Linear Dimmable Current Controller for Low PowerAutomotive LED Lighting

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Abstract

A novel highly dimmable current controller which is a linear one is employed in the application of low power automotive is discussed here. Light Emitting Diode is the one which drives current that is linearly controlled to decrease the intensity of LED to limit the destruction of the LED and improve its reliability. Although many dimming techniques for LED lighting are available, our proposed method outperforms the existing methods in terms of power consumption and the no. of transistors used in the proposed design. This emits 100mA and decrease the LED current which is going linearly based on the theory of dimming control voltage. Toggling of LED is avoided finally in comparison with the existing system. This circuit isdeveloped in 0.18µm process technology and Cadence ADE with Spectre is employed for simulation purpose. The proposed method utilizes a maximum power of 392.85 mW when the supply voltageis 4V and the control voltage is 4V at the temperature of 27^{o}C.

Keywords—Automotive, Linear Dimmable Current Controller, LED Lighting, Low Power,

I. INTRODUCTION

In the past few years, lighting from LED is becoming more and more popular and cost effective due to its better lighting options in comparison with that of the existing solutions like CFL, HID lamps etc. It generates better performance in terms of lighting. It has benefits like long life, cost effective, maintenance is very low and saves energy etc. Itis an innovation in lighting system that is employed in traffic lights, automobiles etc.

Drivers in LED are an important aspect in LED lighting solutions to attain obliges appropriate lighting options in various applications. In contrast to traditional power supplies, LED driver actively responds to the variations of the LED circuits by providing continuous current since its properties may vary according to the change in the temperature. Therefore, LED lighting performance is based on Driver of an LED. Even though many LED drivers are present, a particular LED driver is chosen for a particular application and it is employed.

LEDs are inherently dimmable and needs a typical driver for dimming or to change the behavior of the LED and toimprove the life. The performance of LED dimming is obtainedbased on ability and compatibility of a driver employing a dimming equipment. Color rendering, glare and brightness are controlled by the dimming circuit present in the LED driver. LEDs functioning at low temperature and current since they will be damaged when vice –versa. Digital current controller like Pulse Width Modulator (PWM) generates noise and Electro-Magnetic Interference (EMI) in the LED driver and consumes more switching or dynamic power. Whereas, linear dimmable current controllers are more suitable for low power applications like automotive lighting since they are battery operated.

Due to the similar current which is an average one, there will be an increase in crest factor and heat produced. Also, light sources that are dimmed are an important aspect in many lighting applications like architectural lighting to get operational necessities of a space. We know that dimming is employed for the purpose of preservation of energy. We have two techniques to dim the light by LEDs. First is the decrease in current and the second is decrease in the width of a pulse generated. They are dependent on current control.

Here, we develop an innovative light reduction technique for a multipath average current LLC resonant LED driver. If PWM light reduction is ON, then a resonant LLC converter functions with a condition of full-load. Intensity of an LED is headed by the ratio of timing of ON state and timing of OFF state of the dimming signal from PWM.A high power factor, less THD of AC LED is employed that is connected to switched LED module and is implemented on a FPGA. Therefore, AC LED efficiency is improved specifically.

An LED driver known as floating-buck dimmable employed for solid-state lighting applications is discussed here. Using this driver, we can achieve an adaptive timing difference compensation that is improved to fine tune the timing of OFF state to activate the driver to get average current of an LED by supplying various voltages and different loads at the output. It has high operating frequency and quick settling time.

Another method for dimmable LED drivers is the dimming-feedback control method that has an average DC loop gain. Since the above method headed by steady-state error of the feedback system, balancing the LED current circuit may not be necessary to supervise the output LED current based on the phase angle of the voltage at the input of a TRIAC- dimmable LED driver. LED employing pseudo-sine-current controller eliminates the dependent elements. Delay-lock loop confirms the function of input voltage and current of an AC to get high PF and low THD.

Here, we discuss about an LED driver that is energy efficient which is employed in lighting of indoors. This is attained by adaptive voltage regulation that limits losses in the power of a current regulator which is a linear one. Also, we introduce a resistive DAC which is given as a feedback input of a DC-DC converter. Analog LED voltage and current supervised to get a color LED achieves in more number of components and complexity is also high.

