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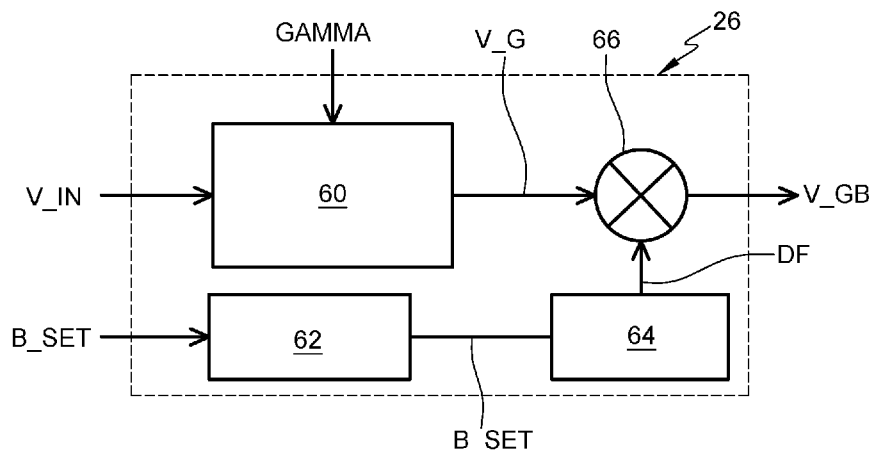


Fig. 5

(57) Abstract: The present description concerns a display screen comprising an array of display pixels each comprising a least one light-emitting diode, the display screen further comprising a first circuit (60) configured to receive initial video data (V_IN) and to apply a gamma decoding to the received initial video data (V_IN) to produce gamma corrected video data (V_G), a second circuit (62) configured to receive a brightness setting (B_SET), a third circuit (64) configured to provide a decrease factor (DE) that depends on the brightness setting (B_SET), and a fourth circuit (66) configured to multiply the gamma corrected video data (V_G) by the decrease factor (DE) to provide brightness and gamma corrected video data (V_GB).



DESCRIPTION

TITLE: *Display screen comprising display pixels having light-emitting diodes*

This patent application claims priority from French patent application FR23/06905 which will be considered as an integral part of this description.

Technical background

[0001] The present disclosure generally concerns display screens comprising display pixels having light-emitting diodes.

Prior art

[0002] A pixel of an image corresponds to the unit element of the image displayed by a display screen. For the display of color images, a display screen generally comprises, for the display of each pixel of the image, at least three components, also called display sub-pixels, which each emit a light radiation substantially in a single color (for example, red, green, and blue). The superposition of the radiations emitted by the three display sub-pixels provides the observer with the colored sensation corresponding to the pixel of the displayed image. In this case, the assembly formed by the three display sub-pixels used for the display of a pixel of an image is called display pixel of the display screen. Each display sub-pixel may comprise a light source, particularly a light-emitting diode.

[0003] The display pixels of a display screen may be distributed in an array, each display pixel being located at the intersection of a row (also called line) and of a column of the array. Electrodes are provided along the rows and the columns to connect each display pixels to control circuits. Generally, a selection and timing circuit is

connected to the row electrodes. Each row of display pixels is successively selected by signal transmitted along the row electrodes by the selection and timing circuit, and the display pixels of the selected row are programmed to display the desired image pixels by signals transmitted along the column electrodes.

[0004] An active array is a screen drive architecture enabling to maintain all the pixel rows active for the entire duration of an image, conversely to arrays said to be passive, where each row is only active for a time $T = T_{\text{frame}}/M$ (where T_{frame} is the duration of the display of the whole image and M is the number of lines of the screen). This enables to increase the luminosity of the display screen. Further, it is possible to send low voltage or current levels on the array control lines, which enables to display bigger data flows.

[0005] It is known to control a light emitting diode, by pulse-width modulation, also called PWM (English acronym for Pulse Width Modulation). This type of control consists in circulating successive current pulses of constant intensity in the light-emitting diode, the pulses being repeated cyclically, the duty cycle determining the light intensity emitted by the light-emitting diode. Such a control advantageously makes it possible to operate the light-emitting diode at its optimum operating point where the efficiency of the light-emitting diode, equal to the ratio between the light power emitted by the light-emitting diode and the electrical power consumed by the light-emitting diode, is maximum. A PWM control usually requires the transmission by the selection and timing circuit of a successions of pulses on the row electrodes, the durations between the pulses depending on the image pixel to be displayed.

[0006] A display screen usually also comprises a setting to vary the global brightness of the image that is displayed. A way of decreasing the brightness of a displayed image with respect to a maximal brightness is to decrease the durations between the pulses of the transmission by the selection and timing circuit.

[0007] A drawback is that it can be difficult for the selection and timing circuit to provide pulses separated by short durations when the brightness is set to be low. There can be a limit to the minimum brightness that can be reached. Another drawback is that the selection and timing circuit needs to be able to provide many different successions of pulses separated by different durations according to the brightness settings.

Summary of the invention

[0008] An object of an embodiment is to provide a display screen comprising light-emitting diodes overcoming all or part of the disadvantages of existing display screens.

[0009] Another object of an embodiment is that the selection and timing circuit provides the same succession of pulses for a PWM control regardless the brightness setting.

[0010] Another object of an embodiment is that there is no limit to the minimum brightness that can be reached.

[0011] Another object of an embodiment is that the structure of the selection and timing circuit is simple.

[0012] An embodiment provides a display screen comprising an array of display pixels each comprising a least one light-emitting diode, the display screen further comprising a first circuit configured to receive initial digital video data and to apply a gamma decoding to the received initial digital video data to produce gamma corrected digital video

data, a second circuit configured to receive a brightness setting, a third circuit configured to provide a digital decrease factor that depends on the brightness setting, and a fourth circuit configured to multiply the gamma corrected digital video data by the digital decrease factor to provide brightness and gamma corrected digital video data. The brightness correction is applied to the video data before they are transmitted to the display pixels. Therefore, the display pixels can advantageously be operated independently from the brightness correction. Moreover, there can be advantageously no limit to the minimum brightness that can be reached.

[0013] According to an embodiment, the display pixels are arranged in rows and columns, the display screen further comprising a data driver configured to provide video data to the columns of display pixels based on the brightness and gamma corrected digital video data. Therefore, the display pixels can advantageously be operated independently from the brightness correction.

[0014] According to an embodiment, each display pixels comprises a driver circuit configured to determine a digital signal from the video data and to control the light-emitting diode based on the digital signal.

[0015] According to an embodiment, the driver circuit is configured to control the light-emitting diode by pulse-width modulation based on the digital signal. Such a control advantageously makes it possible to operate the light-emitting diode at its optimum operating point where the efficiency of the light-emitting diode is maximum.

[0016] According to an embodiment, the display screen comprises a selection and timing circuit configured to provide a succession of pulses to each row of display

pixels. The pulses supplied by selection and timing circuit are, during a display phase, advantageously the same whatever the brightness setting is. Therefore, the structure of the selection and timing circuit can be simple.

[0017] According to an embodiment, the driver circuit is configured to turn on or turn off the light-emitting diode at the rate of the succession of pulses.

[0018] Another embodiment provides a method for displaying images by a display screen comprising an array of display pixels each comprising a least one light-emitting diode, comprising the following steps;

- receiving initial digital video data;
- applying a gamma decoding to the received initial digital video data to produce gamma corrected digital video data;
- receiving a brightness setting;
- providing a digital decrease factor that depends on the brightness setting;
- multiplying the gamma corrected digital video data by the digital decrease factor to provide brightness and gamma corrected digital video data.

