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EP 1950728 A2
WO 2008/140667 A1
WO 2008/010913 A2
WO 2007/049489 A1

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INT CL **G02F, G09G, H03K**
Other: **WPI, EPODOC, TXTE**

(54) Title of the Invention: **Method and apparatus for generating a switching waveform**
Abstract Title: **Randomly or pseudo-randomly modulated switching waveform for LED backlight**

(57) A switching waveform is generated for driving LED chains for a LCD backlight so as to reduce flicker. The spectral energy of the waveform is uniformly distributed by modulating 315 a variable control signal output from a brightness control 309 with the random or pseudo-random output of a spread spectrum signal generator 311 to generate at 301 a switching waveform in which a temporal characteristic, such as transition timing of a PWM waveform or the pattern of a PDM waveform, is modified to spread its spectrum more evenly with lower harmonic amplitudes (fig 5) to drive a LED array 305 used to backlight a LCD display.

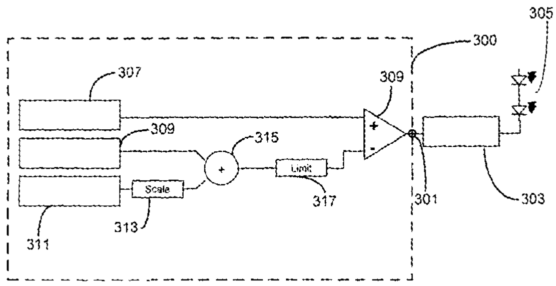

Figure 3

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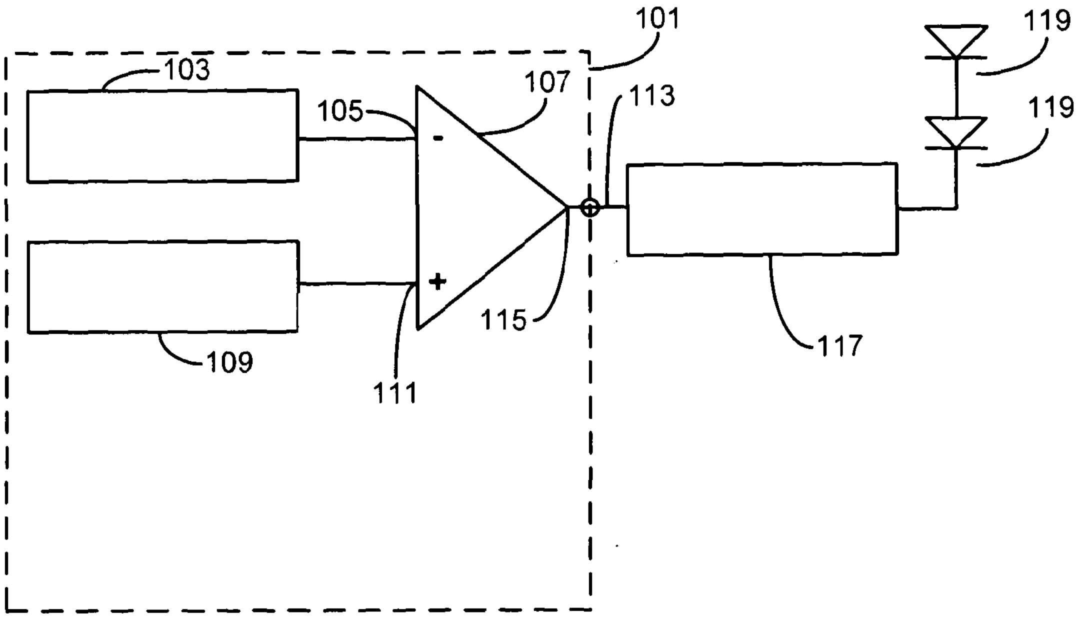

