International Journal of Control and Automation
Vol.7, No.5 (2014), pp.133-142
http://dx.doi.org/10.14257/ijca.2014.7.5.15

Current mode LED Driving Circuit using Asymptotic Method

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Abstract

In this paper, it was supposed to current mode design included to required current of ideal LED, through asymptotic method for LED driving. LED`s current characteristic has exponential function, and implementation of driving circuit exists problems. However, it can be designed to linear current source through asymptotic method for ideal required current

Proposed LED driving circuits was confirmed the linearity to switched input constant current sources, and driving circuits was designed to satisfy the LED current requirement.

Proposed circuit has LSB corresponding to 800μA in 9.6um width and confirmed by Dong-Bu 0.35um CMOS process.

Keywords: *Asymptotic, LED, Constant Current, Current Mode*

1. Introduction

Such as Incandescent, fluorescent, previous light-device`s generation coming to ends. Next generation`s light-device is LED. Long-life, low-power, luminance characteristics, and because it has a number of advantages [1]. It has been used in various application and steadily increasing demands. In order to effectively utilize LED, LED driving circuit in consideration of characteristics is indispensable.

ISSN: 2005-4297 IJCA

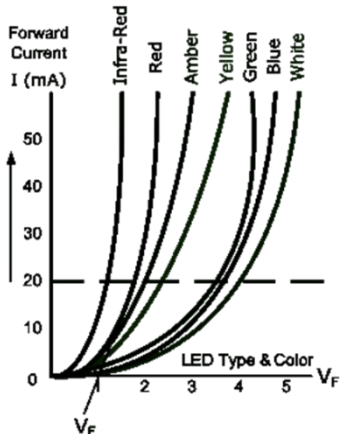

Figure 1. LED Characteristic [2]

Figure 1 shows general LED`s characteristics.

X-axis represent voltage, Y-axis driving current. And, it shows color variation, corresponding to LED is forward bias voltage. LED is generally used in 2~4 V driving range. And has rapid current characteristic on voltage variation [3].

Equation 1 shows non-linear model of diode, PN junction structure [4].

$$I_D = I_s\left(e^{\frac{V_D}{V_T}} - 1\right) \qquad (1)$$

V_T is thermal voltage, I_S is reverse saturation current, V_D is supplied voltage. I_D is current variation of diode. Diode`s current has exponential function according to diode voltage $V_D$. This exponential characteristic means the current requirement of LED. Ideal LED driving circuit`s current sources are required to sufficient design for current requirement characteristics of LED

Equation 2 is the exponential polynomial by Taylor-Maclaurin series.

$$e^{\frac{V_D}{V_T}} = 1 + \frac{\frac{V_D}{V_T}}{1!} + \frac{\frac{V_D}{V_T}^2}{2!} + \frac{\frac{V_D}{V_T}^3}{3!} + \cdots, \frac{V_D}{V_T} < \infty \qquad (2)$$

The general non-linear model`s exponential development could represented by up to one order term. Therefore, approximate non-linear model of diode can be expressed as Equation 3.

$$I_D = I_s\frac{V_D}{V_T} \qquad (3)$$

Thermal voltage has 26 mV in room temperature, 300 K, IS has 10^{-13} mA, reverse saturation current [4].

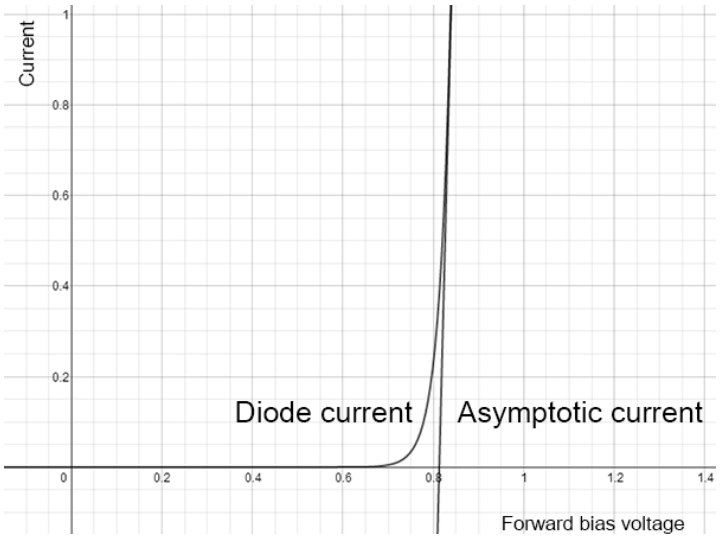

Figure 2. Comparison with Ideal and Asymptotic LED Characteristic

Figure 2 shows comparison with ideal and asymptotic LED characteristic.