[0019] According to an embodiment, the display pixels are arranged in rows and columns, the method further comprising the step of providing video data to the columns of display pixels based on the brightness and gamma corrected digital video data.

[0020] According to an embodiment, each display pixels comprises a driver circuit configured to determine a digital signal from the video data and to control the light-emitting diode based on the digital signal.

[0021] According to an embodiment, the driver circuit is configured to control the light-emitting diode by pulse-width modulation based on the digital signal.

[0022] According to an embodiment, the method comprises providing a succession of pulses to each row of display pixels.

[0023] According to an embodiment, the driver circuit is configured to turn on or turn off the light-emitting diode at the rate of the succession of pulses.

Brief description of the drawings

[0024] The foregoing features and advantages, as well as others, will be described in detail in the rest of the disclosure of specific embodiments given by way of illustration and not limitation with reference to the accompanying drawings, in which:

[0025] Figure 1 partially and schematically shows an example of a display screen;

[0026] Figure 2 shows an example of a block diagram of a display pixel of the display screen of Figure 1;

[0027] Figure 3 shows examples of timing diagrams of a signal used by the display pixel of Figure 2 for controlling a light-emitting diode by pulse-width modulation and of the current supplied to the light-emitting diode;

[0028] Figure 4 shows examples of timing diagrams of a timing signal and current pulses for controlling a light-emitting diode by pulse-width modulation for different brightness settings;

[0029] Figure 5 shows an embodiment of a block diagram of a circuit of the display screen of Figure 1 for varying the brightness of the displayed images;

[0030] Figure 6 shows a curve of evolution of a decreasing factor determined by the circuit of Figure 5 with respect to brightness settings;

[0031] Figure 7 shows examples of equivalent gamma decoding functions implemented by the circuit of Figure 5; and

[0032] Figure 8 shows examples of timing diagrams of a timing signal and current pulses for controlling a light-emitting diode by pulse-width modulation for different brightness settings by using the circuit of Figure 5.

Description of the embodiments

[0033] Like features have been designated by like references in the various figures. In particular, the structural and/or functional features that are common among the various embodiments may have the same references and may dispose identical structural, dimensional and material properties. For the sake of clarity, only the steps and elements that are useful for an understanding of the embodiments described herein have been illustrated and described in detail.

[0034] In the following description, when reference is made to terms qualifying absolute positions, such as terms "front", "rear", "top", "bottom", "left", "right", etc., or relative positions, such as terms "above", "under", "upper", "lower", etc., or to terms qualifying directions, such as terms "horizontal", "vertical", etc., it is referred, unless specified otherwise, to the orientation of the drawings or to a display screen in a normal position of use.

[0035] Unless indicated otherwise, when reference is made to two elements connected together, this signifies a direct connection without any intermediate elements other than

conductors, and when reference is made to two elements coupled together, this signifies that these two elements can be connected or they can be coupled via one or more other elements.

[0036] Further, there is called "binary signal" a signal which alternates between a first constant state, for example, a low state, noted "0", and a second constant state, for example, a high state, noted "1". The high and low states of different binary signals of a same electronic circuit may be different. In practice, the binary signals may correspond to voltages which may not be perfectly constant in the high or low state.

[0037] Further, unless indicated otherwise, when it is spoken of a voltage at a conductive pad, the difference between the potential at said conductive pad and a reference potential, for example, the ground, taken as equal to 0 V, is considered.

[0038] Unless specified otherwise, the expressions "around", "approximately", "substantially" and "in the order of" signify within 10%, and preferably within 5%.

[0039] Figure 1 partially and schematically shows a known example of a display screen 10. Display screen 10 comprises display pixels $12_{i,j}$, for example, arranged in M rows and in N columns, M being an integer varying from 1 to 8,000 and N being an integer varying from 1 to 16,000, i being an integer varying from 1 to M, and j being an integer varying from 1 to N. As an example, in Figure 1, M and N are equal to 6. Each display pixel $12_{i,j}$ is coupled to a source of a low reference potential Gnd, for example, the ground, via an electrode 14_i and to a source of a high reference potential Vcc via an electrode 16_j . As an example, electrodes 14_i are shown as being aligned along the rows in

Figure 1 and electrodes 16_j are shown as being aligned along the columns in Figure 1, the reverse layout being possible. The power supply voltage of the display screen corresponds to the voltage between high reference potential V_{cc} and low reference potential Gnd , and is noted V_{cc} like the high reference potential. Power supply voltage V_{cc} particularly depends on the arrangement of the light-emitting diodes and on the technology according to which the light-emitting diodes are manufactured. As an example, power supply voltage V_{cc} may be in the order of from 4 V to 5 V.

[0040] For each row, the display pixels $12_{i,j}$ in the row are coupled to a row electrode 18_i . For each column, the display pixels $12_{i,j}$ in the column are coupled to a column electrode 20_j . Display screen 10 comprises a selection and timing circuit 22 coupled to row electrodes 18_i and adapted to delivering a selection and timing signal Com_i on each row electrode 18_i . Display screen 10 comprises a data delivery circuit 24 coupled to column electrodes 20_j and adapted to delivering a data signal $Data_j$ on each column electrode 20_j . Selection and timing circuit 22 and control circuit 24 are controlled by a circuit 26, for example comprising a processor. Circuit 26 receives video data V_IN and a brightness setting B_SET . Data signal $Data_j$ are generated from video data V_IN .

[0041] Figure 2 shows an example of a block diagram of a display pixel $12_{i,j}$ of display screen 10. For a color display screen, display pixel $12_{i,j}$ comprises a light-emitting circuit comprising at least three light-emitting diodes LED emitting radiations of different colors, a single light-emitting diode LED being shown in Figure 2. Each light-emitting diode LED is series-coupled to a controllable current source CS, for example comprising a MOS transistor in series with a current source providing a constant

current. In the present example, for each light-emitting diode LED, the anode of light-emitting diode LED receives high reference potential V_{cc} and the cathode of light-emitting diode LED is for example coupled to a terminal of controllable current source CS, the other terminal of controllable current source CS receiving low reference potential Gnd. In case of a monochrome display screen, each display pixel $12_{i,j}$ can comprise a light-emitting circuit comprising a single light-emitting diode LED.

[0042] Display pixel $12_{i,j}$ further comprises a driver circuit 40 for driving controllable current source CS. Driver circuit 40 may particularly comprise electronic components such as MOS transistors. Driver circuit 40 comprises a storage circuit 48 (Color Data registers) clocked by a clock signal Clk configured to store digital color signals R, G, B based on received digital data Data. Digital color signals R, G, B comprise each a number NB of bits, from the most significant bit, called MSB, to the least significant bit, called LSB, and are representative of the image pixel color components to be displayed. Driver circuit 40 comprises a circuit 50 (LED driver) configured to control the controllable current sources CS coupled to light-emitting diodes LED with signals I_{red} , I_{green} , and I_{blue} , obtained from digital color signals R, G, B, and from a signal PWM. Data Data can correspond to signal $Data_j$ transmitted to the display pixel $12_{i,j}$ on column electrode 20_j during a selection phase. Signal PWM can correspond to selection and timing signal Com_i transmitted to the display pixel $12_{i,j}$ on row electrode 18_i during a display phase.