Figure 1

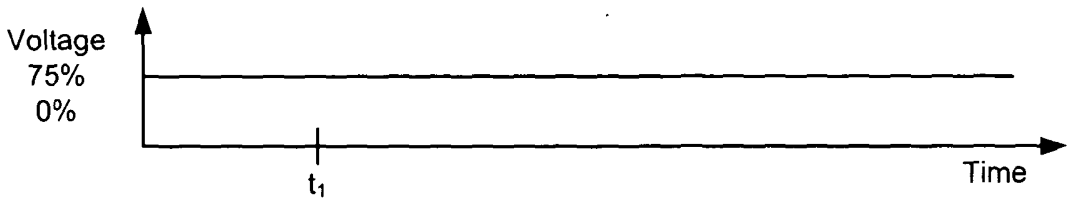

Figure 2a

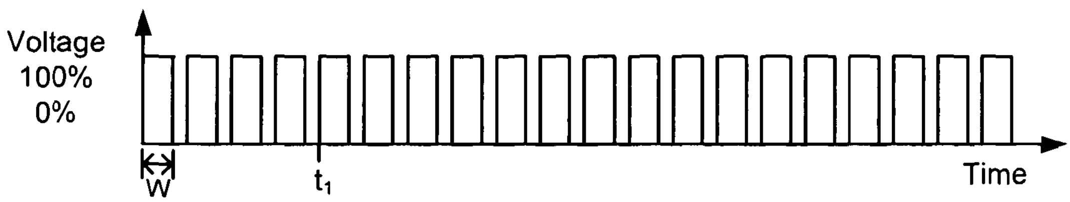

Figure 2b

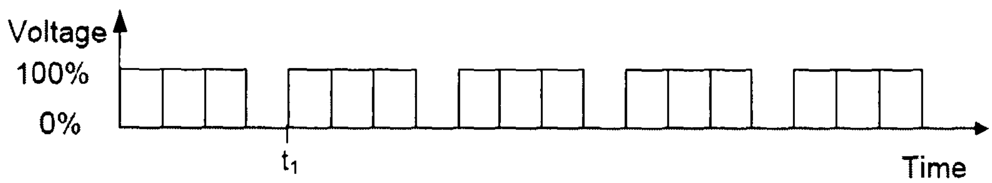

Figure 2c

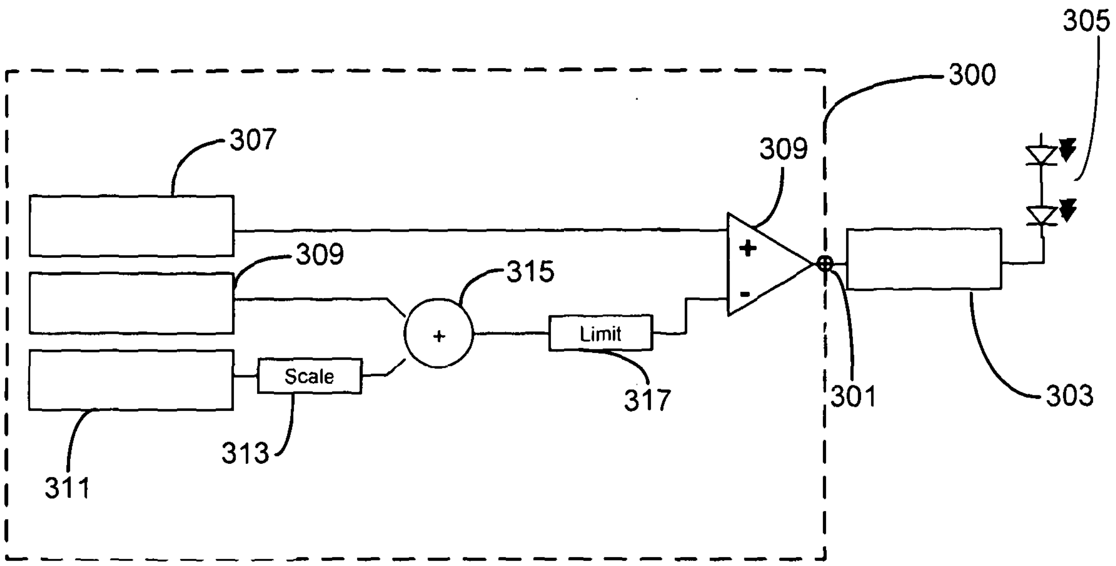

Figure 3

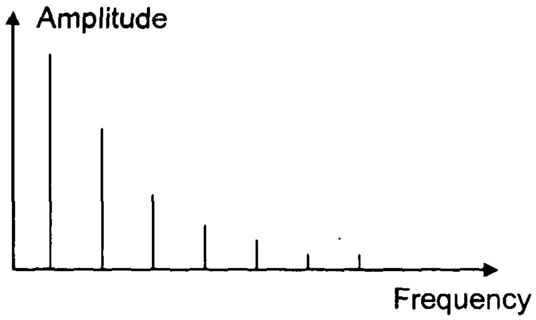

Figure 4

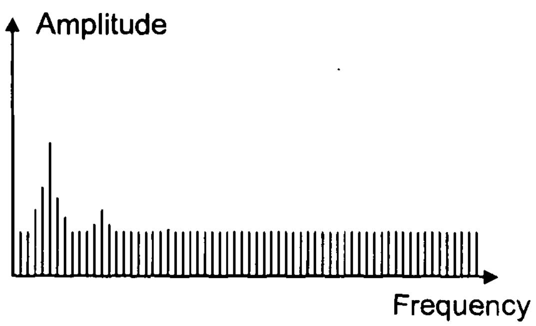

Figure 5

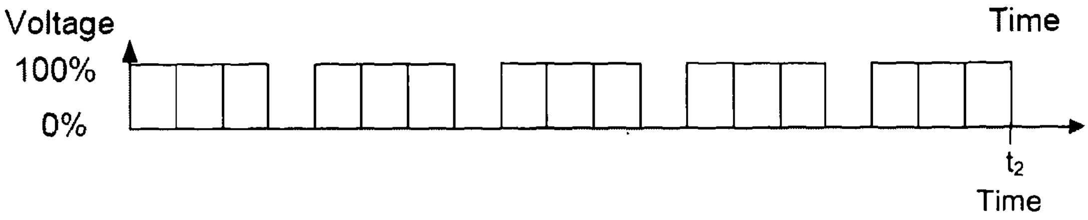

Figure 6a

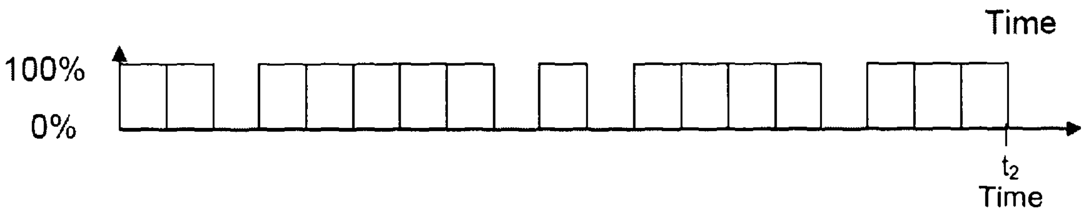

Figure 6b

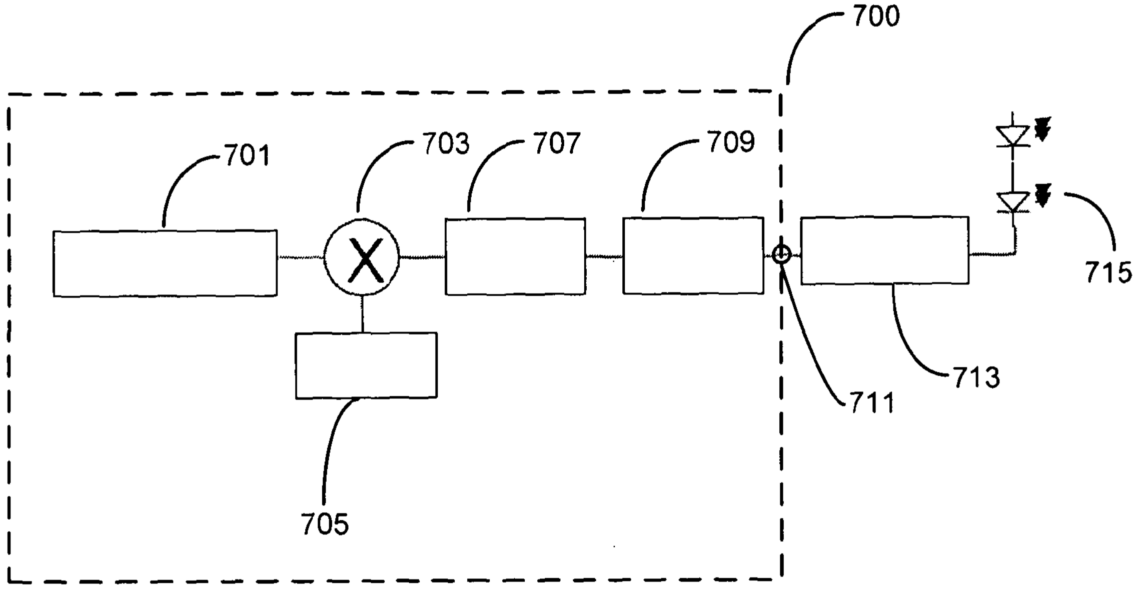

Figure 7

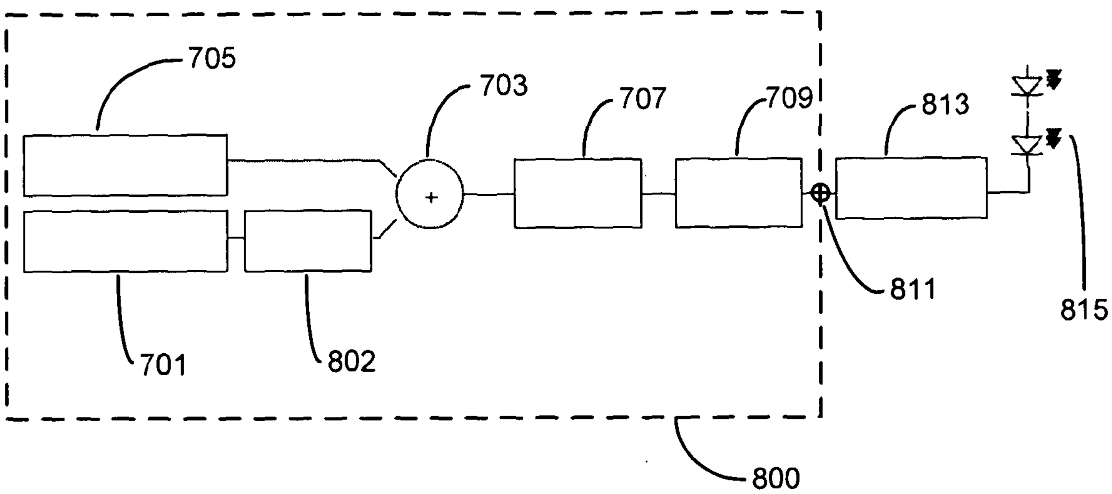

Figure 8

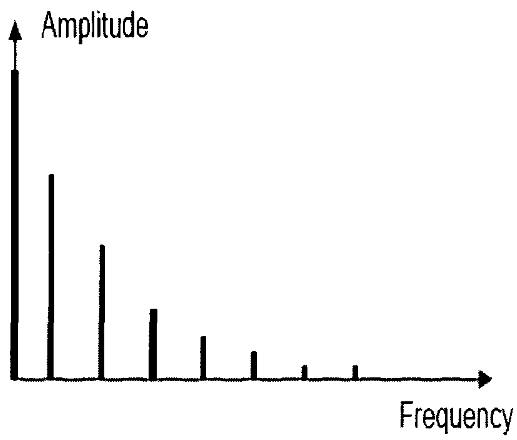

Figure 9

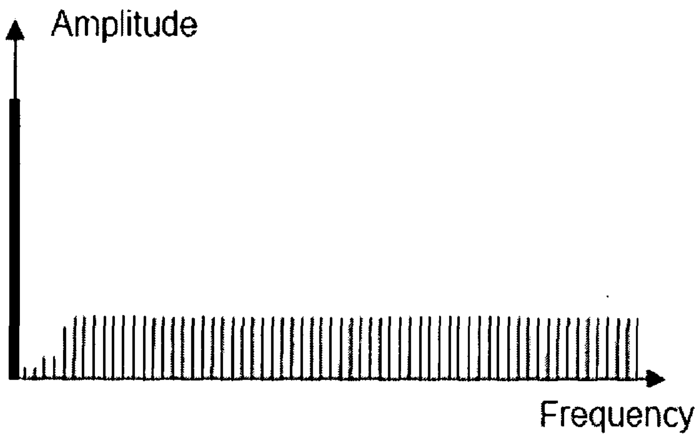

Figure 10

METHOD AND APPARATUS FOR GENERATING A SWITCHING WAVEFORM

FIELD OF THE INVENTION

The present invention relates to method and apparatus for generating a switching waveform. In particular, it relates to generating switching waveforms for illuminating a LED backlight for a LCD in controlling the brightness of the backlight.

BACKGROUND OF THE INVENTION

Many techniques have been developed to control the brightness of LEDs in LCD backlights. Some LED backlights use white LEDs while others use a combination of coloured LEDs to produce the required white light. In the latter case, the resultant colour is very dependant on the relative brightness of the LEDs and the relationship between the forward current of a LED and its brightness which is not precisely linear. The precise colour of a white LED can also change with its forward current. For this reason the brightness of LED backlights