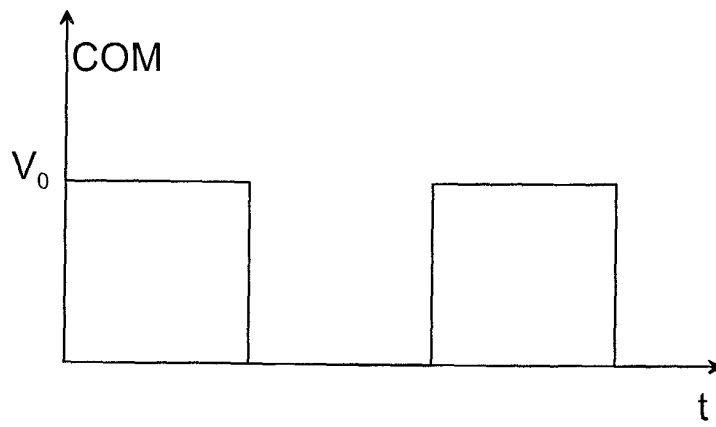


Fig. 1c

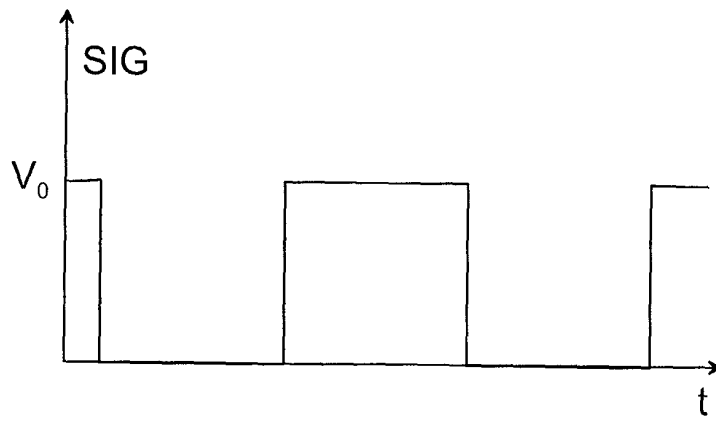


Fig. 1d

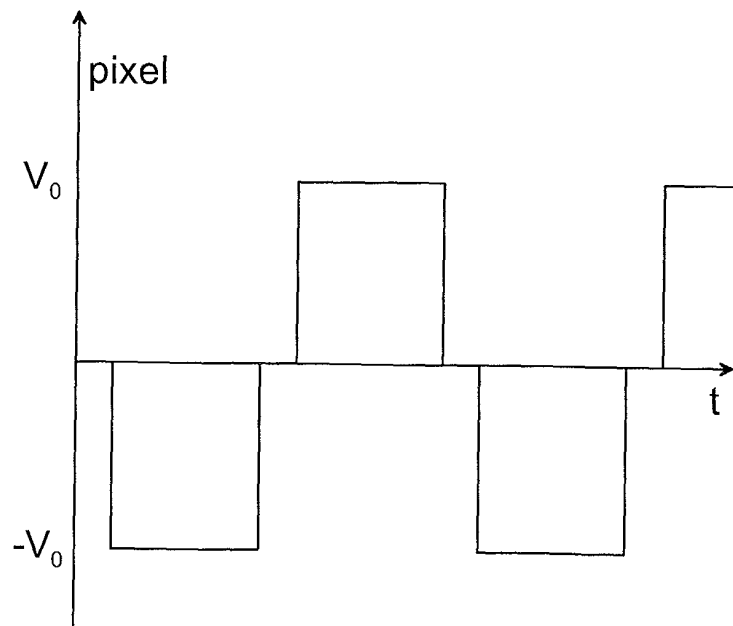


Fig. 1e

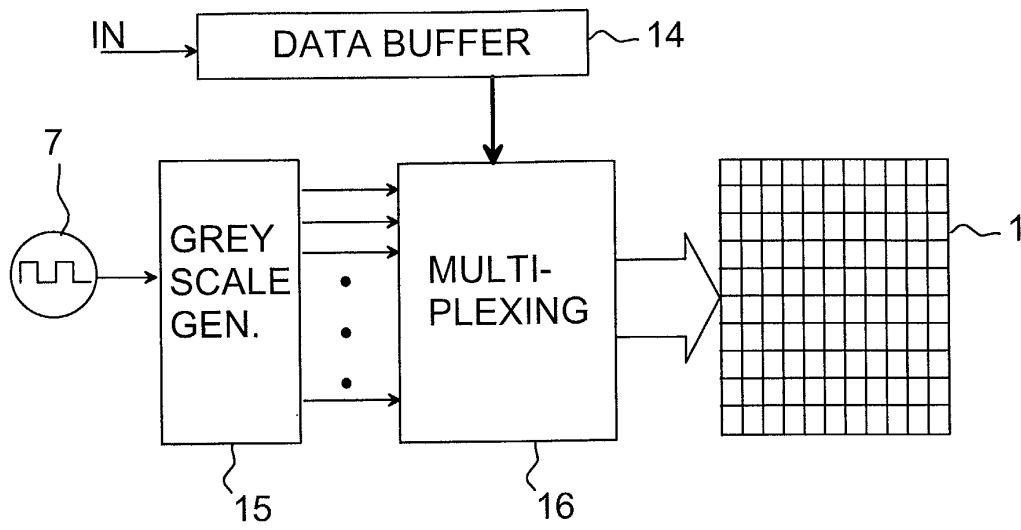


Fig. 1f

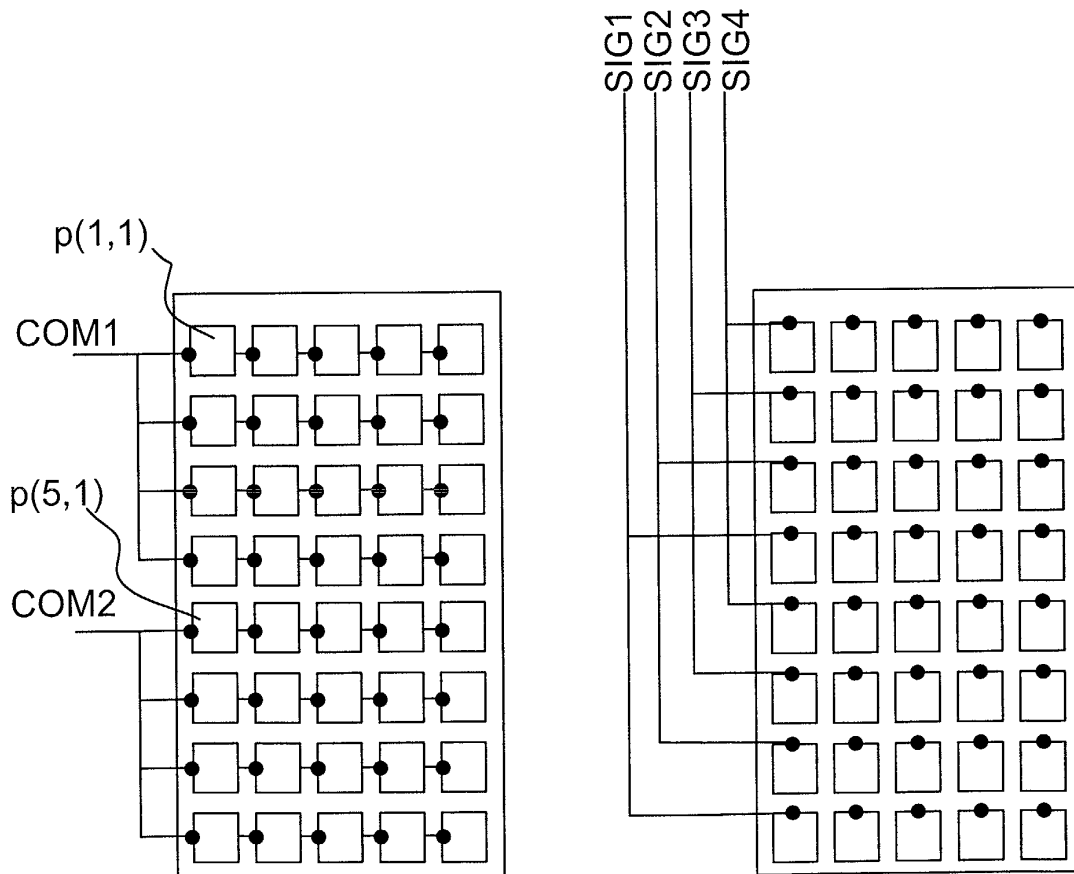


Fig. 2a

Fig. 2b

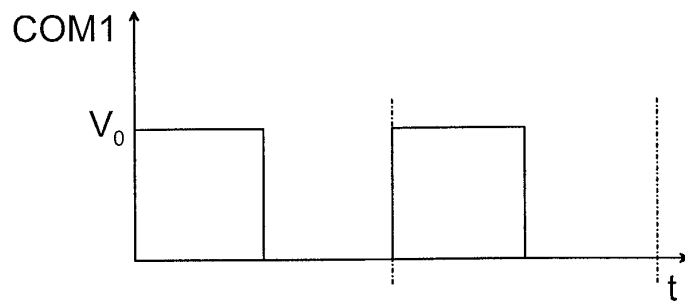


Fig. 2c