[0043] Figure 3 shows a timing diagrams of signal PWM and signals I_{red_1} , I_{red_2} , I_{red_3} , and I_{red_4} corresponding to signal I_{red} provided by circuit 50 of display pixel $12_{i,j}$ of Figure 2 for the display of four

different digital color signals R. According to an embodiment, light-emitting diodes LED of display pixel 12_{1,j} are controlled by pulse-width modulation. For this purpose, during a display phase, signal PWM exhibits a succession of pulses at logical state "1" which rates the operation of circuit 50 for the control of light-emitting diodes LED by pulse-width modulation. The number of pulses in the succession of pulses can correspond to the number NB+1.

[0044] As an example, when current source CS corresponds to current source providing a constant current in series with a MOS transistor, the MOS transistor is turned on or is turned off according to the logical value "0" or "1" of each bit of color signal R, G, or B, from the most significant bit MSB to the least significant bit LSB, at the rate of the pulses of signal PWM, the MOS transistor being maintained on or off until the next pulse of signal PWM. Therefore, the current source CS is switched on or off during NB successive durations according to the logical values of the bits of the digital signal R, G, or B. For example, current source CS can be switched on during a duration when the bit of the color digital data associated with this time interval is at logical value "1" and can be switched off during a duration when the bit of the color digital data associated with this time interval is at logical value "0". The duration between two successive pulses of signal PWM is divided each time by two, so that the total duration for which the light-emitting diode is on depends on the value of color signal R, G, or B. The succession of pulses of signal PWM can be repeated until the display of another image pixel. In that case, the succession of pulses of signal PWM forms a display cycle and the display phase comprises more than one display cycle.

[0045] In Figure 3, as an example, number NB is equal to 7 and only one display cycle is shown. Signal I_red_1 is obtained for the display of an image pixel color component corresponding to color signal R equal to "1010101". Signal I_red_2 is obtained for the display of an image pixel color component corresponding to color signal R equal to "0101010". Signal I_red_3 is obtained for the display of an image pixel color component corresponding to color signal R equal to "1111111". Signal I_red_4 is obtained for the display of an image pixel color component corresponding to color signal R equal to "0000000".

[0046] Circuit 26 of display screen 10 usually also receives a setting B_SET to vary the global brightness of the image that is displayed. This setting B_SET can be distinct from the video data received by circuit 26. As an example, the brightness setting can be controlled by the person watching the display screen 10. A way of decreasing the brightness of a displayed image with respect to a maximal brightness is to decrease the duration of a display cycle with respect to the maximal duration T_{max} of a display cycle used for the maximal brightness, the light emitting diode LED being switched off during the rest of duration T_{max}.

[0047] Figure 4 shows timing diagrams of signal PWM and signal I_red provided by circuit 50 of display pixel 12_{i,j} of Figure 2 for the display of the same color digital signal "1010101" for three value of a brightness setting. The upper signals corresponds to the signal PWM and signal I_red when the cycle duration is equal to a maximal display cycle duration T_{max}. The middle signal corresponds to the signal PWM and signal I_red when the cycle duration is equal substantially to 50% of maximal display cycle duration T_{max}. The lower signal corresponds to the signal

PWM and signal I_{red} when the cycle duration is equal substantially to 10% of maximal PWM cycle duration T_{max} .

[0048] The decrease of the duration of a PWM cycle with respect to the maximal display cycle duration T_{max} leads to the decrease of each duration associated with each bit of the color digital signal. This means that the pulses of the selection and timing signal Com_i need to be generated closer by selection and timing circuit 22.

[0049] A difficulty is to generate the pulses for providing the shortest duration associated with the LSB. Indeed, the propagation time of selection and timing signal Com_i between display pixel $12_{i,j}$ and timing circuit 22 varies with respect to the position of display pixel $12_{i,j}$ on display screen 10. In the arrangement shown in Figure 1, the propagation time on row electrodes 18_i is the shortest for the display pixels $12_{i,j}$ on the first column that is the closest to selection and timing circuit 22 and is the longest for the display pixels $12_{i,j}$ on the last column that is the furthest from timing circuit 22. It is necessary to take into account of these different propagation times to make sure that, for each row, all the pulses of selection and timing signal Com_i during a display cycle are correctly transmitted to all the display pixels of the row. This can result in an upper limit as regards the operation speed of the display screen.

[0050] Moreover, as shown in Figure 4, different signals PWM need to be sent to the display pixels according to the brightness setting. This can result in a selection and timing circuit 22 having a complex structure to be able to generate many different signals PWM.

[0051] Moreover, there is a limitation of minimum brightness control range. As an example, let us consider a display

screen where the refresh frequency is equal to 120 Hz, the minimum pulse duration is equal to 50 ns, and NB is equal to 16. The minimum possible display cycle duration is equal to 50 ns times 2^{16} , that is equal to 3,28 ms. This corresponds to a minimum brightness equal to 39% of the maximum brightness.

[0052] Figure 5 shows a block diagram of an embodiment of a part of circuit 26 of display screen 10.

[0053] Circuit 26 comprises:

- a circuit 60 configured to receive video data V_IN, to receive a gamma setting GAMMA and to apply to the received video data V_IN a gamma correction in order to provide successive gamma corrected video data V_G;
- a circuit 62 configured to receive brightness setting B_SET and to store the received brightness setting B_SET;
- a circuit 64 configured to receive brightness setting B_SET stored in circuit 62 and to provide a decreasing factor DF; and
- a circuit 66 configured to multiply each successive gamma corrected video data V_G with decreasing factor DF and to provide successive brightness and gamma corrected video data V_GB.

[0054] Each received video data V_IN comprise NB bits. Each gamma corrected video data V_G comprises NB+a bits. The additional number of bits "a" depends on the type of gamma correction that is performed by circuit 60. The brightness setting comprises K bits. The decreasing factor DF is in the range from 0 to 1. Each brightness and gamma corrected video data V_GB comprises NB+a bits. Data signal Data_j can correspond to brightness and gamma corrected video data V_GB.

[0055] Figure 6 shows a curve of evolution of decreasing factor DF with respect to brightness setting B_SET. In the example shown in Figure 6, the decreasing factor DF varies linearly with brightness setting B_SET.

[0056] The human eyes are much more sensitive to changes in dark tones than they are to similar changes in bright tones. A photodetector usually provides an analog electric image pixel signal that has a substantially linear relationship with the number of photons hitting the sensor. If the display system was operated with a digital driving method such as pulse-width modulation operation, a high number of bits would need to be used for the digital image pixel signals for the dark tones to be described with enough precision. A digitalization with a low number of bits results in a posterization of the displayed image for the dark tones.

[0057] To optimize the usage of bits when encoding an image and/or to optimize the bandwidth used to transport an image, a non-linear operation, generally called gamma encoding or gamma compression, is applied to image pixel signal provided by the photodetector to redistribute native image sensor tonal levels into ones which are more perceptually uniform for the human eyes. Gamma encoding is for example defined by the following power-law expression:

[0058] [Math 1]

$$V_{out} = V_{in}^{\gamma_c}$$

where the non-negative real input value V_{in} is raised to the power γ_c to get the output value V_{out} , with, for example, V_{in} and V_{out} in the range 0-1. The exponent γ_c usually is equal to 1/2.2.

[0059] To display the image pixel, the inverse non-linear operation, called gamma decoding or gamma expansion, is

applied to the image pixel signal to effectively convert it back into light from the original scene. Gamma decoding is for example defined by the following power-law expression:

[0060] [Math 2]

$$V_{out} = V_{in}^{\gamma_d}$$

where the non-negative real input value V_{in} is raised to the power γ_d to get the output value V_{out} , with, for example, V_{in} and V_{out} in the range 0-1. The exponent γ_d usually is equal to $1/\gamma_d$, that is for example equal to 2.2.