Here, we go for an innovative low power dimmable current controller having linear characteristics which are high for automobile lighting is discussed. It is designed and implemented to produce 100mA to the driver of an LED employing 0.18µm technology.

II. EXISTING CURRENT CONTROLLER

A. *Four-level PMOS current controller*

Below figure shows a four level LED current controller that already exists.

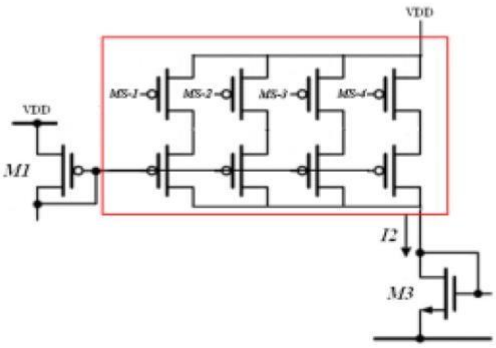

Fig. 1. Schematic representation of Four-level current controller with four PMOS switches [19].

The above existing method agonize from toggling dueto the average current iss dropped suddenly to 75% whereas sink current is incremented by 25% when one branch is switched on.

Similarly when two branches are switched on, total current is reduced to 50%. Switching on the third branch reduces the total current to 75%. This technique exhibits visible flickering effect in the existing system which is clearly shown in Fig. 3.

Brightness of the LED is reduced by switching a single branch in the four level current controllers. Due to this functionality, 25 mA is reduced. Similarly, the average current is decreased to 50%, 75% and 100% switching on second, third and fourth branches respectively [19]. This causes sudden reduction in the total LED current which causes visible flickering effect. The existing current controller needs an Analog Digital Convertor (ADC) to control the current which consume area and power.

B. *Analog to Digital Converter*

ADC dependent on inverter is employed to convert analog to digital signal in place of comparator based ADC that is more spatial. It is used a comparator that functions to get its meta-stability point. If the control voltage moves away the meta-stability point, then the appropriate inverter output is a pull-down. Also, ADC is more spatial and consumption of dynamic power is also more.

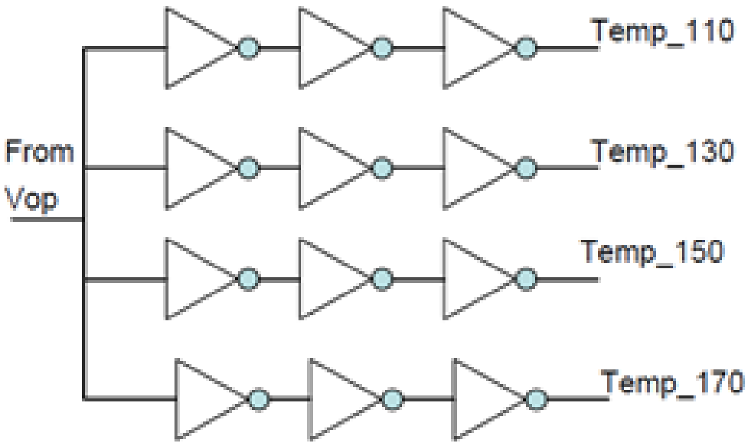

Fig. 2. Schematic representation of Inverter based Analog to Digital Converter [19].

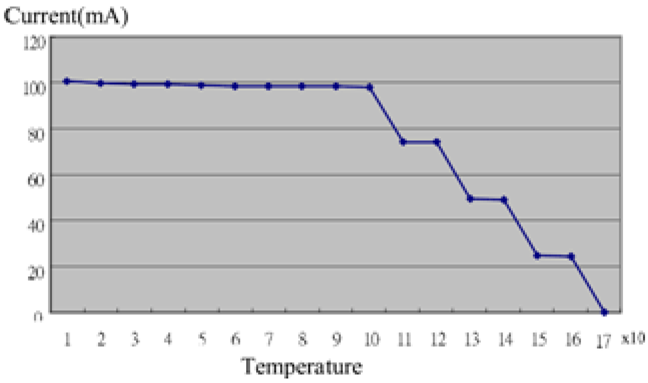

Fig. 3. Flickering effect of the existing system [19]

