



(11) **EP 2 081 414 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**22.07.2009 Bulletin 2009/30**

(51) Int Cl.:  
**H05B 33/08 (2006.01)**

(21) Application number: **08000321.3**

(22) Date of filing: **09.01.2008**

(84) Designated Contracting States:  
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR  
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT  
RO SE SI SK TR**  
Designated Extension States:  
**AL BA MK RS**

(71) Applicant: **Infineon Technologies Austria AG  
9500 Villach (AT)**

(72) Inventors:  
• **Logiudice, Andrea  
35136 Padova (IT)**

• **Bernacchia, Giuseppe Dr.  
35027 Noventa Padovana (IT)**  
• **Scenini, Andrea  
35031 Abano Terme (IT)**

(74) Representative: **Patentanwälte  
Westphal, Mussnug & Partner  
Herzog-Wilhelm-Strasse 26  
80331 München (DE)**

(54) **Sigma delta LED driver**

(57) A driver circuit for driving a light emitting diode comprising a controllable current source for connecting to the light emitting diode, the current source being configured to regulate a load current passing through the light emitting diode dependent on a control signal, and a

modulator unit configured for generating the control signal, where the control signal is dependent on a pulse-density modulated signal.

**EP 2 081 414 A1**

**Description**

## TECHNICAL FIELD

5 **[0001]** The invention relates to the field of driver circuits for light emitting diodes (LEDs) , especially multi-colour light emitting diodes.

## BACKGROUND

10 **[0002]** The brightness of light emitting diodes (LEDs) is directly dependent on the load current flowing through the diode. To vary the brightness of a LED it is known to use a controllable current source that is set to a current representing a desired brightness. In digitally controlled applications a digital-to-analog converter (DAC) may be used to set the current of the controllable current source.

15 **[0003]** Since the human eye cannot resolve high frequency brightness fluctuations of approximately 100 hertz or higher, it is known to supply the LED with a pulse width modulated current. In this case the human eye low-pass filters the resulting pulse width modulated brightness of the LED, i.e. the eye can only sense a mean brightness that depends on the mean LED current which is proportional to the duty cycle of the pulse width modulation.

20 **[0004]** It is known to combine light of different colours (e.g. red, green, and blue) and different brightness to generate nearly any colour sensation in the visible spectrum of light. In modern illumination systems or displays a combination of at least three LEDs of different colours are used to provide a multi-colour illumination. The LED-triples may be arranged in a matrix like structure thus forming a display where each "pixel" of the display is represented by a LED-triple typically comprising a red, a green, and a blue LED. To vary the colour of a pixel the brightness of the different LEDs has to be individually adjustable. Each of the three LEDs may therefore be driven by a pulse-width modulated current signal of a sufficiently high frequency, for example 400 hertz.

25 **[0005]** However, the resolution requirements are quite high for modern illumination systems or displays. That is, the brightness of a single LED should be adjustable to at least 4096 different brightness values which corresponds to a brightness resolution of 12 Bit. When using pulse width modulation for controlling the brightness, a time resolution of approximately 600 nanoseconds has to be provided in order to be able to resolve a PWM period of, for example, 2.5 milliseconds (corresponds to 400 hertz) with 12 bits. This entails the need for very fast switching currents with all the known problems coming therewith. Particularly, the electromagnetic compatibility (EMC) is low when switching currents with rise and fall times in the sub-microsecond range.

30 **[0006]** Driving the LEDs with a continuous current whose value is controlled by a DAC is also not satisfying since the wavelength of the colour of a single LED may vary over the LED current. This entails a very complex brightness control in multi-colour LED systems since the colour has to be corrected when changing the brightness of a three LED pixel.

35 **[0007]** There is a need for an alternative concept for driving LED, particularly improving the electromagnetic compatibility compared to PWM driven LED systems.

## SUMMARY

40 **[0008]** One example of the invention relates to a driver circuit for driving a light emitting diode. The circuit comprises: a controllable current source connected in series to the light emitting diode, the current source being configured to provide a load current to the light emitting diode dependent on a control signal; and a modulator unit configured for generating the control signal, where the control signal is dependent on a pulse-density modulated signal.

45 **[0009]** A further example of the invention relates to a method for driving a light emitting diode. The method comprises: providing a signal representing a desired brightness or colour; modulating the desired signal thus generating a pulse-density modulated signal; providing a current to the light emitting diode dependent on the pulse-density modulated signal.