is normally controlled by pulsing the LED on and off at a single current and adjusting the proportion of the time that they are switched on. The pulse rate is chosen so that the response of the human eye averages the perceived brightness and the backlight does not flicker.

Pulse Width Modulation (PWM) is commonly used to control the brightness of LED backlights for LCDs. Figure 1 illustrates a simple schematic of a simple PWM waveform generator employed for brightness control. The PWM waveform generator 101 comprises a brightness controller 103 connected to a first input terminal 105 of a comparator 107. The PWM waveform generator 101 further comprises a sawtooth generator 109 connected to a second input terminal 111 of the comparator 107. The PWM waveform generator 101 further comprises an output terminal 113 which is connected to the output terminal 115 of the comparator 107.

The output terminal 113 of the PWM waveform generator 101 is connected to the input of a LED driver 117. The output of the LED driver 117 is connected to at least one LED chain comprising a plurality of LEDs 119.

In operation, the brightness controller 103 provided by user input or other display controls that output the brightness level. The output brightness level is compared with a sawtooth waveform, output by the sawtooth generator 109, by the comparator 107. The resulting output of the comparator 107 is a pulse waveform in which the width of the pulse is varied in accordance with any variation in the determined brightness level. The pulse waveform is then used by the LED driver 117 to turn the LEDs 119 on or off by a period determined by the pulse width and hence dependent on the brightness level.

Examples of known drive circuit for LCD backlights using a PWM waveform are disclosed by US Patent Applications Nos. 2007/236445 and 2004/0145560.

Prior art techniques switch the LEDs on and off altering the ratio of on and off time to achieve the required average brightness (as perceived by a viewer). However, in such known systems, interaction (intermodulation) of the video signal being displayed and the PWM signal occurs. This may result in motion artefacts, flicker and moving or static patterning providing undesirable effects to the display.

The Pulse Width Modulation (PWM) signal typically consists of a series of pulses with a constant repetition rate, the resolution being conveyed by adjusting the on/off ratio or duty cycle of the signal.

This results in a signal with a spectrum containing strong harmonics at the repetition frequency and multiples of that frequency. When PWM is used to control the brightness of a LED backlight for a LCD the PWM pulse rate may beat with the video signal being displayed producing interference patterns or flicker.

One known solution to reduce the visible artefacts is to synchronise the PWM pulse rate to the video raster (the video line or frame rate). This makes any intermodulation artefacts static when viewed on the display and therefore much less detrimental to the perceived image quality.