III. PROPOSED CURRENT CONTROLLER

A novel highly linear dimmable current controller in GPDK 180nm process technology is developed here. In the proposed highly linear current controller, branches are not switched individually. Instead, all branches are controlled simultaneously in a highly linear manner to provide linear LED control current which will eliminate the visible flickering effect. Since the branches are not switching, switching power or dynamic power dissipation is greatly reduced. Moreover, switching noise is also eliminated in the proposed design. Since very few transistors are used to implement the current controller, the overall consumption of power and the area are decreased to great extent. The proposed linear dimmable current controller is designed to supply 100 mA current.

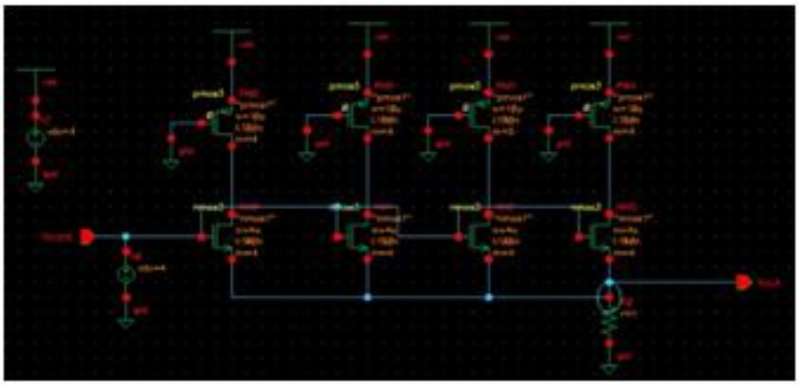

Fig. 4. Proposed Liner Dimmable Current Controller

Here, the discussed method is developed in the pseudo nMOS style which provides low power consumption. Schematic diagram of the proposed highly linear dimmable current controller is shown in above figure. In the proposed technique, pMOS device is biased in the triode region so that the pMOS device works as a constant current source. nMOS devices are used to control the current provided by the pMOS. Current can be controlled by varying the control voltage applied the gate terminal of the nMOS devices.

IV. SIMULATION RESULTS

Cadence ADE with Spectre is employed for simulation purpose. Simulations were carried out at 27^{o} C for normal operation. As the effective gate voltage increases, the conductivity of the nMOS device is increased. The proposed current controller provides maximum current of 99.8 mA when the control voltage is 4 V and minimum of 10 nA at zero voltage.

TABLE 1. LED DRIVING CURRENT AT VARIOUS CONTROL VOLTAGES

Control Voltage (V)	0.4	0.8	1.2	1.6	2.0
Current (mA)	0.56	8.0	21.7	34.2	45.9
Control Voltage (V)	2.4	2.8	3.2	3.6	4
Current (mA)	57.0	67.9	78.6	88.8	99.8

The above table shows that the evaluated sinking current of the above discussed method at different voltages.