[0061] The gamma decoding operation is performed by circuit 60. Gamma setting GAMMA can correspond to exponent γ_d , that is for example equal to 2, 2.2, or 2.4.

[0062] The multiplication of each gamma corrected video data V_G by decreasing factor DF is equivalent to resize the gamma decoding function that is applied to received video data V_{IN} .

[0063] Figure 7 shows the equivalent gamma decoding function I_{gam100} , I_{gam50} , I_{gam25} applied to the received video data V_{IN} for different brightness settings B_{SET} corresponding to a brightness equal to 100% (curve I_{gam100}), 50% (I_{gam50}), and 25% (I_{gam25}). In Figure 7, the y-axis indicates the number of levels of the brightness and gamma corrected video data V_{GB} and the x-axis indicates the number of levels of the received video data V_{IN} . To make tones appear smooth and continuous in an image, it is usually enough to be able to code at least 256 different levels of luminance, which should theoretically only require 8 bits.

[0064] As an example, Table 1 below comprises:

-in the first column entitled "Gray Scale (8-bit)", the 256 gray scale values in decimal notation that can be coded

with 8 bits;

-in the second column entitled "Ideal Linear (16-bit)", the corresponding ideal obtained values in decimal notation after a linear conversion that can be coded with 16 bits;

-in the third column entitled "Ideal 2.2 (16-bit)", the corresponding ideal obtained values in decimal notation after a gamma conversion with γ equal to 2.2 that can be coded with 16 bits;

-in the fourth column entitled "100% brightness", the corresponding real values in decimal notation after a multiplication by a decrease factor equal to 1;

-in the fifth column entitled "50% brightness", the corresponding real values in decimal notation after a multiplication by a decrease factor equal to 0,5; and

-in the sixth column entitled "25% brightness", the corresponding real values in decimal notation after a multiplication by a decrease factor equal to 0,25.

[0065] [Table 1]

Gray Scale(8-bit)	Ideal Linear (16-bit)	Ideal 2.2 (16-bit)	100% brightness	50% brightness	25% brightness
0	0	0,00	0	0	0
1	511	1,51	2	1	1
2	767	3,69	4	2	1
3	1023	6,95	7	4	2
4	1279	11,36	11	6	3
5	1535	16,97	17	9	4
6	1791	23,83	24	12	6
7	2047	31,97	32	16	8
8	2303	41,43	41	21	10
9	2559	52,24	52	26	13
10	2815	64,43	64	32	16
11	3071	78,03	78	39	20
12	3327	93,06	93	47	23
13	3583	109,54	110	55	28
14	3839	127,50	128	64	32
15	4095	146,96	147	74	37
16	4351	167,93	168	84	42
17	4607	190,44	190	95	48
18	4863	214,50	214	107	54
19	5119	240,13	240	120	60

20	5375	267,34	267	134	67
21	5631	296,16	296	148	74
22	5887	326,59	327	164	82
23	6143	358,65	359	180	90
24	6399	392,35	392	196	98
25	6655	427,72	428	214	107
26	6911	464,75	465	233	116
27	7167	503,47	503	252	126
28	7423	543,88	544	272	136
29	7679	586,01	586	293	147
30	7935	629,85	630	315	158
31	8191	675,42	675	338	169
32	8447	722,73	723	362	181
33	8703	771,80	772	386	193
34	8959	822,63	823	412	206
35	9215	875,23	875	438	219
36	9471	929,61	930	465	233
37	9727	985,79	986	493	247
38	9983	1043,77	1044	522	261
39	10239	1103,57	1104	552	276
40	10495	1165,18	1165	583	291
41	10751	1228,63	1229	615	307
42	11007	1293,91	1294	647	324
43	11263	1361,04	1361	681	340
44	11519	1430,03	1430	715	358
45	11775	1500,88	1501	751	375
46	12031	1573,61	1574	787	394
47	12287	1648,21	1648	824	412
48	12543	1724,71	1725	863	431
49	12799	1803,10	1803	902	451
50	13055	1883,39	1883	942	471
51	13311	1965,60	1966	983	492
52	13567	2049,73	2050	1025	513
53	13823	2135,78	2136	1068	534
54	14079	2223,77	2224	1112	556
55	14335	2313,70	2314	1157	579
56	14591	2405,58	2406	1203	602
57	14847	2499,41	2499	1250	625
58	15103	2595,20	2595	1298	649
59	15359	2692,96	2693	1347	673
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61	15871	2894,42	2894	1447	724
62	16127	2998,13	2998	1499	750
63	16383	3103,83	3104	1552	776
64	16639	3211,53	3212	1606	803
65	16895	3321,24	3321	1661	830
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67	17407	3546,70	3547	1774	887
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75	19455	4530,03	4530	2265	1133
76	19711	4662,20	4662	2331	1166
77	19967	4796,45	4796	2398	1199
78	20223	4932,79	4933	2467	1233
79	20479	5071,21	5071	2536	1268
80	20735	5211,72	5212	2606	1303
81	20991	5354,33	5354	2677	1339
82	21247	5499,04	5499	2750	1375
83	21503	5645,86	5646	2823	1412
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86	22271	6099,01	6099	3050	1525
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88	22783	6411,74	6412	3206	1603
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90	23295	6733,02	6733	3367	1683
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92	23807	7062,89	7063	3532	1766
93	24063	7231,05	7231	3616	1808
94	24319	7401,38	7401	3701	1850
95	24575	7573,87	7574	3787	1894
96	24831	7748,53	7749	3875	1937
97	25087	7925,36	7925	3963	1981
98	25343	8104,38	8104	4052	2026
99	25599	8285,57	8286	4143	2072
100	25855	8468,96	8469	4235	2117
101	26111	8654,54	8655	4328	2164
102	26367	8842,31	8842	4421	2211
103	26623	9032,28	9032	4516	2258
104	26879	9224,46	9224	4612	2306
105	27135	9418,85	9419	4710	2355
106	27391	9615,45	9615	4808	2404
107	27647	9814,26	9814	4907	2454
108	27903	10015,30	10015	5008	2504
109	28159	10218,57	10219	5110	2555
110	28415	10424,06	10424	5212	2606
111	28671	10631,79	10632	5316	2658
112	28927	10841,75	10842	5421	2711
113	29183	11053,96	11054	5527	2764
114	29439	11268,41	11268	5634	2817
115	29695	11485,12	11485	5743	2871
116	29951	11704,07	11704	5852	2926
117	30207	11925,28	11925	5963	2981
118	30463	12148,76	12149	6075	3037
119	30719	12374,50	12374	6187	3094
120	30975	12602,51	12603	6302	3151
121	31231	12832,79	12833	6417	3208
122	31487	13065,34	13065	6533	3266
123	31743	13300,18	13300	6650	3325
124	31999	13537,30	13537	6769	3384
125	32255	13776,71	13777	6889	3444

