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A COMPREHENSIVE SURVEY OF LED DRIVER IC DESIGN TECHNIQUES

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ABSTRACT

The Light-Emitting Diode (LED) driver is an important part of Visible Light Communication (VLC) systems. The main challenge of the VLC LED driver is to offer a high data transmission rate with high power efficiency. This paper presents the various existing design of LED drive incorporating various technologies. These designs support the electrical and optical characterization by using orthogonal frequency division multiplexing (OFDM) signals. A current steering digital to analog converter (DAC) based LED driver circuit supporting 4-channels with an 8-bit resolution in a 0.18 µm complementary metal oxide semiconductor (CMOS) technology. The LED driver used in the pulse current modulator driving technique supplies pulse driving current between 0mA~250mA and operates between 500k-Hz~1M-Hz. LED driver circuit also incorporating digitally-controlled analog circuit blocks to deliver concurrent illumination control and serial data transmission. Conventional LED drivers for High brightness applications consist of switching-type converters which require passive components like high value inductors and electrolytic capacitors for their operation. The future scope is an impedance reduction technique to enhance the bandwidth of the LED driver and a first-order pre-equalizer is utilized to enhance the electron-optical-electron (E/O/E) bandwidth in the VLC system

I. INTRODUCTION

The high power LED will play an important role in the next lighting generation since its high efficiency, long lifetime, and small size. Moreover, it has been developed in lots of fields such as indoor lighting, vehicle lighting, traffic signals and indicator panel. Compare with the incandescent lamp and fluorescent lamp, LED is more suitable for the high speed communications because of its wide modulation bandwidth. Therefore, LED is able to function as not only lighting but also communication. For the reasons outlined above, LED has great potential of development in the future, and there have been many researchers engaged in the field of communication network based on LED. Besides, there are many advantages to cultivate VLC technology on indoor lighting; for example, it is highly privacy, less costly, and needless to use another interface general in traditional microwave communication.

Led Driver And Control IC Design

The architecture of LED driver is shown in Fig.1, it involves three parts, one is the power stage, another is the control IC, and the other is the first-order pre-equalizer.

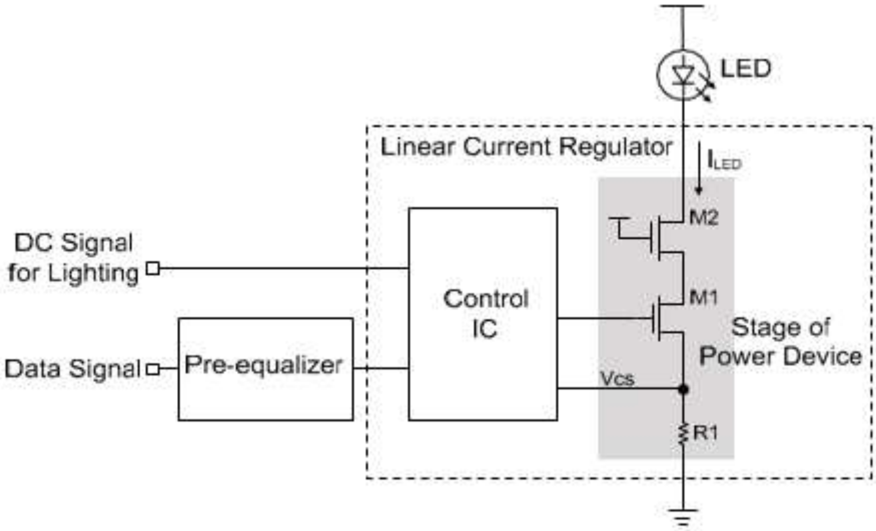

Fig. 1, Architecture of the led driver.[1]