## BRIEF DESCRIPTION OF THE DRAWINGS

50 **[0010]** The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, instead emphasis being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts. In the drawings:

55 FIG. 1 is a block diagram of a LED driver circuit for driving multi-colour LEDs;

FIG. 2 is a block diagram of a digital sigma-delta modulator providing a pulse-density modulated output signal;

FIG. 3 is a block diagram of a LED driver circuit comprising the sigma-delta modulator of FIG. 2;

FIG. 4 is a block diagram of a LED driver circuit comprising a sigma-delta modulator with a multi-bit output;

FIG. 5 is a block diagram of a LED driver circuit corresponding to FIG. 3 but with a dither noise added to the input for preventing limit cycles;

FIG. 6 is a block diagram of a LED driver circuit for driving multi-colour LEDs with a sigma-delta modulator comprising three times the driver circuit of FIG. 3;

FIG. 7 is a block diagram of a further LED driver circuit, where the load current passing through a LED is controlled by means of a bypass current source;

FIG. 8 is a block diagram of the LED driver of FIG. 7 where MOS transistors operate as switchable bypass current sources.

## DETAILED DESCRIPTION

**[0011]** FIG. 1 illustrates a known LED driver circuit for driving a LED triple, where each LED has a different colour. Such LED triples can be - if adequately controlled - used for generating any colour of the visible spectrum by means of additive mixture of colours. For this purpose usually a red LED  $LD_R$ , a green LED  $LD_G$ , and a blue LED  $LD_B$  are used. For controlling the brightness of each LED  $LD_R$ ,  $LD_G$ ,  $LD_B$  each LED is connected in series to a respective controllable (in the present example switchable) current source  $Q_R$ ,  $Q_G$ , and  $Q_B$ . If, for example, yellow light is to be generated, then the load current through the red LED  $LD_R$  has to be zero and the load currents through the green LED  $LD_G$  and the red LED  $LD_R$  have to be approximately the same, where the absolute current value depends on the desired brightness of the yellow light.

**[0012]** However, the wavelength of the light emitted by the LEDs will vary dependent on the load current passing through the LEDs. This dependency entails a change in hue when changing the load current for adjusting the brightness value. To avoid this effect it is known to use switchable current sources  $Q_R$ ,  $Q_G$ ,  $Q_B$  each controlled by a pulse width modulated (PWM) control signal. The hue of the LEDs is does not change since the brightness value is not adjusted by continuously adjusting the load currents but by adjusting the duty cycle of the PWM control signal. The "averaging" of the PWM signal is performed by the human eye.

**[0013]** In driver circuit of FIG. 1 the hue is selected by a pointer CS that identifies an entry of a calibration table 10 where the corresponding load current values  $S_R$ ,  $S_G$ ,  $S_B$  for the three LEDs are stored. The stored values  $S_R$ ,  $S_G$ ,  $S_B$  are calibrated for maximum brightness and are multiplied (multiplier 11) with a brightness value  $S_B$  for a reduced brightness. The resulting desired average current values  $I_R=S_R S_{BR}$ ,  $I_G=S_G S_{BR}$ ,  $I_B=S_B S_{BR}$  are fed to the pulse width modulators  $PWM_R$ ,  $PWM_G$ ,  $PWM_B$  that generate a respective PWM control signal having the desired mean value for driving the LEDs.

**[0014]** In digitally controlled systems the desired average current values  $I_R$ ,  $I_G$ ,  $I_B$  are typically provided as 12 bit words. The repetition frequency of the PWM pulses is typically 400Hz which is high enough that the human eye does not sense any flickering. However, PWM frequencies ranging from 100 Hz to 600 Hz are commonly used for this purpose. As already discussed above a very fast switching of the load currents is necessary for providing the desired 12 bit resolution which entails, for example, EMC problems.

**[0015]** FIG. 2 illustrates a sigma-delta modulator 1 ( $\Sigma$ - $\Delta$  modulator, often also denoted as delta-sigma modulator) for providing a pulse density modulated signal PDM for driving a LED LD, respectively the corresponding current source Q. A pulse density modulated signal is a generally non periodic bit-stream with an average value corresponding to the input signal, i.e. the desired average load current I in the present example. In the present example the input signal I is a sequence of 12 bit words. The bit-stream is a sequence of equally spaced bits, i.e. a high level represents a binary "1" and a low level a binary "0". The density of "1" in the pulse density modulated signal is high if the level of the input signal of the sigma-delta modulator is high. However, the length of one bit symbol ("1" or "0") is always the same and is equal to the period of the bit-rate frequency. For example at a bit-rate of 40 kHz, the length of a bit symbol is 25  $\mu$ s.