Figure 2 shows result that non-linear model was expressed in close proximity by offset adjustment. Non-linear model means that it was sufficient to current requirement by linear current supply. The LED driving source control method has a constant-current and constant voltage control, but because the LED is a current driven, it is effective when using a constant-current control [5].

And LED as light source, can be achieved uniform luminance characteristics according to dimming in wide current driving range. Maximum current rating, general LED`s current driving range, is about 70 mA [6]. Therefore, in order to effective LED control, wide dimming constant-current controller is indispensable.

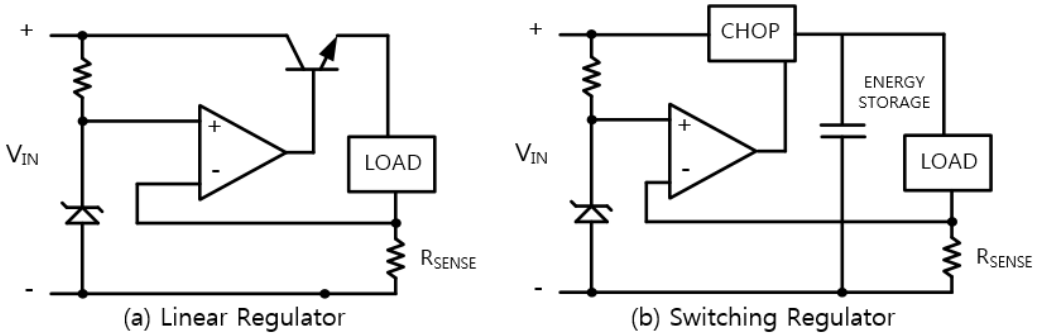

Figure 3. Conventional LED Driver Circuit

Figure 3 shows linear regulator and switching regulator in previous study for LED driving circuit.

Both of regulator monitoring the current variation by R_{SENSE} register. Through TR or the switching block contained energy storage, compared with a reference voltage, constant current or constant voltage output is supplied [7]. Reference Regulator can supply reference current or voltage corresponding to thermal voltage by IR drop or band-gap reference [8].

Current LED linear driving circuit and switching circuit has trade-off including linearity, power efficiency, switching noise, design complexity. Linear regulator can confirm effective current regulation characteristic, relatively low compared to switching regulator [9]. Switching regulator has advantage, high efficiency, but has disadvantage noise of switching operation, high design complexity. Therefore, effective LED driving circuit is design of constant current, high linearity and efficiency.

In this paper, it was supposed to current mode design included to required current of ideal LED, through asymptotic method for LED driving [10].

2. Design of Current mode LED Driving Circuit using Asymptotic Method

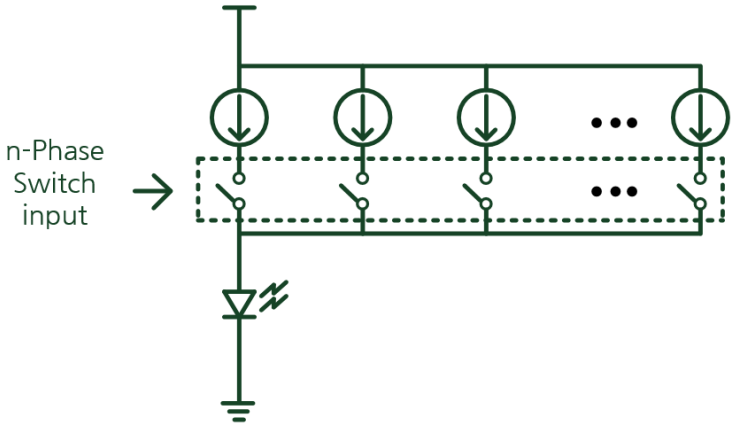

Figure 4. Current Mode LED Driver Circuit

Figure 4 shows proposed current mode switching LED driving circuit.

In this paper, is was approximately represented current non-linear LED model to first order polynomial by asymptotic method. And it is designed switching regulator for guarantee linearity. Current channel column of the MOSFETs is constituted for LED`s current supply by n-phase switch input.