The LED Driver has linear current modulation, stage of power device, design of control IC and pre-equalizer introduced. Every Electronic circuit is assumed to operate off some supply voltage which is usually assumed to be constant. A voltage regulator is a power electronic circuit that maintains a constant output voltage irrespective of change in load current or line voltage. Many different types of voltage regulators with a variety of control schemes are used. With the increase in circuit complexity and improved technology a more severe requirement for accurate and fast regulation is desired. This has led to need for newer and more reliable design of dc-dc converters. The dc-dc converter inputs an unregulated dc voltage input and outputs a constant or regulated voltage. The regulators can be mainly classified into linear and switching regulators. All regulators have a power transfer stage and a control circuitry to sense the output voltage and adjust the power transfer stage to maintain the constant output voltage. Since a feedback loop is necessary to maintain regulation, some type of compensation is required to maintain loop stability.

II. RELATED WORK

Yu chen lee et. al. [1]: combines the function of lighting with VLC technology, and LED driver uses linear current regulation and controls the AC and DC current signal through a single power device for the purposes of high speed, high efficiency and high integration. In addition, this work utilizes an impedance reduction technique to enhance the electric bandwidth of it. And a first-order pre-equalizer before control IC is utilized to enhance the E/O/E bandwidth which is limited by the phosphor-converted LED original. This VLC LED driver is fabricated in a standard 0.5um CMOS technology with chip area 1540µm×1250µm. It is available in a standard SOP-16 pin package. The optical modulation bandwidth of 10.9 MHz has been achieved with the forward biased LED current of 350 mA. By using the OFDM data modulation scheme, the data rate of 50 Mb/s is demonstrated.

Aravind V. N. Jalajakumari et.al. [2]: illustrate an energy efficient light emitting diode (LED) driver circuit for visible light communications (VLC) and results from the electrical and optical characterization are presented. A current steering digital to analog converter (DAC) based LED driver circuit supporting 4-channels with an 8-bit resolution is realized in a 0.18 µm complementary metal oxide semiconductor (CMOS) technology. Each channel delivers a full-scale current of 255 mA and achieves up to 67% electrical efficiency when driving 250 MS/s orthogonal frequency division multiplexing (OFDM) signals. Optical differential drive capability is demonstrated by using two output branches of a single channel to drive two different LEDs with an SNR improvement (>5 dB). The chip is also capable of full digital control of color shift keying (CSK) using multi-color LEDs enabling lighting color-temperature adjustment, dimming and multiple-input and multiple-output (MIMO) optical communications and these aspects will be the subject of future research.

Ali Mirvakili et.al. [3]: works on solid-state lighting technology has opened the door to a myriad of applications using light-emitting diodes for both illumination and optical wireless networking. Low-power CMOS technology enables realization of mixed-mode, system-on-chip driver circuits integrating multiple

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functions on a single substrate to control LED device performance, luminance, and data modulation for "intelligent" visible light networking. This paper presents a novel LED driver circuit architecture incorporating digitally-controlled analog circuit blocks to deliver concurrent illumination control and serial data transmission. To achieve this goal, a bi-level pulse-width modulation (PWM) driving scheme is applied to enable data transmission during the "OFF" period of the LED drive current. With 3-bit PWM dimming resolution, the driver circuit enables linear luminous intensity control from 5% to 100%. Pseudo-random binary sequences (PRBS) are generated to compare circuit performance for various data modulation formats. The LED driver circuit is simulated in a 0.5µm CMOS process and exhibits a worst-case power consumption of 100mW with 33mA peak PWM current. For simulation results, the electrical equivalent model of the LED is used. In this model, the series voltage is 1.5 volts, the series resistance is 10 Ohms, the shunt parasitic capacitance is 10pF and the supply voltage (VDD) is 3V. This series resistance was calculated using the I-V characteristic of a typical LED at a particular LED forward voltage.