**[0016]** The sigma-delta modulator 1 comprises a forward path comprising an integrator 30 and a quantiser 20. It further comprises a feedback path comprising a delay element 21. The delay element receives the 1-bit output signal PDM [k] of the quantiser 20 and provides the signal at its output delayed by a sample and as a 12 bit word, i.e. the bit value of the 1-bit input signal of the delay element 21 is copied to the most significant bit of the respective output signal. "k" thereby is a time index. The delayed output signal PDM[k-1] is subtracted (subtractor 22) from the input signal I[k] and the resulting difference I[k]-PDM[k-1] is supplied to the integrator 30 that has its output connected to the quantiser 20.

**[0017]** In the present example the integrator 30 is a standard first-order digital integrator with a delay element 32 in a feedback path and an adder 31. The transfer function of the integrator in the z-domain is  $1/(1-z^{-1})$ . However higher order integrators may also be applied. The quantiser 20 may be a simple comparator element. In the present example the quantiser provides the most significant bit of its 12-bit input signal value at its output. However, also multi-bit quantiser

20 are applicable for providing an N-bit output PDM signal which is a stream of N-bit words or a set of N "parallel" bit-streams.

**[0018]** For proper operation of the sigma-delta modulator 1 the input signal has to be strongly over-sampled. Then the quantisation noise is "shifted" towards higher frequencies and can therefore be removed by a simple low-pass filtering which is - in the present case - advantageously performed by the human eye. The noise shaping properties of sigma delta modulators are well known and not further discussed here. For a bandwidth of the input signal  $I_R$  of 400 Hz an over-sampling frequency of 40 kHz is sufficient to provide a signal-to-noise ratio ( $SNR_{dB}$ ) of at least 74dB which corresponds to an effective resolution of 12 bits. The effective number of bits (ENOB) may be calculated as

$$ENOB = (SNR_{dB} - 1.76) / 6.02, \quad (1)$$

whereby the signal-to-noise ratio  $SNR_{dB}$  may be calculated as

$$SNR_{dB} = 6.02N + 1.76 - 5.17 + 30 \log_{10}(OSR) \quad (2)$$

for a sigma-delta modulator 1 with a first order integrator 30, an over-sampling rate OSR (ratio of sampling rate and bandwidth) and a N-bit quantiser 20 (N=1 in the present example). For a sigma-delta modulator 1 with a second order integrator 30 the signal-to-noise ratio  $SNR_{dB}$  is given by

$$SNR_{dB} = 6.02N + 1.76 - 12.9 + 50 \log_{10}(OSR). \quad (3)$$

**[0019]** From the discussion above it can be seen, that at a given resolution, for example 12 bit, and moderate frequencies of about 40 kHz a sigma-delta modulator provides a pulse-density modulated output signal which may be used for controlling the current sources  $Q_R$ ,  $Q_G$ ,  $Q_B$  connected to the LEDs  $LD_R$ ,  $LD_G$ ,  $LD_B$  in a LED driver circuit such as the circuit of FIG. 1.

**[0020]** For a stable operation within the desired resolution the sigma-delta modulator may comprise an anti-aliasing filter for limiting the bandwidth of its input signal to a predefined bandwidth of, for example, 400 Hz.

**[0021]** Compared to the circuit of FIG. 1 that uses PWM modulators for driving the LEDs the rise and fall times of the switching can be much longer when using a sigma-delta modulator instead, since the bit-stream comes at relatively low frequencies of about 40 kHz. Longer rise and fall times entail less electromagnetic interferences (EMI) and a better electromagnetic compatibility (EMC).

**[0022]** FIG. 3 shows the application of the sigma-delta modulator 1 of FIG. 2 in a LED driver circuit. Only one LED LD connected in series to one current source Q is depicted in FIG. 3. However, the circuit of FIG. 3 may be tripled to form a driver circuit for three LEDs  $LD_R$ ,  $LD_G$ ,  $LD_B$  of different colours analogous to the circuit of FIG. 1. The sigma-delta modulator 1 receives a desired average current value I and provides a corresponding pulse bit-stream which is a pulse-density modulated control signal supplied to the switchable current source Q. The input I of the sigma-delta modulator 1 may be derived from a calibration table analogous to the circuit of FIG. 1.