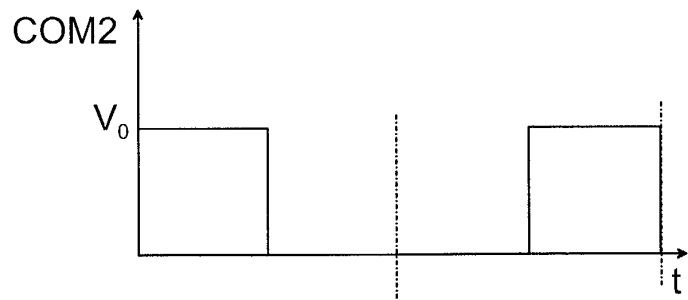


Fig. 2d

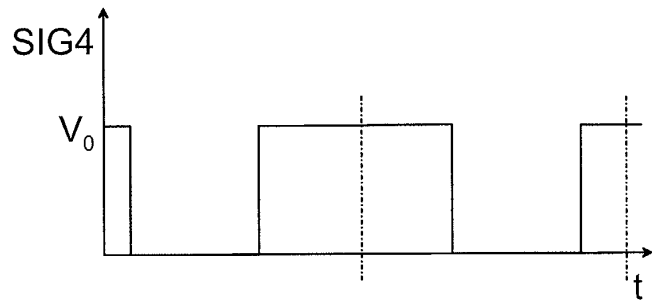


Fig. 2e

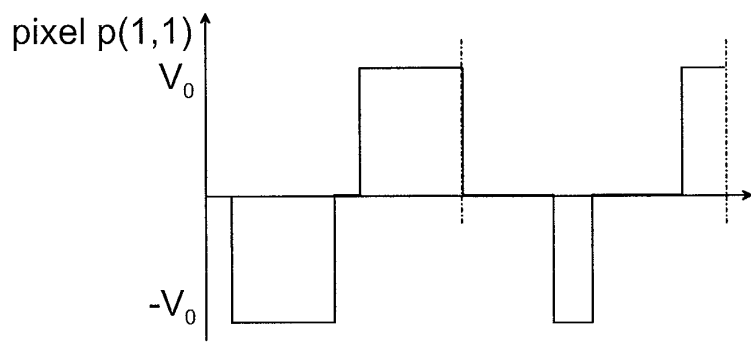


Fig. 2f

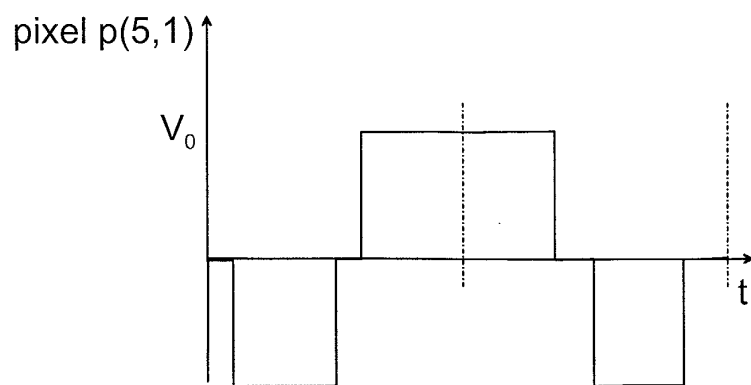


Fig. 2g

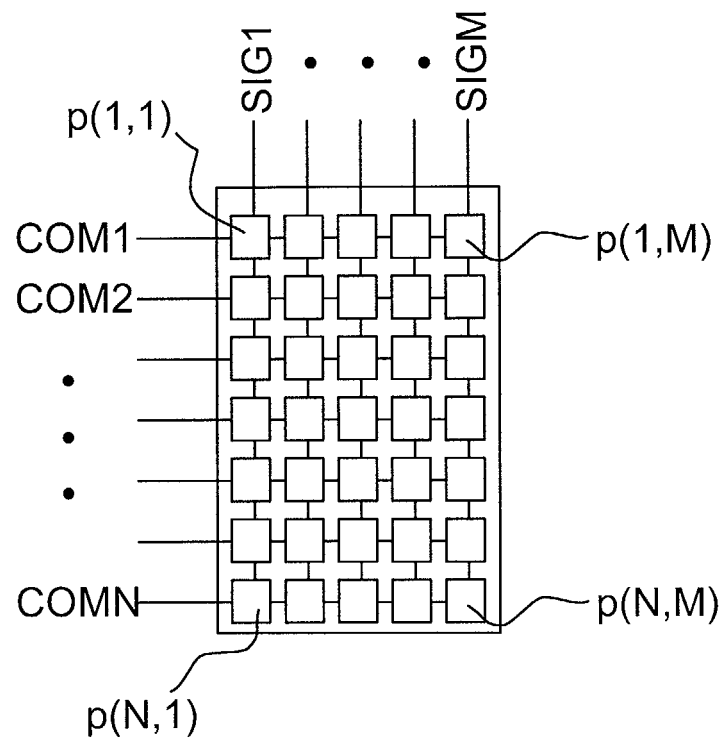


Fig. 3a

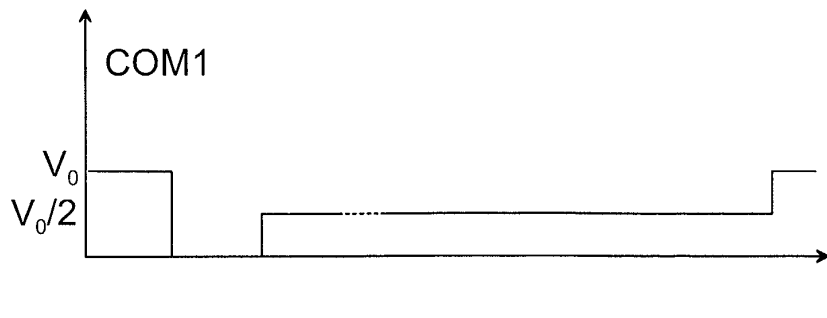


Fig. 3b