126	32511	14018,41	14018	7009	3505
127	32767	14262,40	14262	7131	3566
128	33023	14508,70	14509	7255	3627
129	33279	14757,29	14757	7379	3689
130	33535	15008,19	15008	7504	3752
131	33791	15261,40	15261	7631	3815
132	34047	15516,92	15517	7759	3879
133	34303	15774,76	15775	7888	3944
134	34559	16034,91	16035	8018	4009
135	34815	16297,39	16297	8149	4074
136	35071	16562,20	16562	8281	4141
137	35327	16829,33	16829	8415	4207
138	35583	17098,80	17099	8550	4275
139	35839	17370,61	17371	8686	4343
140	36095	17644,75	17645	8823	4411
141	36351	17921,24	17921	8961	4480
142	36607	18200,07	18200	9100	4550
143	36863	18481,26	18481	9241	4620
144	37119	18764,80	18765	9383	4691
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146	37631	19338,94	19339	9670	4835
147	37887	19629,56	19630	9815	4908
148	38143	19922,54	19923	9962	4981
149	38399	20217,89	20218	10109	5055
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152	39167	21118,19	21118	10559	5280
153	39423	21423,05	21423	10712	5356
154	39679	21730,29	21730	10865	5433
155	39935	22039,93	22040	11020	5510
156	40191	22351,95	22352	11176	5588
157	40447	22666,37	22666	11333	5667
158	40703	22983,18	22983	11492	5746
159	40959	23302,40	23302	11651	5826
160	41215	23624,01	23624	11812	5906
161	41471	23948,04	23948	11974	5987
162	41727	24274,47	24274	12137	6069
163	41983	24603,32	24603	12302	6151
164	42239	24934,58	24935	12468	6234
165	42495	25268,26	25268	12634	6317
166	42751	25604,36	25604	12802	6401
167	43007	25942,88	25943	12972	6486
168	43263	26283,83	26284	13142	6571
169	43519	26627,21	26627	13314	6657
170	43775	26973,02	26973	13487	6743
171	44031	27321,27	27321	13661	6830
172	44287	27671,95	27672	13836	6918
173	44543	28025,08	28025	14013	7006
174	44799	28380,65	28381	14191	7095
175	45055	28738,67	28739	14370	7185
176	45311	29099,13	29099	14550	7275
177	45567	29462,05	29462	14731	7366
178	45823	29827,43	29827	14914	7457

179	46079	30195,26	30195	15098	7549
180	46335	30565,55	30566	15283	7642
181	46591	30938,30	30938	15469	7735
182	46847	31313,53	31314	15657	7829
183	47103	31691,21	31691	15846	7923
184	47359	32071,38	32071	16036	8018
185	47615	32454,01	32454	16227	8114
186	47871	32839,12	32839	16420	8210
187	48127	33226,71	33227	16614	8307
188	48383	33616,79	33617	16809	8404
189	48639	34009,34	34009	17005	8502
190	48895	34404,39	34404	17202	8601
191	49151	34801,92	34802	17401	8701
192	49407	35201,95	35202	17601	8801
193	49663	35604,47	35604	17802	8901
194	49919	36009,49	36009	18005	9002
195	50175	36417,01	36417	18209	9104
196	50431	36827,03	36827	18414	9207
197	50687	37239,56	37240	18620	9310
198	50943	37654,59	37655	18828	9414
199	51199	38072,14	38072	19036	9518
200	51455	38492,20	38492	19246	9623
201	51711	38914,77	38915	19458	9729
202	51967	39339,86	39340	19670	9835
203	52223	39767,48	39767	19884	9942
204	52479	40197,61	40198	20099	10050
205	52735	40630,27	40630	20315	10158
206	52991	41065,46	41065	20533	10266
207	53247	41503,18	41503	20752	10376
208	53503	41943,43	41943	20972	10486
209	53759	42386,21	42386	21193	10597
210	54015	42831,54	42832	21416	10708
211	54271	43279,40	43279	21640	10820
212	54527	43729,81	43730	21865	10933
213	54783	44182,76	44183	22092	11046
214	55039	44638,26	44638	22319	11160
215	55295	45096,30	45096	22548	11274
216	55551	45556,90	45557	22779	11389
217	55807	46020,05	46020	23010	11505
218	56063	46485,76	46486	23243	11622
219	56319	46954,03	46954	23477	11739
220	56575	47424,86	47425	23713	11856
221	56831	47898,25	47898	23949	11975
222	57087	48374,21	48374	24187	12094
223	57343	48852,74	48853	24427	12213
224	57599	49333,84	49334	24667	12334
225	57855	49817,51	49818	24909	12455
226	58111	50303,75	50304	25152	12576
227	58367	50792,58	50793	25397	12698
228	58623	51283,98	51284	25642	12821
229	58879	51777,96	51778	25889	12945
230	59135	52274,53	52275	26138	13069
231	59391	52773,69	52774	26387	13194

232	59647	53275,43	53275	26638	13319
233	59903	53779,76	53780	26890	13445
234	60159	54286,69	54287	27144	13572
235	60415	54796,21	54796	27398	13699
236	60671	55308,33	55308	27654	13827
237	60927	55823,05	55823	27912	13956
238	61183	56340,37	56340	28170	14085
239	61439	56860,30	56860	28430	14215
240	61695	57382,83	57383	28692	14346
241	61951	57907,97	57908	28954	14477
242	62207	58435,72	58436	29218	14609
243	62463	58966,08	58966	29483	14742
244	62719	59499,06	59499	29750	14875
245	62975	60034,66	60035	30018	15009
246	63231	60572,87	60573	30287	15143
247	63487	61113,70	61114	30557	15279
248	63743	61657,16	61657	30829	15414
249	63999	62203,25	62203	31102	15551
250	64255	62751,96	62752	31376	15688
251	64511	63303,30	63303	31652	15826
252	64767	63857,27	63857	31929	15964
253	65023	64413,88	64414	32207	16104
254	65279	64973,12	64973	32487	16243
255	65535	65535,00	65535	32768	16384

[0066] Figure 8 shows examples of timing diagrams of signal PWM and signals I_red_100, I_red_50, and I_red_25 provided by circuit 50 of display pixel 12_{i,j} of Figure 2 for the display of the same initial video data V_IN for three values of a brightness setting. The gamma corrected video data V_G for initial video data V_IN corresponds to the digital signal "1010101". Signal I_red_100 corresponds to a brightness equal to 100%, that is a decrease factor DF equal to 1, so that the brightness and gamma corrected video data V_GB also corresponds to the digital signal "1010101". Signal I_red_50 corresponds to a brightness equal to 50%, that is a decrease factor DF equal to 0.5, so that the brightness and gamma corrected video data V_GB corresponds to the digital signal "0101010". Signal I_red_25 corresponds to a brightness equal to 25%, that is a decrease factor equal DF to 0.25, so that the brightness and gamma corrected video data V_GB corresponds to the digital signal "0010101".

[0067] A brightness setting in the range from 0% to 100% can be achieved without requiring the generation of a very short time intervals. The gamma decoding operation is independent from the brightness command. The only additional circuit that is required to implement the brightness command in the previously disclosed embodiment is the use of a multiplier 66. The selection and timing signal Com_i supplied by selection and timing circuit 22 is, during a display phase, advantageously the same whatever the brightness setting is. Therefore, the structure of the selection and timing circuit 22 can be simple.

[0068] Various embodiments and variants have been described. Those skilled in the art will understand that certain features of these various embodiments and variants may be combined, and other variants will occur to those skilled in the art. In particular, the PWM modulation may be internally generated in the driver circuit 40 of display pixel $12_{i,j}$ to avoid using signal Com_i to generate it. Other embodiments may also use other electro-optical components such as organic light-emitting diodes.

[0069] Finally, the practical implementation of the described embodiments and variations is within the abilities of those skilled in the art based on the functional indications given hereabove.