**[0023]** FIG. 4 illustrates another example of how to apply a sigma delta modulator in a LED driver circuit. This example is especially useful when using a sigma-delta modulator 1 with a multi-bit quantiser 20, e.g. a 3-bit quantiser. In this case the sigma-delta modulator 1 does not provide a single bit output signal PDM but a stream of 3-bit words, i.e. three parallel bit-streams. For transforming this three bit-streams into one control signal for driving the current source Q a second modulator 2 may be employed, for example, a pulse-width modulator (PWM) or a pulse frequency modulator (PFM). In the present example a PWM is used as second modulator. In contrast to the example of FIG. 1 the PWM needs only to resolve 8 different positions (3 Bits) in time during the PWM period of, for example, 25  $\mu$ s. As a consequence the steepness of the switching edges may be lower by a factor of five due to the sigma-delta modulator 1 arranged upstream to the sigma delta modulator while maintaining or even increasing the resolution. Alternatively a 3-bit digital-to-analog converter may be used as second modulator 2. In this case the sigma-delta modulator 1 arranged upstream to the digital-to-analog converter (DAC) has the advantage that a low resolution DAC is sufficient. Compared to the circuit of FIG. 3 the present example allows for even slower switching frequencies which may be advantageous in case the connection between the LED and the driver circuit comprises long cables. Furthermore switching losses are lower.

**[0024]** When modulating a constant input signal  $I$  then the pulse density modulated output signal of the sigma-delta modulator 1 (bit-stream) may exhibit some periodicity. This undesired effect is due to limit cycles and the spectrum of the bit-stream has so-called idle-tones, i.e. peaks at certain discrete frequencies. To avoid the idle tones a low power noise signal  $n[k]$  having zero mean and, for example, a triangular or a rectangular probability density function may be added to the input signal  $I$  as depicted in FIG. 5 by means of an adder 12. This technique is also referred to as "dithering". Due to the noise-shaping properties of sigma-delta modulators 1 the power of the dither noise  $n[k]$  is "shifted" towards higher frequencies that cannot be resolved by the human eye. That is, the human eye performs a low-pass filtering of the bit-stream. The dithering technique results in a lower signal-to-noise ratio but, however, the desired resolution of the sigma-delta modulator can be achieved regardless of the lower signal-to-noise ratio. Furthermore, the idle tones are suppressed and the undesired periodicity of the bit-stream is destroyed.

**[0025]** FIG. 6 illustrates, by means of a block diagram, a LED driver circuit for driving multi-colour LEDs with a sigma-delta modulator 1, the LED driver circuit comprising three times the driver circuit of FIG. 3. Of course driver circuits with a sigma-delta modulator 1 having a second modulator connected downstream thereof as depicted in FIG. 4 are also applicable for building up a multi-colour LED driver. In the present example one driver circuit according to FIG. 3 is employed for each colour channel (red, green, and blue). Furthermore a dither noise may be added to the input signals  $I_R$ ,  $I_G$ ,  $I_B$  of each colour channel as discussed with reference to FIG. 5. Apart from the sigma-delta modulator 1 the further components of the multi-colour LED driver circuit correspond to the components of the circuit discussed with reference to FIG. 1.

**[0026]** FIG. 7 illustrates another driver circuit for driving a plurality of light emitting diodes  $LD_1, LD_2, \dots, LD_N$ . However, the driver circuit of FIG. 7 may be usefully employed for driving at least two light emitting diodes  $LD_1, LD_2$ . The driver circuit comprises a main current source  $Q_M$  providing a main current  $I_{QM}$ . A plurality of bypass current sources  $Q_1, Q_2, \dots, Q_N$  are connected in series to the main current source  $Q_M$  and have terminals for connecting one light emitting diode  $LD_1, LD_2, \dots, LD_N$  in parallel to each bypass current source  $Q_1, Q_2, \dots, Q_N$ . Each bypass current source  $Q_1, Q_2, \dots, Q_N$  drives a bypass current  $I_{Q1}, I_{Q2}, \dots, I_{QN}$ .

**[0027]** Each bypass current source  $Q_1, Q_2, \dots, Q_N$  and the respective light emitting diode  $LD_1, LD_2, \dots, LD_N$  form a parallel circuit, wherein all these parallel circuits are connected in series.

**[0028]** A sigma-delta modulator 1 is connected to each bypass current source  $Q_1, Q_2, \dots, Q_N$  and configured to control the respective bypass current  $I_{Q1}, I_{Q2}, \dots, I_{QN}$  passing through the respective bypass current source  $Q_1, Q_2, \dots, Q_N$ . As a result, the effective load current  $I_{LD1}$ , that passes through a certain light emitting diode  $LD_1$  of the plurality of light emitting diodes, equals to the difference between the main current  $I_{QM}$  and the respective bypass current  $I_{Q1}$ , that is:

$$I_{LDi} = I_{QM} - I_{Qi},$$

whereby  $i$  is an index ranging from 1 to  $N$  denoting the number of the bypass current source  $Q_i$  driving the bypass current  $I_{Qi}$  and the light emitting diode  $LD_i$  with the load current  $I_{LDi}$ .

