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Hybrid Low Frequency Switching Linear LED Driver for Controlling Dimming Range

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Abstract: LED lighting has been widely utilized in different application scenarios. To save energy and cost, dimming technologies have also been developed so that the lighting can be dimmed in different situations. Wide dimming range is useful for accommodating very different operating conditions. Traditionally, there are different categories of dimming methods, including analog dimming and pulsed width modulation (PWM) dimming. In analog dimming, the amount of LED current used to drive the LED light is conventionally determined based on the amplitude of an analog signal. Since there is current level adjustment in analog dimming, inherently there is a disadvantage where colour temperature variation can occur. The use of analog dimming (especially at low dimming levels) is not recommended in applications where colour of the LED is critical. In PWM dimming, the amount of the LED current used for driving the LED light is usually determined based on the pulse width and period of a PWM signal. When the dimming level is decreased and the on-duty state of the LED current is shortened, human eyes perceive a flicker of light. Thus restricting the dimming range (threshold on minimum pulse width) to achieve predictable performance from the LED product. The main objective of this proposed work is to design and build a new hardware model of hybrid low frequency switching linear LED driver for controlling dimming range with respect to dimming levels by using suitable methods at particular level of dimming. The performance of the proposed system is verified through hardware testing and using LT-SPICE simulation tool.

Index Terms: Light Emitting Diode, Pulse Width Modulation, Linear Technology, Switched Mode Power supply.

I. Introduction

In the present situation green technology development is highly demanded as energy crises and the problems of the environment are considered as serious issue. Lighting equipment energy consumption is highly significant so there is a need to implement cost effective and energy saving solution over conventional lighting sources. The most vital and promising technology that have emerged out is photovoltaic. Solar energy is that the most non-conventional energy supply gaining interest throughout the globe that has no harmful environmental impact. This DC source is utilised for LED lighting applications by using suitable driver circuit to perform dimming. LED lighting has been widely utilized in different application scenarios.

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To save energy and cost, dimming technologies have also been developed so that the lighting can be dimmed in different situations. Dimming can be defined as the process of controlling the amount of electrical power supplied to a light source. Traditionally, there are different categories of dimming methods, including analog dimming and pulse width modulation (PWM) dimming. Two of the methods considered here are analog dimming & PWM dimming.

The implementation of LED lighting is based on constant current at the output side so it is prime important to develop driving circuit for LED string. There is a tremendous scope for LED lighting as a lighting source because of their high luminous efficiency, energy saving and longer lifetime. Therefore to implement LED lighting world-wide there is a need of LED power drive to provide constant current to the output LED string which makes the stability in the brightness of all LEDs which are connected in the string. LEDs are nonlinear devices (forward current versus forward voltage) having forward voltage as a function of temperature. Therefore this forward voltage is needed to be controlled by regulating the current and this can be achieved by using LED power drive. LEDs are not a purely resistive load like an incandescent lamp therefore drivers are required to provide a power factor close to unity.

II. Literature Survey

LED lighting device is provided to capable of suppressing intermediate flickering level in which the level of dimming is moved from a high level to low level. The present solutions for wide dimming range applications use two power sources for operation, one for providing constant current output part and the other for PWM current output part. As the cost of semiconductor LED chips is falling, there is a need to optimize the LED driver circuitry to suit the above mentioned control thus making the overall system attractive for the customers. The use of analog dimming (especially at low dimming levels) is not recommended in applications where colour of the LED is critical. In PWM dimming, the amount of the LED current used for driving the LED light is usually calculated based on the width of the pulse and the time period of the PWM signal. When the level of dimming is decreased and the state of on-duty of the LED current is reduced, human eyes perceive a light flickering. Thus restricting the range of dimming (threshold on minimum pulse width) to achieve satisfactory performance from the LED product [1].

"LED power driving circuit for street light application" by A.D. Gajbhare and S.S.
Mopari discusses about the practical implementation of 100 W street light driving circuit in which flyback converter topology is used. The constant output current is provided to LED string by it.