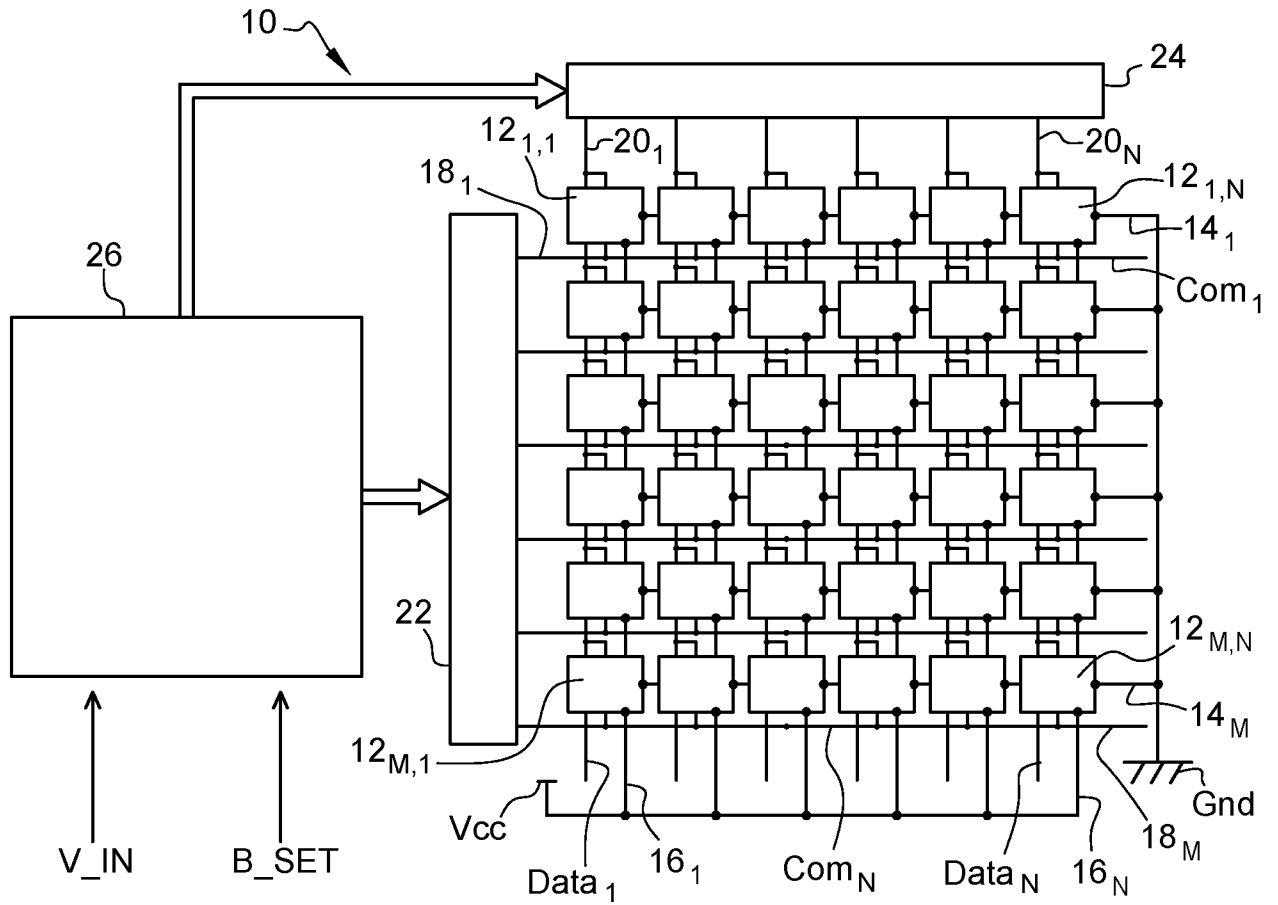
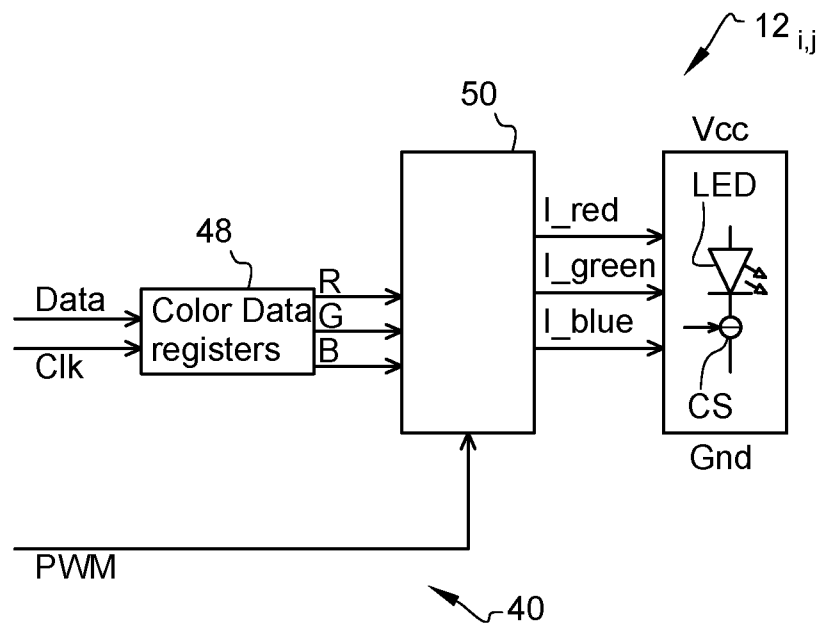
CLAIMS

1. Display screen (10) comprising an array of display pixels ($12_{i,j}$) each comprising a least one light-emitting diode (LED), the display screen further comprising a first circuit (60) configured to receive initial digital video data (V_{IN}) and to apply a gamma decoding to the received initial digital video data (V_{IN}) to produce gamma corrected digital video data (V_G), a second circuit (62) configured to receive a brightness setting (B_{SET}), a third circuit (64) configured to provide a digital decrease factor (DF) that depends on the brightness setting (B_{SET}), and a fourth circuit (66) configured to multiply the gamma corrected digital video data (V_G) by the digital decrease factor (DF) to provide brightness and gamma corrected digital video data (V_{GB}).
2. Display screen according to claim 1, wherein the display pixels ($12_{i,j}$) are arranged in rows and columns, the display screen further comprising a data driver (24) configured to provide video data ($Data_j$) to the columns of display pixels ($12_{i,j}$) based on the brightness and gamma corrected digital video data (V_{GB}).
3. Display screen according to claim 2, wherein each display pixels ($12_{i,j}$) comprises a driver circuit (40) configured to determine a digital signal (R, G, B) from the video data ($Data_j$) and to control the light-emitting diode (LED) based on the digital signal.
4. Display screen according to claim 3, wherein the driver circuit (40) is configured to control the light-emitting diode (LED) by pulse-width modulation based on the digital signal (R, G, B).