**[0029]** Similar to the examples of FIGs. 3, 4, and 5 the brightness of each single LED  $LD_i$  may be adjusted to a desired value by appropriately controlling the bypass currents  $I_{Qi}$  and thus the load currents  $I_{LDi}$  by means of the sigma-delta modulators 1.

**[0030]** Each sigma delta-modulator 1 may comprise a digitally addressable bus interface, for example a serial bus interface for connecting a serial bus 30. The desired current or brightness value may be received from the bus 30 as a binary word. For multi-colour illumination the brightness values may be taken from a calibration table as illustrated in the example of FIG. 1. Of course the sigma-delta modulators 1 of the present example may be followed by a second modulator 2, e.g. a pulse-width modulator, as discussed with reference to FIG. 4.

**[0031]** FIG. 8 illustrates an example similar to the example of FIG. 7, where semiconductor switches, i.e. transistors, e.g. MOS-FETs, are employed as bypass current sources  $Q_i$ . Except of the bypass current sources the example of FIG. 8 is identical to the example of FIG. 7.

**[0032]** In multi-colour applications, for example an illumination device comprising a red LED  $LD_1$ , a green LED  $LD_2$ , and a blue LED  $LD_3$ , and a driver circuit as shown in FIG. 8, the colour generated by mixing the light of the different LEDs may be adjusted by appropriately adjusting the brightness of each single LED  $LD_1, LD_2, LD_3$  by means of the sigma-delta modulators 1. Additionally, the overall brightness may be adjusted by varying the main current  $I_{QM}$ .

## Claims

1. A driver circuit for driving a light emitting diode comprising:

a controllable current source for connecting to the light emitting diode, the current source being configured to regulate a load current passing through the light emitting diode dependent on a control signal;  
a modulator unit configured for generating the control signal, where the control signal is dependent on a pulse-density modulated signal.

- 5
2. The driver circuit of claim 1, where the modulator unit comprises a sigma-delta modulator for providing the pulse-density modulated signal.
- 10
3. The driver circuit of claim 1 or 2, where the pulse-density modulated signal is directly supplied to the current source as the control signal.
- 15
4. The driver circuit of claim 2, where the sigma-delta modulator comprises a multi-bit comparator for providing a multi-bit pulse-density modulated signal.
5. The driver circuit of claim 4, where the modulator unit comprises a second modulator receiving the multi-bit pulse-density modulated signal and providing the control signal to the current source.
6. The driver circuit of claim 5, where the second modulator is a pulse-width modulator or a pulse-frequency modulator.
- 20
7. The driver circuit of claim 6, where the second modulator is a digital-to-analog converter.
8. The driver circuit of one of the claims 1 to 7, where the current source is a transistor.
- 25
9. The driver circuit of one of the claims 1 to 8 further comprising an adder being connected upstream to the sigma-delta modulator, where the adder is configured to receive a first signal representing a desired brightness or colour and to add a dither noise signal thereto, the sum of the signals being supplied to the sigma-delta modulator.
10. A method for driving a light emitting diode comprising:
- 30
- providing a first signal representing a desired brightness or colour;  
generating a pulse-density modulated signal representing the first signal; and  
providing a current to the light emitting diode dependent on the pulse-density modulated signal.
- 35
11. The method of claim 10, where the modulating is performed by a sigma-delta modulator.
12. The method of claim 10 or 11, where the current provided to the light emitting diode is proportional to the pulse-density modulated signal.
- 40
13. The method of claim 11, where the pulse-density modulated signal is a multi-bit pulse-density modulated signal.
14. The method of claim 11 further comprising:
- 45
- providing the multi-bit pulse-density modulated signal to a second modulator that generates a control signal representing the multi-bit pulse-density modulated signal, where the current provided to the light emitting diode is proportional to the control signal.
15. The method of claim 14, where the second modulator is a pulse-width modulator or a pulse-frequency modulator.
16. The method of claim 14, where the second modulator is a digital-to-analog converter.
- 50
17. The method of claim 10, where the pulse-density modulated signal is a stream of bit-symbols of equal length, each bit-symbol representing either the binary symbol "1" or "0".
18. The method of claim 10, where the pulse-density modulated signal is a set of streams of bit-symbols of equal length, each bit-symbol representing either the binary symbol "1" or "0".
- 55
19. The method of one of the claims 10 to 18, where a dither noise signal is added to the first signal before being supplied to the sigma-delta modulator for generating a pulse-density modulated signal therefrom.