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The paper also deals with the basic functional block diagram, necessity of LED power driving circuit, flyback converter topology for continuous conduction mode and the experimental results [2]. In the recent years the Light emitting diodes are introduced in the lighting market, offering consumers performance and features are better than those of traditional lighting systems. The LEDs are used in safety signals for railroad, automotive highway, and other lighting applications have become more common. These have longer life, greater durability and are more energy efficient than traditional lamps. Also deals with the problems dependent changes of LED intensity and colour shift [3].The concepts regarding the light emitting diodes, its equivalent circuit model and nonlinear characteristics curve representing the forward diode voltage versus forward current for the LED sample are discussed in [4]. The different types of LED drivers, the task of designing an LED based system involves the following selection; number and connection scheme of LEDs, linear or switch mode LED driver and type of input supply. Linear drivers are less efficient and larger in size whereas switch mode drivers are more efficient and smaller. The implementation of LED lighting is based on constant current at the output side so it is prime important to develop driving circuit for LED string. So power driver is required to provide constant current to the output LED string which makes the stability in the brightness of all LEDs which are connected in the string [5-6]. There are two broad categories of power supplies: Linear regulated power supply and switched mode power supply (SMPS). Combination of both these types is used in many cases to gain some desired advantages of both the types. The advantages of hybrid power supply which is the combination of both types of power supplies are highlighted in [7]. There are different types of dimming techniques for switched mode LED drivers. The two main techniques discussed here are analog dimming and PWM dimming techniques. A literature note on dimming techniques by Rich Rosen describes some basic LED theory and several techniques used to provide dimming control. Many lighting devices require precise control of regulated currents, which is commonly referred to as dimming control [8].

III. DRIVER CIRCUIT DESIGN AND SIMULATION USIND LT SPICE-IV

The hybrid low frequency switching linear LED driver circuit is designed. The circuit is simulated using LT-spice IV simulation tool by configuring the complete circuit in schematic editor and giving suitable values of each components. The same is implemented in the hardware model and experiment of the complete circuit is carried out. The complete designed closed loop linear LED driver system is shown in the Fig. 3.1

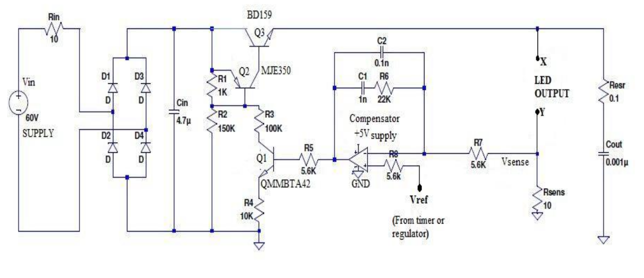

Fig. 3.1 Complete designed closed loop linear LED driver

The following is a design procedure

- Desired cross-over frequency of the total open loop transfer function is chosen, say fco=10 kHz.
- Determining the bode plot of the total open-loop transfer function and noting the gain and phase magnitude, Gain is -12 dB and phase angle is -940.
- The compensated error amplifier should therefore have a gain +12 decibels at 10 kHz to make the loop gain 0 dB. Converting the gain to a ratio of vo/vi.

Gain in dB = 20 log (vc / va)

Now vc / va = R6 / R7, R6 can be calculated by assuming R7.

- The phase angle of the compensated error amplifier at crossover must be adequate to give a phase margin of at least 450. The required phase angle of the amplifier is θcomp = θphase margin – θconverter.

= 45°-(-94)°

= 39°

Then, K = tan (139°/2) = 2.675

C1= 1/ (2.675*2*π*10 k*22 k)

C1 = 0.27 nf

C2 = 2.675/ (2π*10k*22k)

C2 = 1.93 nf

IV. PWM GENERATOR DESIGN

The analog dimming is employed using the circuit diagram shown in Fig 4.1. The supply voltage of 5 V to NE555 timer and op-amp is supplied from voltage regulator LR8 and output 1.8 V is connected to Vref of Op-amp. Thus the complete designed LR8 regulator is used for applying analog signal as reference voltage to Op-amp for the operation of analog dimming by disconnecting the timer output to the regulator.