Ying-Yan Lin et.al. [11]: design an innovative efficiency-boosting technique is successfully applied to typical linear light emitting diode (LED) drivers. Furthermore, p-channel MOSFET (PMOS) pass element with elaborate metal layout pattern is used to reduce dropout loss and a 5V regulated voltage is obtained from the wide range input voltage to power some sub-circuits. This will further diminish power dissipation and thus enhance efficiency. The driver has been fabricated on a 0.5 µm Bipolar CMOS DMOS (BCD) process. Simulation results show that when driving three high brightness light emitting diodes (HB-LEDs) in series, it can achieve maximum efficiency of 91.12% at ILOAD = 350 mA, which is improved by 7.3%, as compared with that of the typical one under the same condition. Besides, the proposed driver is able to operate with a wide input voltage range (6V~32V) and deliver output current up to 350 mA, with an accuracy of ±3%, regardless of process voltage temperature (PVT) variations. Besides, the dropout voltage is only 450mV when ILOAD = 350 mA and VIN = 12 V.

A new linear LED Driver has been developed and fabricated based on the analysis of efficiency deficiency on the typical drivers. In the proposed design, efforts are effectively made to diminish current-sense dissipation, regardless of input voltage or LED current, the dropout voltage of the pass element as well as the dissipation of sub-circuits, so that efficiency of the whole driver can be significantly boosted. The whole driver has confirmed this efficiency improvement as well as extra features including PWM dimming, thermal-shutdown and current-limiting of the proposed linear LED driver.

Ming-Shian Lin et.al. [8]: design a LED driver that is based on pulse current modulator. The proposed pulse current modulator consists of a voltage-controlled oscillator (VCO), a pulse generator, a series buffer, a single stage amplifier, a power transistor, and a sense resistance. A complete analysis and introduction of the proposed pulse current driving technique and the conventional driving technique presented. The LED driver used in the pulse current modulator driving technique supplies pulse driving current between 0mA~250mA and operates between 500k-Hz~1M-Hz. The LED driver is fabricated with CMOS 0.35-µm 2P4M technology. The chip area with pads is 935µm×956µm.

Piero Malcovati Lin et.al. [7]: illustrate the buck –boost Dc-Dc converter for LED driver. The buck-boost DC-DC converter includes the LED in the control feedback loop and has to provide fast turn-on and load transients(on the order of 20µs), in order to allow pulsed operation of the LED itself. The DC-DC converter features three different modes of operation, namely buck, buck-boost and boost mode, which are automatically selected based on the value of voltage VC. He presented DC-DC converter has been fabricated in a 0.18µm CMOS process with 5V option. The chip micrograph is also described. The chip area, dominated by the power transistors, is 1.65×2.5mm2, including the pads. The DC-DC converter has been characterized with different LEDs, operated at different current values. For the measurements, used a 1µH off-chip inductance. The peak efficiency obtained is equal to 91%. The measured line regulation is lower than 0.2%/V over the output current range, while the load regulation in this particular application is meaningless, Since the voltage drop across the LED and hence Vout changes with Iout. The output voltage ripple is less than 10mV. He also shows the transient response of the DC-DC converter to a red-green transition, i.e., when a green LED is replaced with a red LED with the same current (1.9A). The output voltage of the DC-DC converter, because of the different voltage drop across red and green LEDs, switches from 2.9 to 3.96V in less than 10µs. By contrast, the output current switches from 1.9A to zero and back to 1.9A in less than 20µs, thus allowing pulsed operation of the LEDs and switching among LEDs of different colors.

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Valencia Joyner Lin et.al. [10]: work on a a white LED driver design methodology, combining data transmission and dimming control. This is a design than can be applied to transform off-the shelf LED drivers into optical transmitter circuits for VLC applications. It also has the capability of sending data signals in the format of NRZ, PPM and PWM and concurrently providing dimming control from 10 to 90 %. Operation is linear and flicker-free by implementing a negative feedback loop to control the maximum amount of current passing through the LED's. Control blocks are integrated in a 1.5× 1.5 mm2 integrated circuit implemented in a 180 nm CMOS process. The overall control circuit power consumption is 5 mW and does not significantly degrade the overall driver efficiency. The driver efficiency is 89 % at an LED driver current of 120 mA.