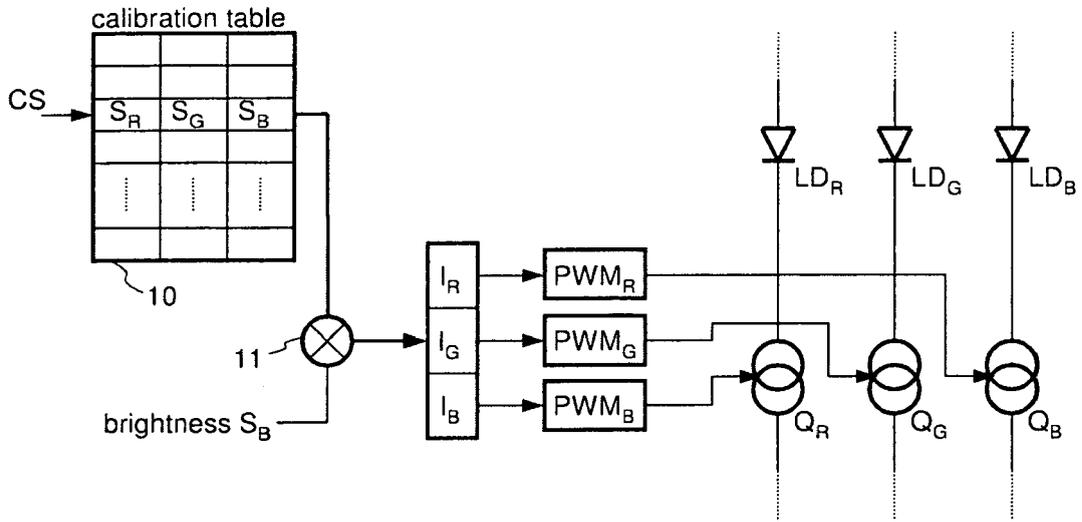


FIG. 1

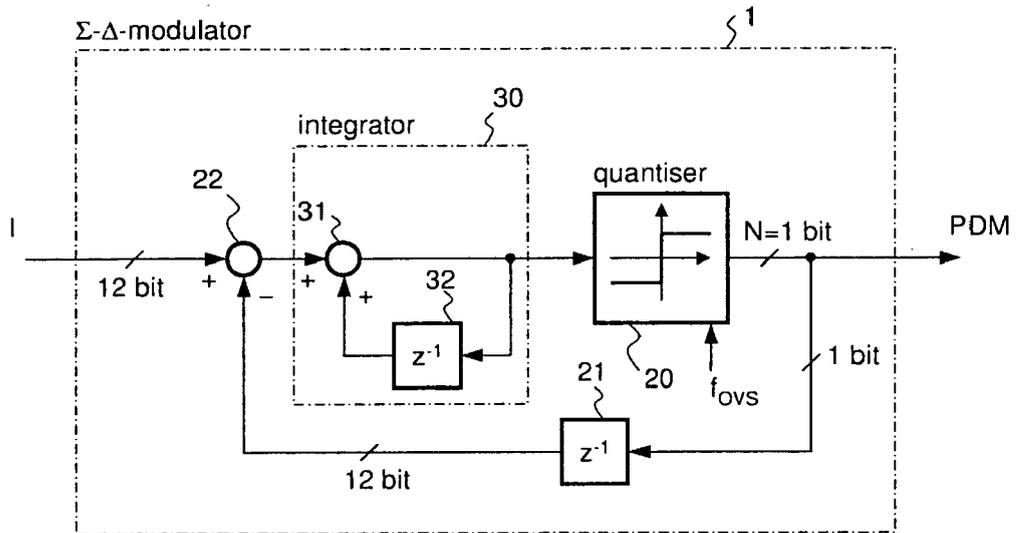


FIG. 2

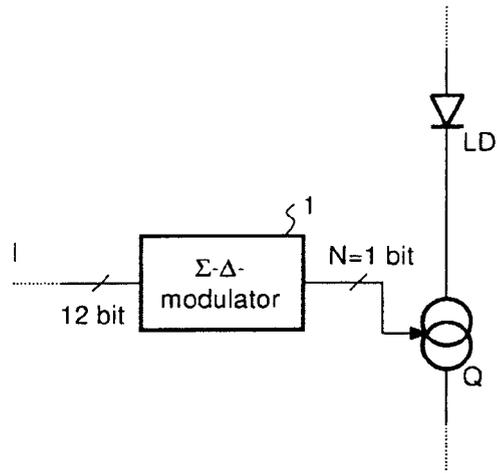


FIG. 3

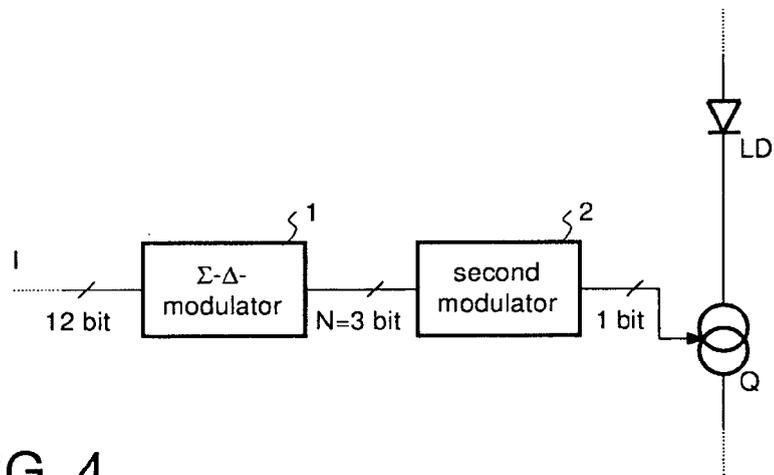


FIG. 4

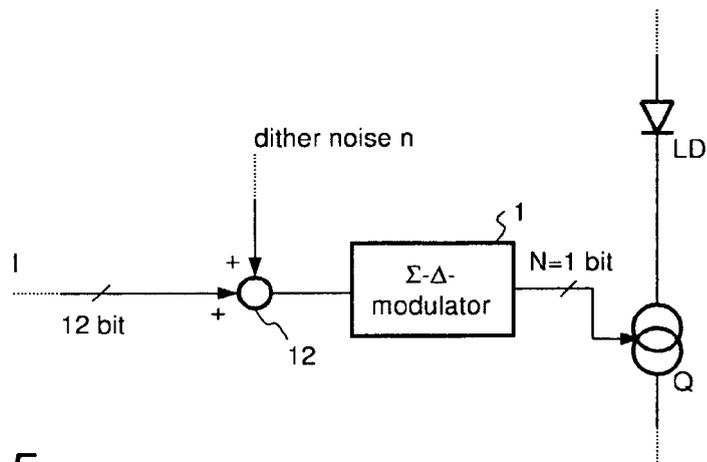


FIG. 5

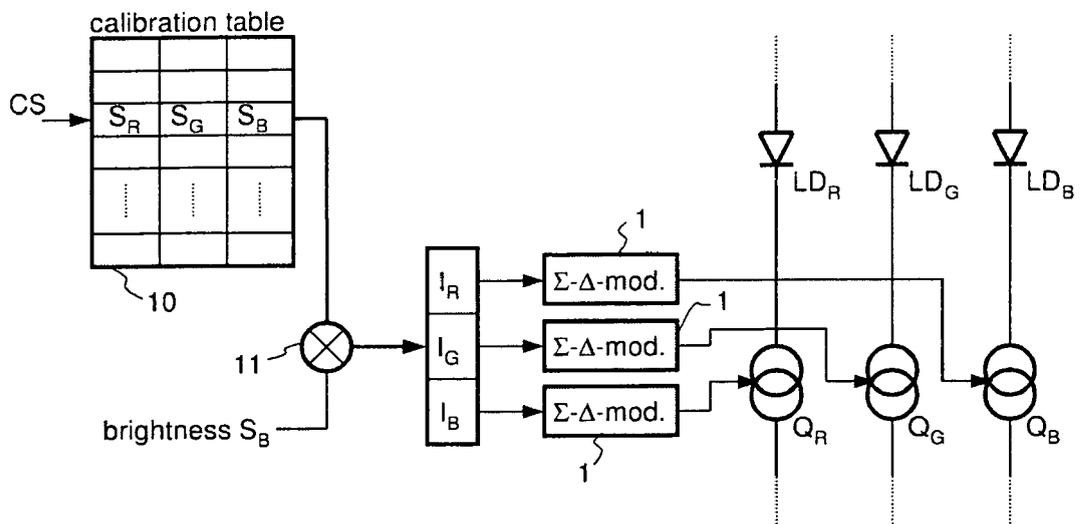


FIG. 6

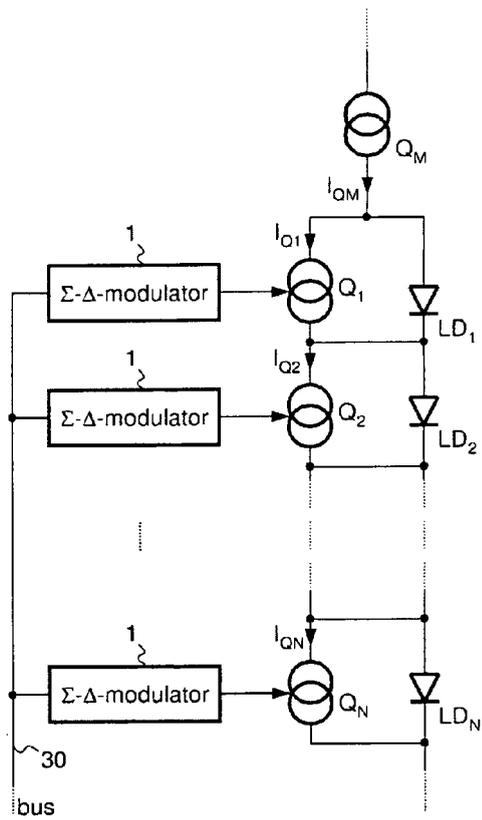


FIG. 7

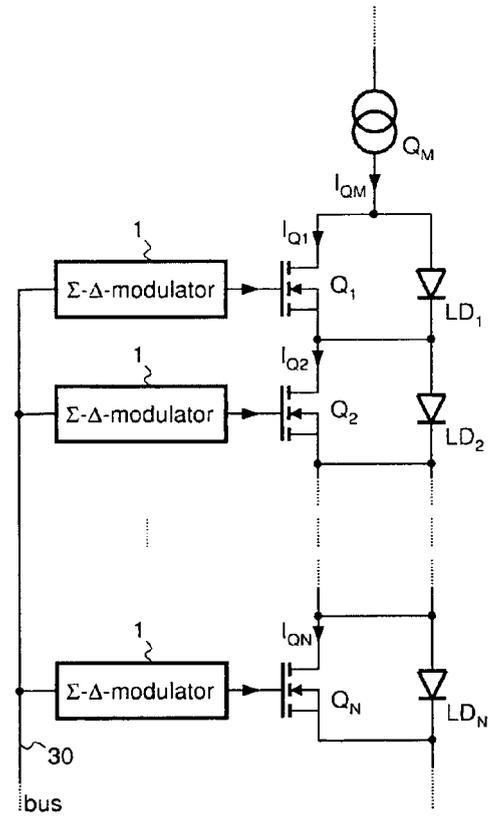


FIG. 8



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2008/000465 A (AUSTRIAMICROSYSTEMS AG [AT]; PAURITSCH MANFRED [AT]) 3 January 2008 (2008-01-03) * page 1, line 19 - page 3, line 10 * * page 4, line 8 - page 