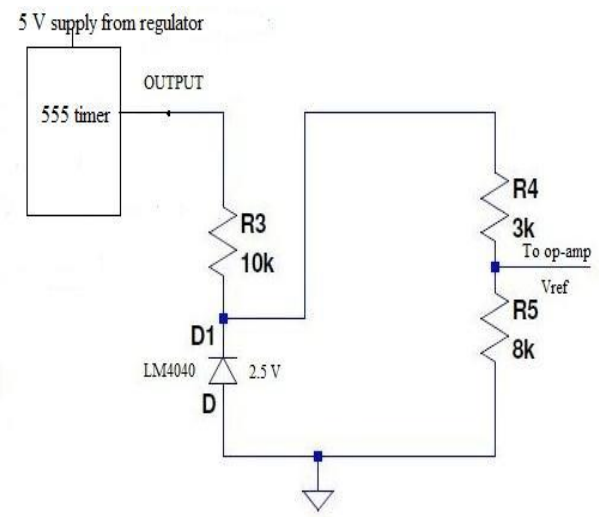

Fig. 4.1 Typical PWM application circuit

V. RESULTS AND DISCUSSIONS

The hybrid low frequency switching linear LED driver circuit is designed and simulated using LT-spice IV simulation tool by configuring the complete circuit in schematic editor and giving suitable values of each components. The complete design of the circuit is discussed in the previous chapter.

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Both the analog dimming and PWM dimming methods are performed here. As stated earlier in case of analog dimming, the amount of LED current to drive the light source is determined based on the analog input signal. So output LED current is proportional to the percentage of the dimming level depend upon the input signal in the range varied between 0% and 100%. Here for the 60 V DC input the various dimming level current output waveforms are given. The DC input voltage waveform and full rated 100 mA current waveform are shown in the Fig. 5.1(a), 50% and 70% dimming is shown in the Fig. 5.1(b) and Fig. 5.1(c) respectively.