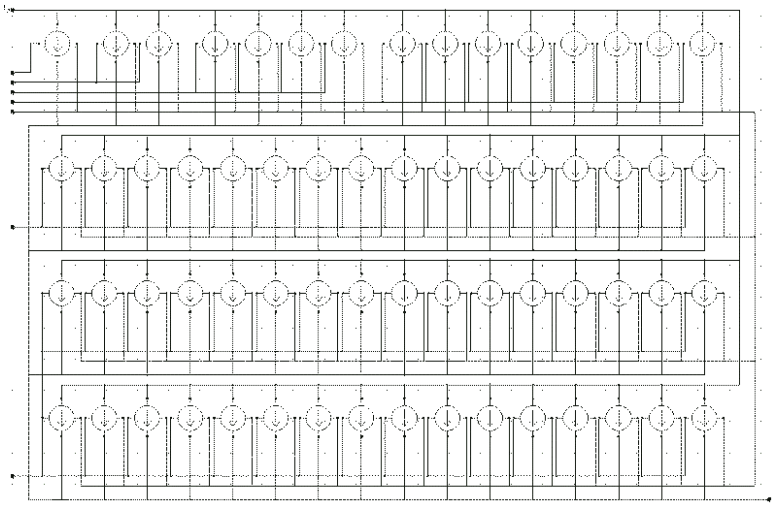

Figure 5. Current Source Column SCHEMATIC

Figure 5 shows current source column design`s SCHEMATIC.

63 units consists of the gate was shown and supplied up to 6-bit switch input. In response to input of the each switch, channel of each MOSFET configured to perform the current supply constant-current regulator.

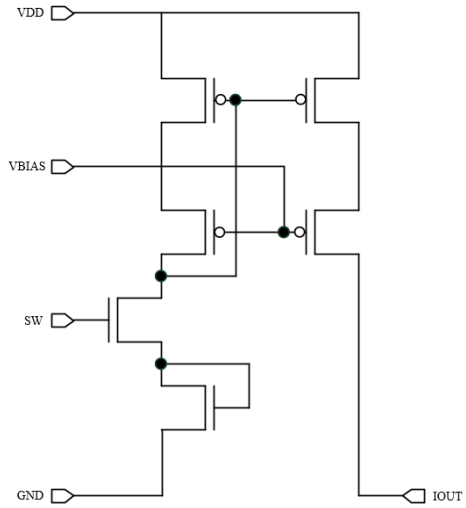

Figure 6. Unit Gate Circuit

Figure 6 shows a used unit-gate circuit.

SW-Pin is designed to switch input signal, VBIAS-PIN is voltage regulation bias, IOUT-PIN is LED current output. Structure of the unit gate was used a modified conventional current mirror, and adding a bias voltage adjustment PMOS block. It is designed directly control the bias current LED by removing the NMOS that can be applied to the load from the output terminal. The minimum width of the gate is 9.6um.

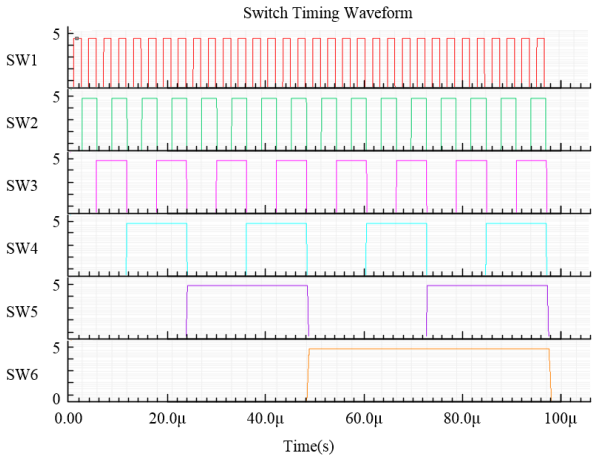

Figure 7. 6-Phase switch input signal

Figure 7 shows 6-phase switch input signal.