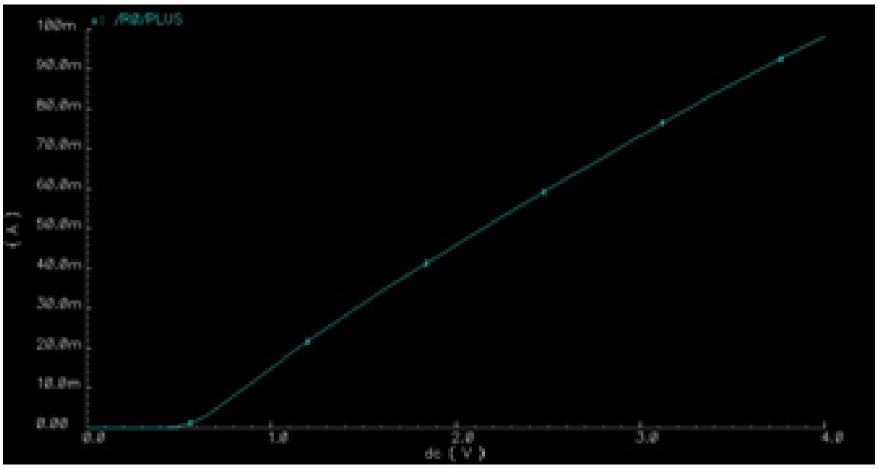

Fig. 5. Sinking Current of the Proposed Current Controller

As the applied control voltage is increased from 0V to 4V, the sinking current is linearly increased from 10 nA to 99.8 mA. At the same time, the LED current is decreased from maximum current to minimum in a linear manner. The proposed dimmable current controller exhibits high linearity which in turn eliminates the flickering effect. This is shown in above figure. As the applied control voltage is increased, the sinking current is increased and hence the LED current will be decreased which will decrease the intensity of the LED in a linear manner. The linear function of the dimmable current controller completely removes the visible flickering in the LED lighting.

Change in the supply voltage may slightly has the influence of linear operation the proposed current controller. As the supply voltage decreases from its normal operating voltage of 4V, the linearity of the current controller is disturbed.

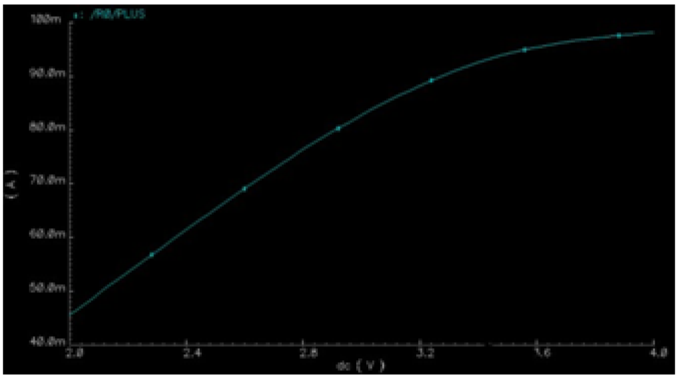

Fig. 6. Impact of Supply Voltage Variation on linear operation

Supply voltage variation at various temperatures also affects the linear operation of the current controller. The force of temperature and change in supply voltage on the linear operation of the proposed current controller is shown below.

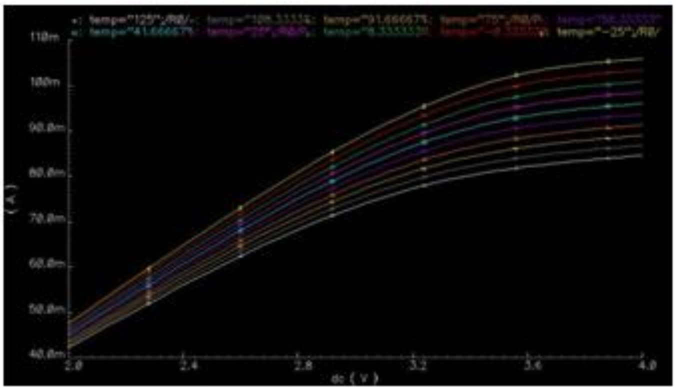

Fig. 7. Impact of temperature and supply voltage variation

Supply voltage is varied between 2V to 4V and the temperature is varied between -25^{o}C to 125^{o}C. As the temperature and the supply voltage are varied, the liner operation is affected. Increase in temperature decreases the sinking current i.e. the sinking current is inversely proportional to the temperature. At 27^{o}C the current controller supplies a sinking current of 100 mA, at -125^{o}C it supplies around 84 mA only.

The impact of temperature when the control voltage is kept at 0V is shown in Fig. 8. As the temperature is increased from -25^{o}C to 125^{o}C, the sink current is increased exponentially. The current at 0V control voltage, -25^{o}C temperature is 0 nA. The sink current is increased to 62 nA when the temperature is kept at 125^{o} C.