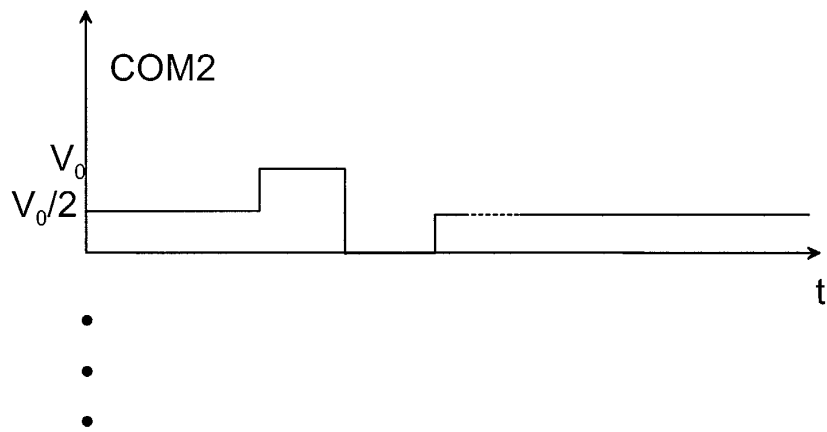


Fig. 3c

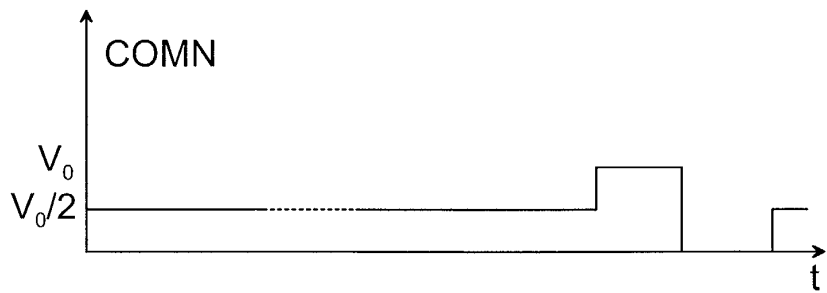


Fig. 3d

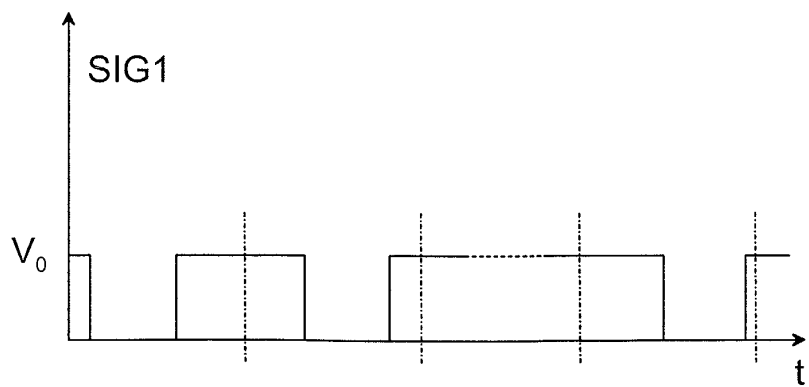


Fig. 3e



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EUROPEAN SEARCH REPORT

Application Number
EP 02 39 6040

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A	* abstract; figures 2,4,5 * * column 2, line 38 - column 3, line 40 * * column 7, line 61 - column 9, line 34 *	6	
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			G09G
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 24 September 2002	Examiner Van Roost, L
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