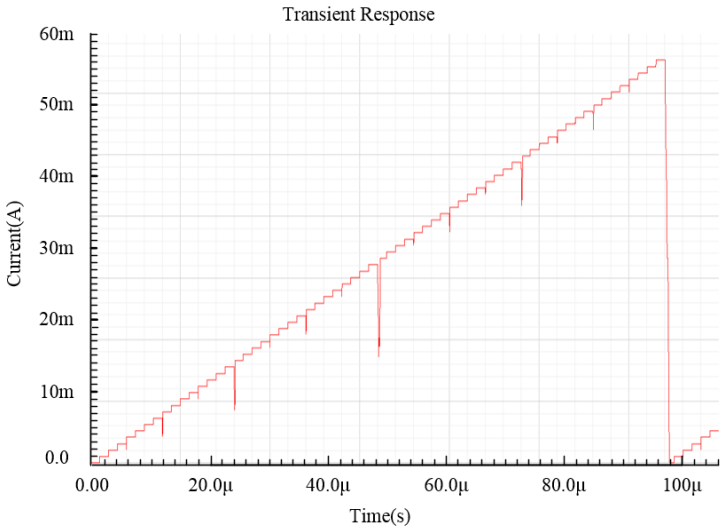

Figure 8. Current mode LED Driving Circuit Result

Figure 7 shows proposed LED driving circuit`s current output result.

X-axis is a time, Y-axis is a current. The output shows the linear regulator at applied to 6 phase switch. The above results were confirmed through the Dong-Bu 0.35µm CMOS process. LED has generally 6~70mA as maximum current rating. Therefore, in this study, minimum current size corresponding to LSB has 800µA in 9.6um width.

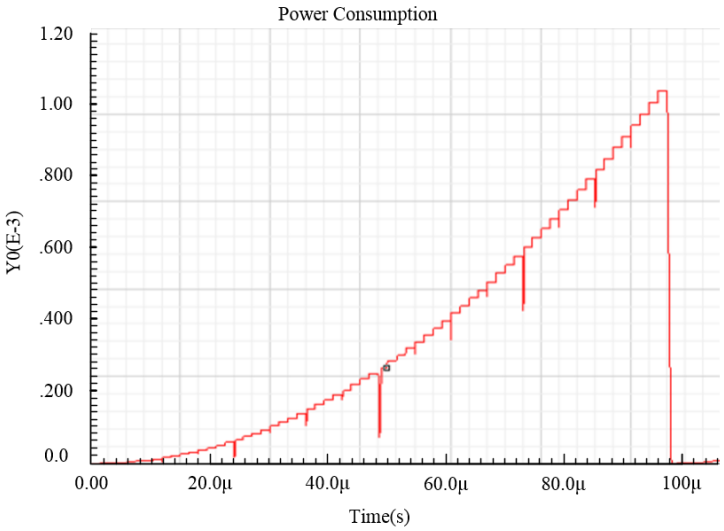

Figure 9. Current mode LED Driving Power Consumption Result

Figure 9 shows proposed LED driving circuits power consumption result.

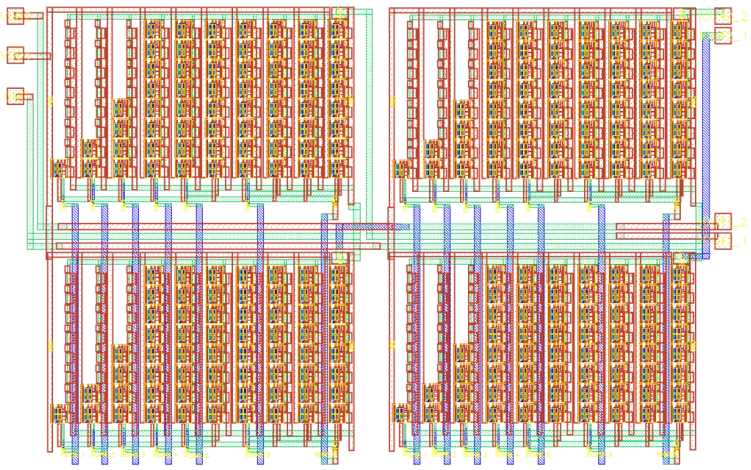

Figure 10. Designed LAYOUT

Figure 10 shows designed LED driving circuit`s LAYOUT.4-channel 6-bit constant current LED linear driving circuit was implemented in 1400*700um, Dong-Bu 0.35 process.

3. Conclusion

In this paper, it was supposed to current mode design included to required current of ideal LED, through asymptotic method for LED driving, and LED driving current`s linearity was confirmed Designed driving circuits operate as constant current source that receives 6-phase resolution switch. Proposed circuit has LSB corresponding to 800μA in 9.6um width and confirmed by Dong-Bu 0.35um CMOS process.

The low power consumption and effective technique to improve reliability of the LED drive circuit is expected through a proposed circuit.

Acknowledgements

This article is a revised and expanded version of a paper entitled Design of Current Mode LED Dimming Controller presented at International Symposium on Advanced and Applied Convergence held on November 14-16, 2013 at Seoul, Korea.

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