However, synchronising the PWM waveform to the video raster, as in the prior art does not eliminate beating (interference patterns or flicker) between the PWM waveform and static or moving picture detail completely. This is because static and moving picture detail are effectively unpredictable and unconstrained (within the spatial temporal constraints of the video system).

Another form of switching waveform commonly used in a variety of applications is Pulse Density Modulation (PDM). However, such switching waveforms are not known for illuminating LEDs of a LCD backlight.

One known technique of generating a PDM waveform uses a series of pulses, typically of constant period. The value of the signal being reconstructed is created by adjusting the ratio of on and off pulses ("1"s and "0"s in a binary sequence). One such known method of creating a PDM waveform is referred to as error feedback in the BBC report BBC RD 1987/12 "accommodating the residue of processed or computed digital video signals within the 8 bit CCIR recommendation 601". This report describes the use of error feedback to round to 8 bits from a higher precision. The resultant waveform is referred to as Pulse Density Modulation (PDM) waveform.

Figures 2a to 2c illustrate the generation of a PWM and a PDM waveforms representing a DC value of 75%. Figure 2a illustrates a dc value of brightness control of a LED backlight for a LCD, for example, at 75%. Figure 2b illustrates a PWM waveform representing the DC value of 75% of Figure 2a. Figure 2c illustrates a PDM waveform representing the DC value of 75% of Figure 2a.

The PWM waveform of Figure 2b comprises a plurality of identical pulses having a period t_1 the width of w of each pulse is such that the duty cycle is 75%. The equivalent PDM waveform of Figure 2c comprises a plurality of identical pulses having a repeat pattern, period t_1 and a pulse density in each period t_1 of 75%.

US Patent No. 2927962 is an early reference of a technique for creating a PDM waveform. It uses error feedback to round to a single bit to be low pass filtered to construct an analogue waveform is often referred to as a Sigma Delta modulation or a Delta Sigma DAC and is widely used in audio converters such as CD players or audio amplifiers.

However, when Error Feedback or Sigma Delta modulation is used to construct a signal, spurious spectral spurs (harmonics and aliases of the signal and its harmonics) are created. This has been overcome previously by spreading the energy across a wide range of spurs by techniques such as adding low level noise to "dither" the process making the artefacts more noise like such as that disclosed by US Patent No.

5404427. This discloses a form of Sigma Delta Modulator which spreads the spurious frequency components by introducing low level pseudo random noise to the error feedback path.

In a DAC the spurious frequency components produced by PDM are often suppressed by a low pass reconstruction filter. PDM has been used in audio amplifiers where the pulse rate is chosen to be well above the response of the speakers or the human ear. In the case of a LCD backlight the frequency components in the drive waveform cannot be removed by a low pass reconstruction filter as the resultant LED current would no longer be "ON" or "OFF". This would reduce power efficiency and introduce variations in colour when the brightness was varied.

Another technique in the prior art used in equipment such as computers is a Spread Spectrum clock. Digital systems operate on a clock to synchronise the transfer of data from one register to another. If that clock is not a pure frequency with low jitter but has designed modulation to spread the spectrum, each frequency component in the emissions from the equipment can be spread over a frequency range lowering the peak amplitude. This technique can only modulate the clock transitions with an amplitude of up to one clock cycle (in practice significantly less to ensure there are no clocking errors).

SUMMARY OF THE INVENTION

The present invention seeks to provide a waveform having reduced spurious frequency components, reduced motion artefacts and/or flicker for driving a LED backlight.

This is achieved according to a first aspect by a method for generating a switching waveform for driving a LED backlight for a LCD, the method comprising the steps of: generating a first signal having uniformly distributed spectral energy; modulating a temporal characteristic of a switching waveform with the generated first signal to distribute the spectral energy of the switching waveform evenly; and outputting the modulated switching waveform to drive at least one LED chain, the at least one LED chain comprising a plurality of LEDs.

This is also achieved by a second aspect by apparatus for generating a switching waveform for driving a LED backlight for a LCD, the apparatus comprising: a generator for generating a first signal having uniformly distributed spectral energy; modulating means for modulating a temporal characteristic of a switching waveform with the generated first signal to distribute the spectral energy of the switching waveform evenly; and an output terminal for outputting the modulated switching waveform to drive at least one LED chain, the at least one LED chain comprising a plurality of LEDs.

The first signal with evenly distributed spectral energy can be synthesised in a number of ways including random or pseudo random generators. It can be synthesised to have a spectrum comprising many closely spaced low level harmonics but without any very low frequency harmonics that might themselves cause visible flicker. This can be done by many methods well known to experts in signal processing for example summing multiple sinusoids or by synthesising the frequency domain signal and Fourier transforming to obtain the time domain. The resultant time domain signal can be stored in a memory and read out, it does not have to be synthesised in real time.

As a result a modulated switching waveform is generated whose spectral energy is more evenly distributed across a greater number of lower amplitude harmonics than a conventional switching waveform reducing spurious frequency components. When used to drive a LED backlight the intermodulation products are also lower resulting in fewer, or less visible picture artefacts. Although the total RF energy in the waveform can be higher than a conventional switching waveform, the peak spectral spurs are lower. Reduced peak spectral spurs mean reduced interference with narrow band systems and is the significant parameter for emissions approvals. The method disclosed can be used in conjunction with other techniques such as a spread spectrum clock.