4, line 27 * * page 9, line 13 - page 9, line 24; figures 1,3,5 *	1-3, 8-12, 17-19	INV. H05B33/08
X	DE 103 57 776 A1 (AUSTRIAMICROSYSTEMS AG UNTERPR [AT]) 14 July 2005 (2005-07-14) * paragraphs [0005] - [0007], [0012], [0031] - [0034], [0039] - [0042]; figures 1-4 *	1-3, 10-12	
X	EP 1 528 841 A (ANYTRONICS LTD [GB]) 4 May 2005 (2005-05-04) * paragraphs [0006], [0061] - [0065]; figures 1,4 *	1-3, 10-12	
E	WO 2008/006450 A (AUSTRIAMICROSYSTEMS AG [AT]; TRATTLER PETER [AT]) 17 January 2008 (2008-01-17) * the whole document *	1-3, 10-12	
A	US 6 573 666 B1 (KILLAT DIRK [DE]) 3 June 2003 (2003-06-03) * column 3, line 31 - column 4, line 16; figure 2 *	4-7	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC) H05B
Place of search The Hague		Date of completion of the search 11 June 2008	Examiner Speiser, Pierre
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 00 0321

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-06-2008

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2008000465	A	03-01-2008	US 2008007497 A1	10-01-2008
DE 10357776	A1	14-07-2005	NONE	
EP 1528841	A	04-05-2005	GB 2407654 A	04-05-2005
WO 2008006450	A	17-01-2008	DE 102006032071 A1	17-01-2008
US 6573666	B1	03-06-2003	EP 1326487 A1	09-07-2003