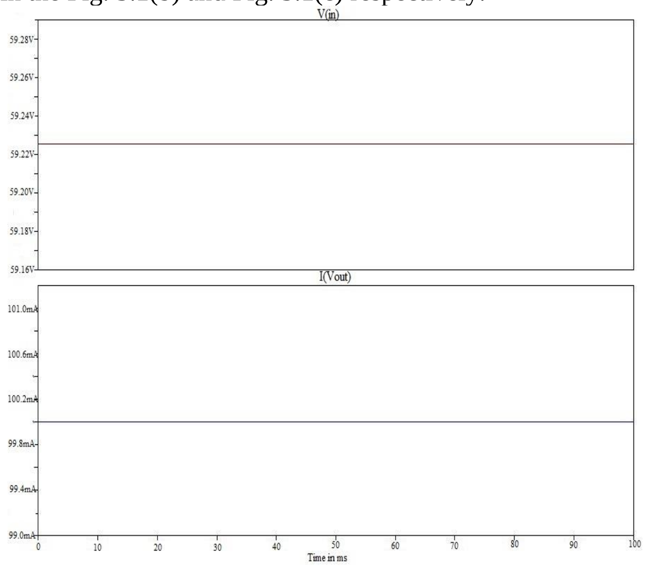

Fig. 5.1 (a) DC input voltage and LED current output waveforms

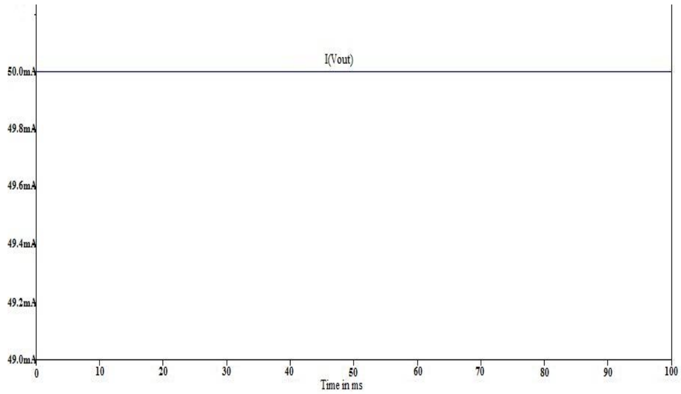

Fig. 5.1 (b) 50% dimming LED current output waveform

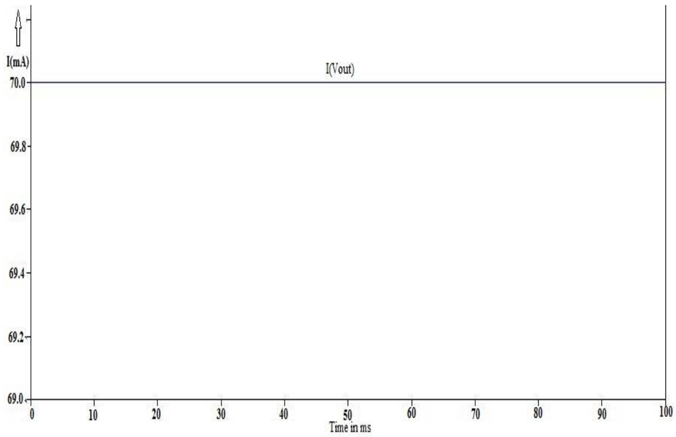

Fig. 5.1 (c) 70% dimming LED current output waveform

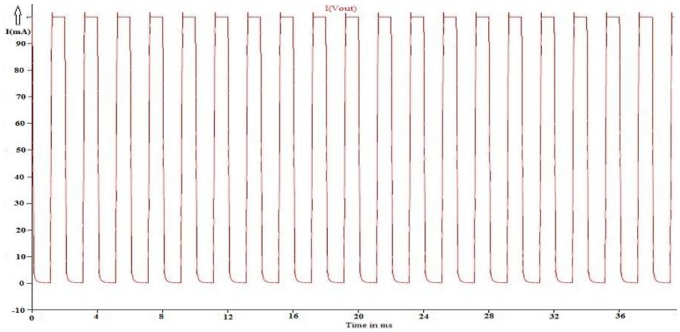

Fig. 5.2 (a) DC input voltage and 70% dimming LED current output waveforms

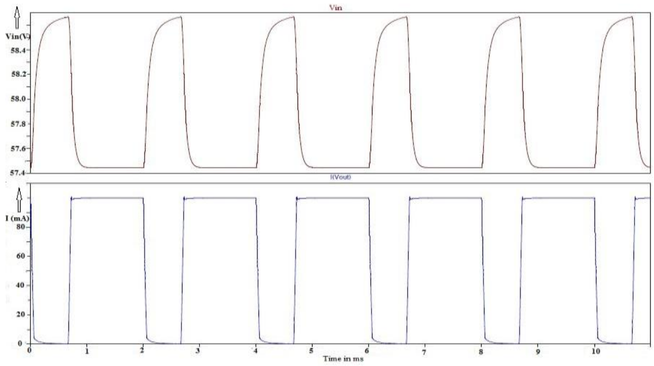

Fig. 5.2 (b) 90% dimming LED current output waveform

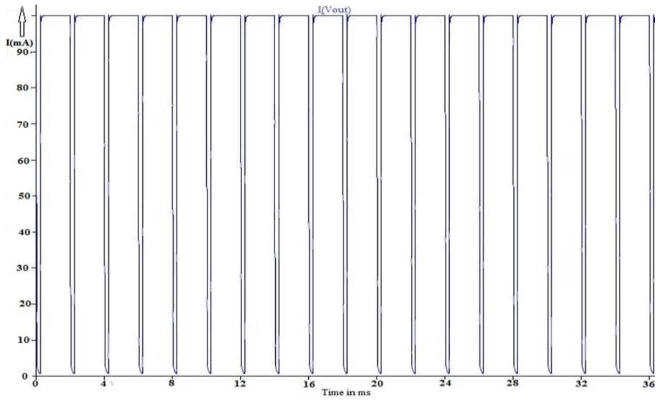

Fig. 5.2 (c) 50% dimming LED current output waveform

In case of PWM dimming, the amount of the LED current used for driving the LED light is usually determined based on the pulse width and period of a PWM signal. It is the actual start and restart of the LED current for short periods of time. Here 60 V DC input is supplied to the driver and time period of 2 ms is considered. The various input-output waveforms are given. The current output will be same for all the dimming levels but only the ON and OFF state time durations going change according to the particular dimming level for the same frequency. In the Fig. 5.2 (a) input voltage and current output is shown, it is for 70% duty cycle that means 70% of the total period, the full rated current is flowing through the lighting device known as ON state time and remaining will be OFF state. In the same way, current output waveforms for 90% and 50% duty cycles are shown in Fig. 5.2 (b) and Fig. 5.2 (c) respectively.

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VI. HARDWARE IMPLIMENTATION RESULTS

A. *Analog dimming experimental results*

The hybrid low frequency switching linear LED driver circuit is designed and simulated using LT-spice and it is implemented through hardware model using suitable components. The following are some of the snapshots of hardware circuit model and the experimental setup in the laboratory.