In an embodiment, the switching waveform is generated from a random or pseudo-random signal. The random or pseudo-random signal may be used to modulate a variable control signal such as, for example, a brightness level of a LCD backlight. To further optimise the spectral characteristics of the modulated signal, the modulated signal may be modified by, for example, it may be filtered by a FIR (Finite Impulse Response) filter.

Further, low frequency components of the random/pseudo-random signal may be removed by use of a filter.

The switching waveform may comprise a pulse width modulated waveform and the temporal characteristic may comprise switching transitions of the pulse width modulated waveform. Alternatively, the switching waveform may comprise a pulse density modulated waveform and the temporal characteristic may comprise a pulse pattern of the pulse density modulated waveform.

In this way the PWM waveform or the PDM waveform with the desired DC or low frequency content (the required brightness in the application of a LED backlight) with a much greater number of lower level spectral components is generated, i.e. a spread spectrum signal is generated. When these intermodulate with the video raster or picture detail of a LCD for example, there are also a much greater number of intermodulation products. This results in any beating patterns being at a much lower level, less strongly patterned and as a result less visible. As a result, the picture quality is improved with reduced motion artefacts, patterning and flicker. Further, reducing beating with other ambient frequencies such as ambient lighting, other displays etc. Furthermore the reduced artefacts are achieved without the need of timing signals from the video path which allows independent development of subsystems and interoperability of both backlight and display technologies. Further driving the LEDs with a PDM waveform maintains the operating point of the LEDs at all brightness levels and hence gives stable chromaticity.

The modified switching waveforms also result in reduced electromagnetic interference with other parts of the display for example the liquid crystal drive signals as well as reduced electromagnetic interference with other equipment and consequently reduced electromagnetic screening is required.

Since the modified switching waveforms have attenuated emissions, this allows higher drive voltages and hence longer chains of LEDs to be used.

BRIEF DESCRIPTION OF DRAWINGS

For a more complete understanding of the present invention, reference is made to the following description in conjunction with the accompanying drawings, in which:

Figure 1 is a simplified schematic of a known technique of controlling brightness of LEDs of a LCD backlight;

Figures 2a to 2c illustrate an example of a conventional PDM waveform representing a DC value of 75%;

Figure 3 is a simplified schematic of apparatus according a first embodiment of the present invention;

Figure 4 is a simplified diagram of the spectrum of the switching waveform output by a conventional PWM generator;

Figure 5 is a simplified diagram of the spectrum of the output by the apparatus of Figure 3;

Figure 6 is a comparison of a classic PDM modulation and that generated by the present invention;

Figure 7 is a simplified schematic of apparatus according a second embodiment of the present invention; and

Figure 8 is a simplified schematic of apparatus according a third embodiment of the present invention;

Figure 9 is a simplified diagram of the spectrum of the switching waveform output by a conventional PDM generator; and

Figure 10 is a simplified diagram of the spectrum of the output by the apparatus of Figure 7 or 8.

DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

A first embodiment of the present invention will be now be described with reference to Figures 3 to 5.

The apparatus comprises a modifying means 300 for outputting a modified PWM waveform. The modifying means 300 comprises an output terminal 301. The output terminal 301 of the modifying means 300 is connected to a LED driver 303. The output of the LED driver 303 is connected to a LED chain of a plurality of serially connected LEDs 305.

The modifying means 300 comprises a counter 307. The output of the counter 307 is connected to a first input of a comparator 309. The modifying means 300 further comprises a brightness control 309 connected to a first input of a modulator, such as a multiplier 315. The modifying means 300 further comprises a signal generator 311. The output of the signal generator 311 is connected to a scalar 313. The output of the scalar 313 is connected to a second input of the modulator 315. The output of the modulator is connected to a limiter 317. The output of the limiter 317 is connected to a second input of the comparator 309. The output of the comparator 309 is connected to the output terminal 301 of the modifying means 300.

In operation, the counter 307 outputs a sawtooth waveform. The frequency of the sawtooth waveform is fast enough so as not to produce visible flicker but not faster than the LED response time. The brightness control 309 outputs a dc level which is an indication of the brightness level required which may be input by the viewer or from control of another part of the display (not shown). The signal generator 311 outputs a randomly or pseudo-randomly variable digital signal between -1 and 1 which is a signal having uniformly distributed spectral energy. The randomly or pseudo-randomly variable signal has a uniform pseudo random probability distribution. This is scaled by the scalar 313 to limit the digital representation of the signal within its extremes, i.e. within its valid range to avoid results being generated out of range that wraps around and produces erroneous results. The signal is scaled so that the distribution of the signal after adding the brightness value covers the full extent of the digital number range. The scaled generated signal is modulated with the brightness level to generate a randomly variable signal whose low frequency content represents the brightness level. The modulated signal is limited by the limiter 317 to limit the modulated signal to the extent of the valid digital number range. The limited, modulated signal is then compared to the sawtooth waveform by the comparator 309 to generate a PWM waveform. The width of the pulses corresponds to the brightness level output by the brightness control 309. The waveform has a period equal to the period of the sawtooth waveform. The transition timing of the pulses randomly or pseudo-randomly vary. The PWM waveform is output on the output terminal 301 of the modifying means 300 and input into the LED driver 303 to switch the LED chain 305 on and off for the required brightness level. The PWM waveform output by the modifying means 300 may switch a plurality of LED chains as required for the backlight via corresponding plurality of drivers (not shown here).