5. Display screen according to any of claims 2 to 4, comprising a selection and timing circuit (24) configured to provide a succession of pulses to each row of display pixels ($12_{i,j}$).
6. Display screen according to claims 3 and 5, wherein the driver circuit (40) is configured to turn on or turn off the light-emitting diode (LED) at the rate of the succession of pulses.
7. Method for displaying images by a display screen (10) comprising an array of display pixels ($12_{i,j}$) each comprising a least one light-emitting diode (LED), comprising the following steps;
 - receiving initial digital video data (V_{IN});
 - applying a gamma decoding to the received initial digital video data (V_{IN}) to produce gamma corrected digital video data (V_G);
 - receiving a brightness setting (B_{SET});
 - providing a digital decrease factor (DF) that depends on the brightness setting (B_{SET});
 - multiplying the gamma corrected digital video data (V_G) by the digital decrease factor (DF) to provide brightness and gamma corrected digital video data (V_{GB}).
8. Method according to claim 7, wherein the display pixels ($12_{i,j}$) are arranged in rows and columns, the method further comprising the step of providing video data ($Data_j$) to the columns of display pixels ($12_{i,j}$) based on the brightness and gamma corrected digital video data (V_{GB}).
9. Method according to claim 8, wherein each display pixels ($12_{i,j}$) comprises a driver circuit (40) configured to determine a digital signal (R, G, B) from the video data ($Data_j$) and to control the light-emitting diode (LED) based on the digital signal.

10. Method according to claim 9 , wherein the driver circuit (40) is configured to control the light-emitting diode (LED) by pulse-width modulation based on the digital signal (R, G, B).
11. Method according to any of claims 8 to 10, comprising providing a succession of pulses to each row of display pixels ($12_{i,j}$).
12. Method according to claims 9 and 11, wherein the driver circuit (40) is configured to turn on or turn off the light-emitting diode (LED) at the rate of the succession of pulses.

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**Fig. 1****Fig. 2**

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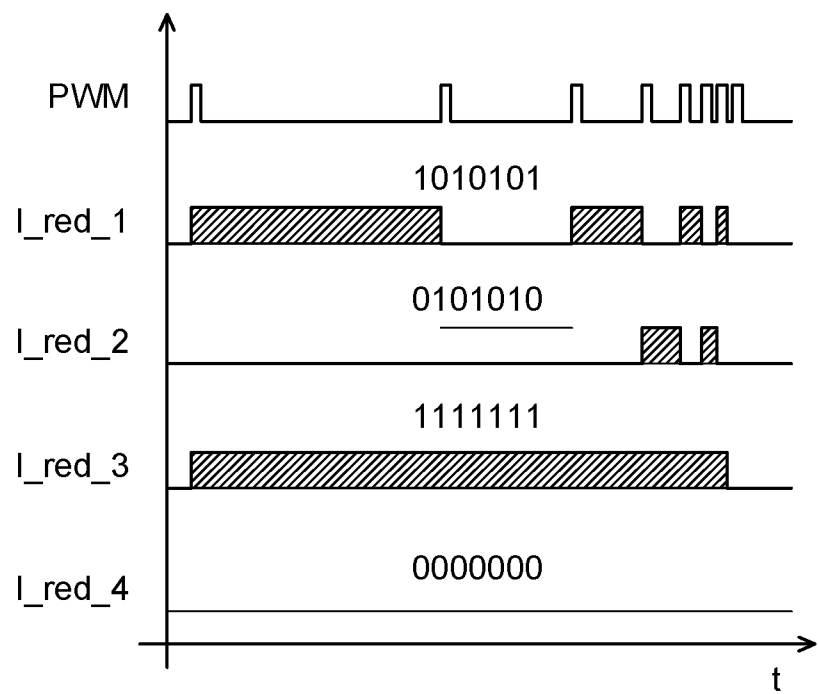


Fig. 3

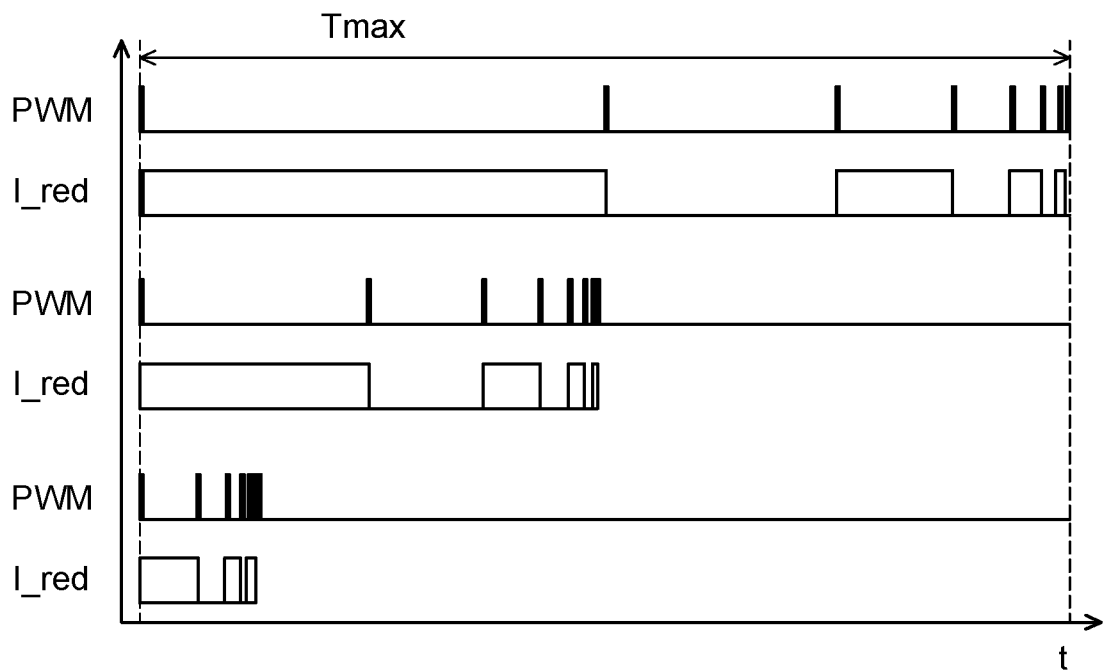
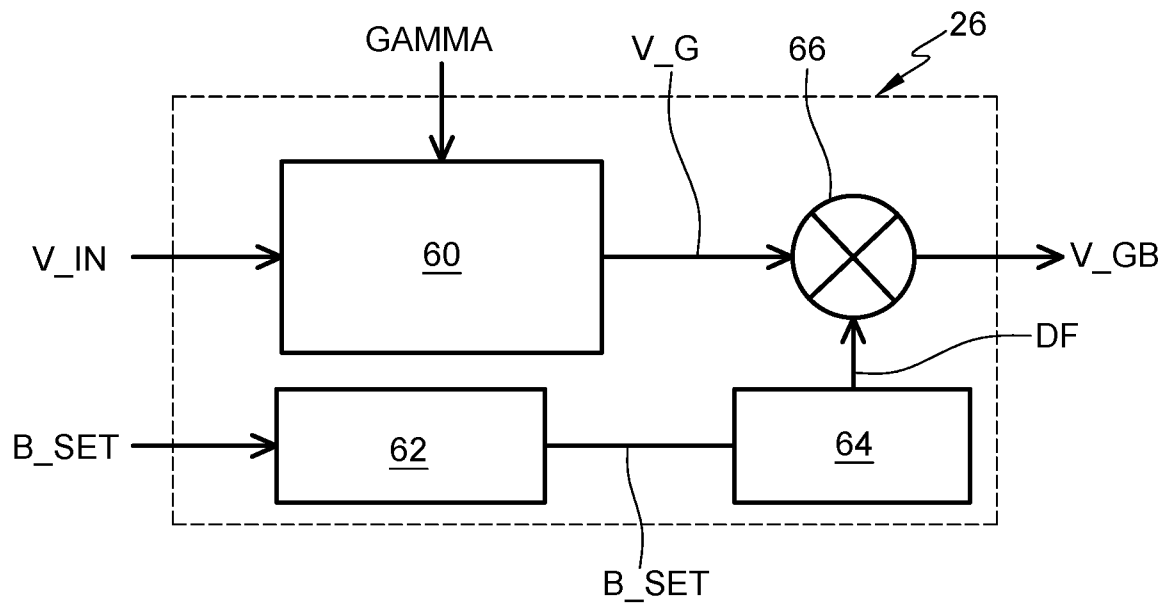
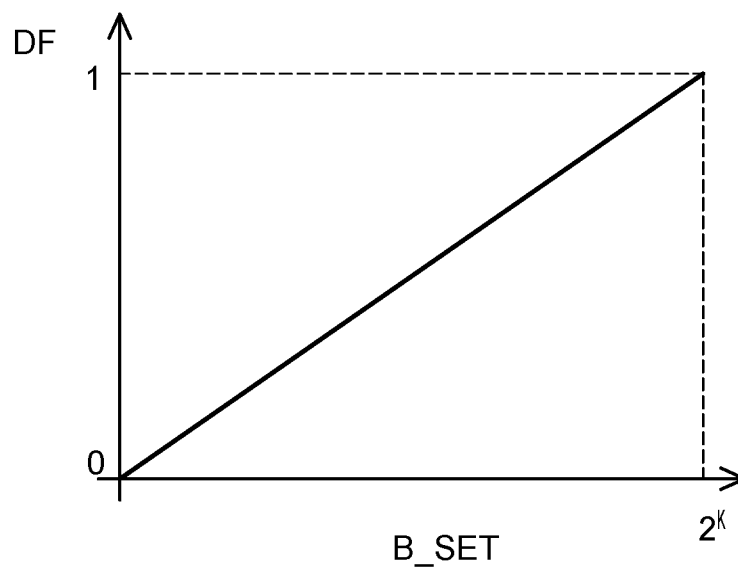