The control voltage to the current controller is varied between 0V to 4V at various temperatures from -25^{o}C to 125^{o}C. The impact of temperature at various control voltage is shown in Fig. 10. When the control voltage is 4V and the temperature is -25^{o}C, the sinking current supplied by the current controller is 100 mA. When the temperate is increased to 125^{o}C, the sinking current is reduced to 84 mA but the linear operation of

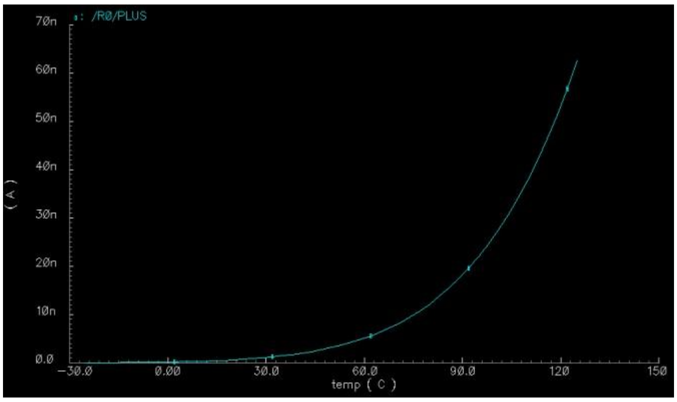

Fig. 8. Impact of Temperature on Current when Control Voltage is 0 V

When the control voltage is kept at 4V and the temperature is varied from -25°C to 125°C, the sinking current is reduced from 106 mA to 84 mA. The impact of temperature on sinking current when the control voltage is kept at 4V is depicted in Fig. 9.

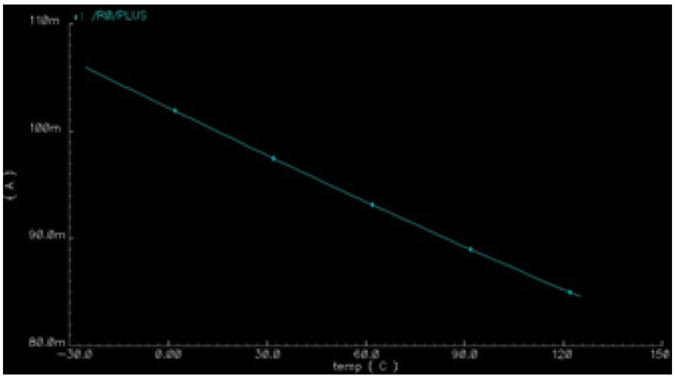

Fig. 9. Impact of Temperature on Current when Control Voltage is 4 V

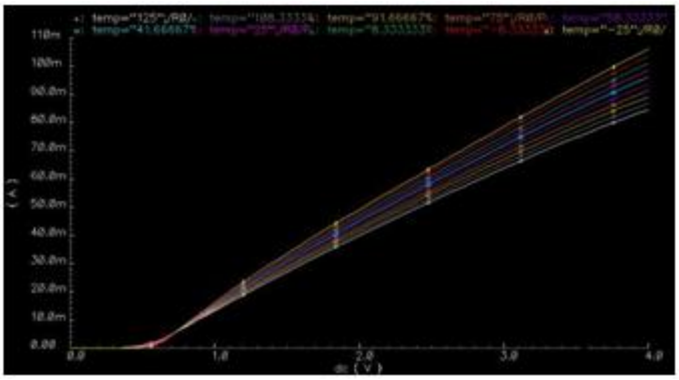

Fig. 10. Impact of Temperature on Current when Control Voltage is 0-4 V

The proposed linear dimmable current controller is not affected by the change in operating temperature. But the total sinking current at full control voltage 4V is reduced to 84 mA when the temperature reaches 125°C.

V. CONCLUSION

A dimmable current controller having high linearity, low power, high efficiency has been proposed. It is implemented to supply 100 mA current and it is tested to help vast temperature ranges from -25oC to 120oC. Here, the toggling effect is removed completely. The proposed method consumes a maximum power 392.85 mW when the supply voltage is 4V and the control voltage is 4V at the temperature of 27oC in 0.18µm process technology. The proposed design consumes only 9 nW when the supply voltage is 4V and the control voltage is 0V. Since the proposed highly linear dimmable current controller consumes very less power, it is more suitable for automotive LED lighting applications.

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