The modifying means of the first embodiment of the present invention modifies the timing of the transitions of the PWM waveform. This spreads the spectral energy. Figure 4 illustrates the spectrum output of a PWM waveform generated by a conventional means as described for example with reference to Figure 1 representing a static value (brightness). The harmonics typically fall with increasing frequency.

As shown in Figure 5, the spectrum of the PWM waveform output by the modifying means of the first embodiment as shown in Figure 3 is generally evenly distributed. This process makes the synchronisation of the PWM waveform to the video raster redundant. Alternatively, it may be used in conjunction with that technique. Importantly, the PWM waveform modified by the modifying means of the first embodiment of Figure 3 reduces image artefacts due to beating between the PWM frequency and static or moving picture detail.

Figure 6a illustrated the PDM waveform representing a dc level of 75% as previously illustrated in Figure 2c and described above. Figure 6b illustrated an example of the waveform of Figure 6a output by the apparatus of Figures 7 and 8 below, that is, the pattern of pulses of the PDM waveform has been modified to break up its periodicity and spread its waveform. Over the time interval of t_2, the density of pulses remains the same, only the pattern of pulses has been modified.

Second and third embodiments of the present invention, which generates the switching waveform of Figure 6b, will now be described with reference to Figures 7 to 10. The modifying means 700 of the second embodiment shown in Figure 7 comprises a pseudo random generator 701 of values 0 to 2. The output of the pseudo random generator 701 is connected to a first input terminal of a modulator 703, such as an adder or multiplier. A second input terminal of the modulator 703 is connected to a brightness control 705. The output of the modulator is connected to the input of a FIR filter 707. The output of the FIR filter 707 is connected to the input of a delta sigma modulator 709. The output of the delta sigma modulator 709 is connected to an output terminal 711 of the modifying means 700. The output terminal 711 is connected to the input of an LED driver 713 or a plurality of LED drivers (not shown here). Each driver 713 is connected to a respective LED chain 715 of a plurality of serially connected LEDs.

The pseudo random generator 701 outputs a multibit representation of a uniformly distributed pseudo random signal. The randomising signal is a multilevel signal represented by a multibit code that has a uniform, pseudo random, probability distribution. The pseudo random signal need not be designed or synthesised by a random process but can be designed to optimise its spread spectrum characteristics, for example, the signal can be synthesised to have a spectrum comprising many closely spaced low level harmonics but without any very low frequency harmonics that might themselves cause visible flicker. This can be done by many methods well know to experts in signal processing for example summing multiple sinusoids or by synthesising the frequency domain signal and Fourier transforming to obtain the time domain. The resultant time domain signal can be stored in a memory and read out, it does not have to be synthesised in real time. The spread spectrum signal is modulated with a signal representing the brightness level output by the brightness control by the modulator 703. The modulated signal output by the modulator 703 is a spread spectrum signal with a dc level or low frequency content, corresponding to the brightness level output by the brightness control 705. The modulated signal is filtered by a band stop finite impulse response (FIR) filter 707. The FIR filter 707 is optional and further optimises the spectral characteristics of the modulation. The filter is optional and further modifies the signal, for example to remove frequencies (other than DC) that might be low enough to be visible to the human eye. This signal is then coded by the delta sigma modulator 709 to output a PDM waveform. The pattern of the waveform being less periodic or coherent as shown in Figure 6b and as a result has a more evenly distributed spectrum. The density of the pulses corresponds to the brightness level output by the brightness control 705.

Without the modulator, if the brightness value were fed directly to the Delta Sigma Modulator 709, it would produce a spectrum containing strong frequency components spaced at frequencies that are very dependant upon the signal being represented (in this case the brightness level). If such a PDM waveform is used to control the brightness of a LED backlight for a LCD display the PDM frequency components could beat with the video signal being displayed producing interference patterns or flicker. This is reduced by breaking up the periodicity of the PDM waveform and hence spreading its spectrum more evenly with lower harmonic amplitudes.

A third embodiment of the present invention will now be described with reference to Figure 8. The modifying means 800 comprises an output terminal 811 connected to a LED driver or drivers 813 to drive LED chain or chains 815 as in the second embodiment above.

The modifying means is similar to that of the second embodiment and a detailed description of it and its operation will not be included here. The modifying means 800 further comprises a high pass filter 802 to remove low frequency components of the spread spectrum that might otherwise be visible as low frequency flicker. This allows longer pseudo-random sequences to be used.