Fig. 4

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**Fig. 5****Fig. 6**

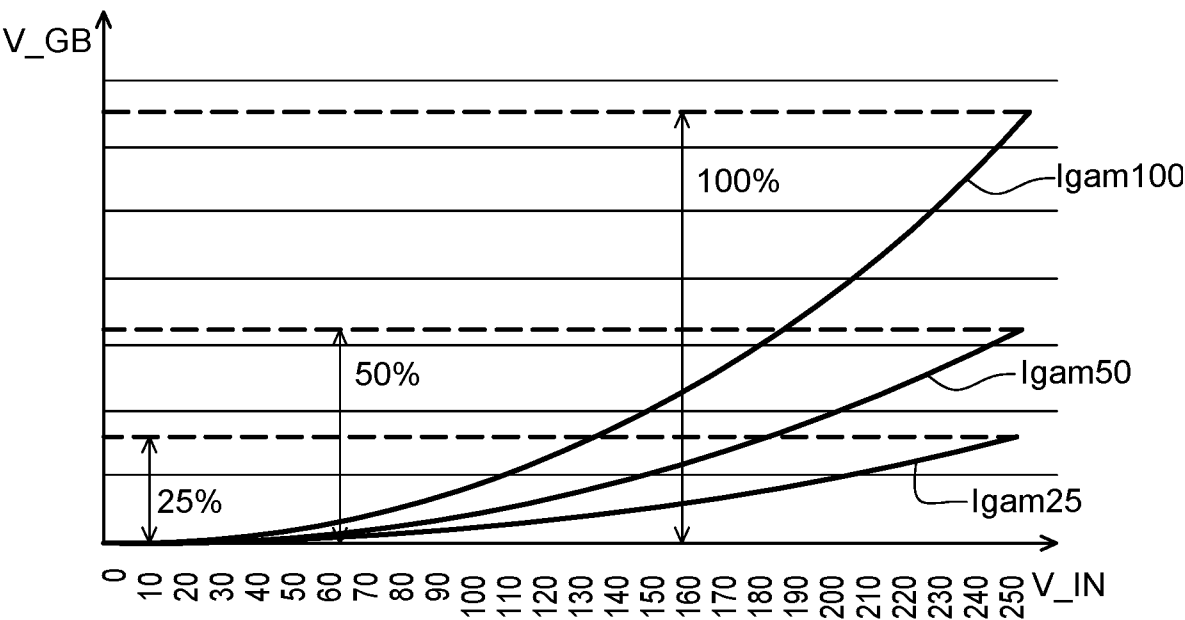


Fig. 7

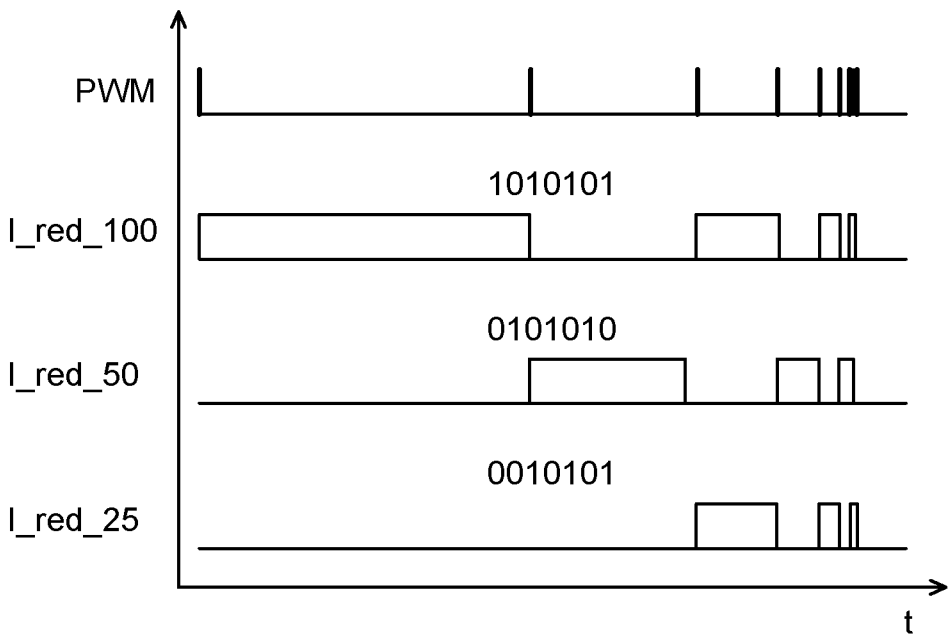


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066882

A. CLASSIFICATION OF SUBJECT MATTER

INV. G09G3/32

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G09G

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 2021/225324 A1 (FURIHATA HIROBUMI [JP] ET AL) 22 July 2021 (2021-07-22) paragraphs [0022] - [0024], [0034] - [0037], [0040], [0043], [0062] - [0063], [0072] - [0077]; figures 1,9 -----	1,2,7,8
X	US 2020/279519 A1 (ORIO MASAO [JP] ET AL) 3 September 2020 (2020-09-03)	1,7
Y	paragraphs [0034] - [0036], [0039] - [0047]; figures 1-2 -----	3-6,9-12
Y	WO 2022/207730 A1 (ALEDIA [FR]) 6 October 2022 (2022-10-06) paragraphs [0042], [0044], [0049] - [0051]; figures 1,4 -----	3-6,9-12
Y	US 2021/049957 A1 (LEE JAE HOON [KR]) 18 February 2021 (2021-02-18) paragraphs [0055] - [0059]; figure 2 -----	1,2,7,8



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

6 September 2024

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/066882

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