Rohan Dayal et.al. [6]: illustrate a novel driver for high brightness LED applications that can directly run from AC voltage. Conventional LED drivers for such applications consist of switching-type converters which require passive components like high value inductors and electrolytic capacitors for their operation. The use of such components increases the size and cost of the LED system while decreasing the overall life time. He shows the circuit only needs active devices like MOSFETs and op-amps for power processing. The input current is selectively controlled to follow a sinusoidal waveform to achieve low harmonic distortion and high power factor. A simple start-up circuit is also designed for self sufficient operation with a more efficient set-up under development. The efficiency of the proposed system is around 82% for a 1.5W converter with 9% total harmonic distortion. Such an implementation is also more suitable for IC design. Both simulation and experimental results have been presented to validate the operation of the proposed set-up.

Cheng-Ta Chiang et.al. [9]: works on a CMOS LED print head driver with compensation circuits. Due to the process and fabrication variations, two compensation circuits are proposed. One is to perform the chip compensation, and the other is to do the pixel compensation. Besides, a method of a single-chip segment exposure is also shows to make the power consumption more efficient. Based upon the device parameters of 0.5µm1P2M CMOS technology with 3.3 V power supply, all the functions and performance of the proposed CMOS LED print head driver with compensation circuits are successfully tested and proven through measurements. The area including ESD I/O pads is 2000 ×2000 μm^2. The proposed chip is suitable for LED printers.

Renbo Xu et.al. [5]: work on high efficiency LED (Light Emitting Diode) driver based on Buck converter, which could operate under a wide AC input voltage range (85 V - 265 V) and drive a series of high power LED. The operation principles, power loss factors of the LED driver in his study are analyzed and discussed in detail and some effective ways to improve efficiency are proposed through system design considerations. To verify the feasibility, a laboratory prototype is also designed and tested for an LED lamp which consists of 16 LUMILEDS LEDs in series. Results show that a high efficiency of 92% at I_o = 350 mA can be achieved and the studied driver might be practical for driving high power LEDs. In the last, the over-all efficiency over 90% is gained through some experiments under variable input and output voltages and verifies the validity of the designed driver.

III. MERITS AND DEMERITS:

LED Brightness and Color Temperature: The concept of the brightness of visible light from an LED is fairly easy to understand. Assigning a numerical value to the perceived brightness of an LED's output can simply be measured in units of luminous flux density, called candelas (cad). The total power output of an LED is a measurement of the amount of Lumens (lm). It is also important to understand that average forward LED current determines the brightness of an LED.

LED Driver also have high performance , TRIAC dimmable and full range dimming capability. LED Driver have also some demerits that is higher complex circuitry, low power consumption, large amount of heat production and elimination of "YELLOW RING" (chromatism phenomenon caused by inhomogeneous phosphor layer of the white light LED) is difficult in the white light LED due to immature behavior.

IV. CONCLUSION

The LED driver combines the function of lighting with VLC technology. LED driver with visible light communication technology is to offer a high data transmission rate with high power efficiency. LED (light-emitting diodes) Driver is mainly used for both illumination and optical wireless networking. LED Driver IC designs support the electrical and optical characterization by using orthogonal frequency division multiplexing (OFDM) signals.

The future work planning of LED driver uses linear current regulation and controls the AC and DC current signal through a single power device for the purposes of high speed, high efficiency and high integration. In addition, LED Driver have an impedance reduction technique to enhance the electric bandwidth of it, and a first-order pre-equalizer before control IC is utilized to enhance the E/O/E bandwidth which is limited by the phosphor-converted LED original. The future scope is the technique that accomplish both leakage reduction and process sensitivity reduction such as combining MTCMOS sleep transistor technique for leakage reduction and the current biasing scheme

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