The PDM waveform generated by the apparatus of the second and third embodiments shown in Figure 7 and 8 has the desired DC or low frequency content (the required brightness) with a much greater number of lower level spectral components as illustrated in Figure 10 when compared with a conventionally generated PDM waveform shown in Figure 9. When these lower level spectral components intermodulate with the video raster or picture detail, there are also a much greater number of intermodulation products. This results in any beating patterns being much lower level, less strongly patterned and as a result less visible.

This is achieved by modifying the periodic pattern of the PDM waveform to spread the spectral energy as illustrated in Figure 6b and described above.

The apparatus of the embodiments above may be utilised with or without synchronisation of the PWM/PDM pulse rate to the video raster. Importantly, the apparatus of the embodiments above dramatically reduces image artefacts due to beating between the PDM frequency components and static or moving picture detail. It does this because the amplitudes of the spectral components are individually of much lower amplitude. Although the total intermodulation energy may be much higher than in the previous solutions, it is less coherent, less patterned, more noise like and lower level.

The embodiments above spread the spectrum over a wider frequency range than achieved by using a spread spectrum clock, for example, and the spacing of the spectral components can be wider than the spread created by such a clock. Hence the apparatus of the embodiments described above may be combined with a spread spectrum clock to useful effect.

All the LEDs in the backlight may be driven by the same signal or individual LEDs or groups of LEDs may be driven by individual generators with uncorrelated random signals, or the same random signal with different phases.

Although embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous modifications without departing from the scope of the invention as set out in the following claims.

CLAIMS

1. A method for generating a switching waveform for driving a LED backlight for a LCD, the method comprising the steps of:
generating a first signal having uniformly distributed spectral energy;
modulating a temporal characteristic of a switching waveform with said generated first signal to distribute the spectral energy of said switching waveform evenly; and
outputting said modulated switching waveform to drive at least one LED chain, said at least one LED chain comprising a plurality of LEDs.

2. A method according to claim 1, wherein the step of generating a first signal having uniformly distributed spectral energy comprises the step of:
generating a random or pseudo-random signal.

3. A method according to claim 2, wherein the step of modulating a temporal characteristic of a switching waveform comprises the step of:
modulating a variable control signal with said random or pseudo-random signal.

4. A method according to claim 3, wherein the method further comprises the step of:
modifying the spectral characteristics of said modulated signal; and
generating said switching waveform from said modified signal.

5. A method according to claim 4, wherein the said step of modifying the spectral characteristics comprises the step of FIR filtering said modulated signal.

6. A method according to any one of claims 2 to 5, wherein the method further comprises the step of:
filtering said random or pseudo-random signal to remove low frequency components of said random or pseudo-random signal.

7. A method according to any one of the preceding claims, wherein said switching waveform comprises a pulse width modulated waveform and said temporal characteristic comprises switching transitions of said pulse width modulated waveform.

8. A method according to any one of claims 1 to 6, wherein said switching waveform comprises a pulse density modulated waveform and said temporal characteristic comprises a pulse pattern of said pulse density modulated waveform.

9. Apparatus for generating a switching waveform for driving a LED backlight for a LCD, the apparatus comprising:
a generator for generating a first signal having uniformly distributed spectral energy;
modulating means for modulating a temporal characteristic of a switching waveform with said generated first signal to distribute the spectral energy of said switching waveform evenly; and
an output terminal for outputting said modulated switching waveform to drive at least one LED chain, said at least one LED chain comprising a plurality of LEDs.

10. Apparatus according to claim 9, wherein the modulating means further comprises:
a modulator for modulating a variable control signal with a random or pseudo-random signal.

11. Apparatus according to claim 10, wherein said modifying means further comprises:
a FIR filter for filtering said modulated signal to modify the spectral characteristics of said modulated signal such that said generator generates said switching waveform from said filtered signal.

12. Apparatus according to claims 10 or 11, wherein said modifying means comprises:
a filter for filtering said random or pseudo-random signal to remove low frequency components of said random or pseudo-random signal.

13. Apparatus according to any one of claims 9 to 12, wherein said switching waveform comprises a pulse width modulated waveform and said temporal characteristic comprises switching transitions of said pulse width modulated waveform.

14. Apparatus according to any one of claims 9 to 12, wherein said switching waveform comprises a pulse density modulated waveform and said temporal characteristic comprises a pulse pattern of said pulse density modulated waveform.

15. A method for driving a LED backlight for a LCD, the method substantially as hereinbefore described with reference to any one of Figures 3 to 10.

16. Apparatus for driving a LED backlight for a LCD, the driver substantially as hereinbefore described with reference to any one of Figures 3 to 10.

Application No: GB0820539.5 **Examiner:** Peter Easterfield

Claims searched: 1 to 14 **Date of search:** 10 March 2009

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	EP 1950728 A2 (SAMSUNG)
A,E	-	WO 2008/140667 A1 (CREE)
A	-	WO 2008/010913 A2 (WANG et al)
A	-	WO 2007/049489 A1 (ROHM)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

G02F; G09G; H03K

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, TXTE

International Classification:

Subclass	Subgroup	Valid From
G09G	0003/34	01/01/2006
G02F	0001/13357	01/01/2006