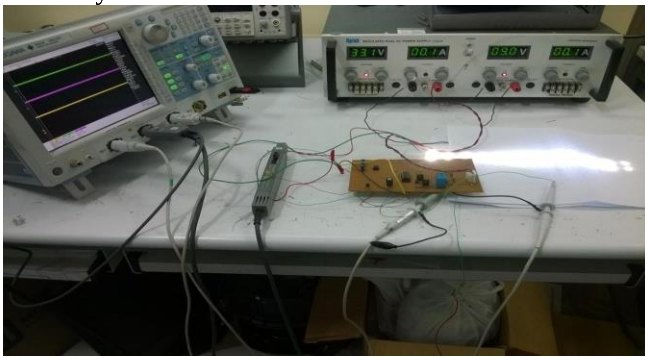

Fig. 6.1 Analog dimming experimental setup

The Fig. 6.1 shows the analog dimming setup which indicates LED voltage, current through LED and reference voltage waveforms and readings. For the analog dimming experiment, all circuit connections are made as in the circuit schematic and power supply is applied. In this method reference voltage is supplied from the regulator circuit to the compensator input, based on the amount of reference voltage the output LED current is depended. The constant current output is maintained by the closed loop driver circuit.

B. *PWM dimming experimental results*

For the PWM dimming experiment, circuit connections are made as given in the schematic. In this method reference voltage which is PWM signal is supplied to the compensator input from timer circuit through a regulator circuit. The supply 60V DC input is applied to the driver with 2ms time period at 450Hz. Waveforms of PWM dimming are shown in Fig. 6.2. The output current will be same for all the dimming levels but only the ON and OFF state time durations going change according to the particular dimming level for the same frequency. The waveforms are of 70% duty cycle that means 70% of the total period.

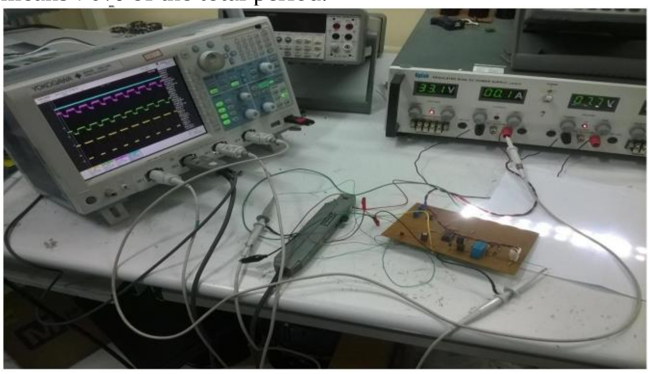

Fig. 6.2 PWM dimming experimental setup

VII. CONCLUSION

In the present work the design of a hardware model of Hybrid low frequency switching linear LED driver for controlling dimming range is developed. The performance of the proposed closed loop system is verified using LT-spice simulation tool and through hardware testing. In this hybrid driver model two dimming methods are adopted in order to use them at suitable dimming levels so that limitations of each method can be reduced. Limitations like LED colour variation which is not recommended in application where colour of the LED is critical normally occurs at low dimming level in case of analog dimming, the flickering in case of PWM is avoided by running at greater frequency (>200Hz) at which human eyes cannot perceive flickering. By comparing the efficiencies of each method separately it can be noticed that analog dimming is better than PWM dimming. But, running a lighting device by switching suitably over a period leads to a less losses than running continuously throughout the period. Therefore in order to avoid running losses the two different methods are to be chosen at suitable running duration at selected dimming levels. The performance of the closed loop driver system is also verified by designing a complete circuit and applying suitable values of each components depending upon the specifications using the LT-spice simulation tool. As with any region in which artificial lighting is used, people like to regulate the lighting level to meet their needs and create a more comfortable environment.

Permitting the occupants of an area to control the lighting level can help reduce brightness when there is an excessive lighting level.

Thus dimming of LED lamps using suitable LED driving circuit is necessary to create a comfortable lighting environment. The reduced power consumption and additional running cost savings can be achieved by the application of LED dimming. LED lamp also produces less heat which interns increase their operation life and safeguards the investment an end-user has made into their LED lamps and also protects environment from global warming.

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