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High Brightness and High Voltage Dimmable LED Driver for Advanced Lighting System

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ABSTRACT In energy efficient system designs, LED lighting leads to reduction in global energy demand. This paper proposes a high brightness, high efficiency, dimmable LED driver based on linear current regulator technology for DC grid distribution systems. The proposed driver has excellent characteristics like highest lumen per watt, long lifetime, high reliability, compact, low cost, both environmental and user friendly which makes it suitable for lighting applications. Steady state and small signal model of the proposed driver are performed which helps in minimizing ground current and accurate compensator design, respectively. These two modelling approaches result in the optimization of both footprint and cost of the driver. The performance of the proposed 20W driver is modeled using real-time simulation in spice software. Experimental prototype is developed to validate the performance of the proposed driver for different dimming levels and achieves a maximum efficiency of 97%.

INDEX TERMS LED driver, dimming, OPAMP dimmer, linear regulator, DC grid distributed system, energy efficiency, analog dimming.

I. INTRODUCTION

Increasing energy demand is driving researchers to develop energy efficient systems to fulfill the needs with lesser energy utilization. Renewable energies, such as photovoltaic, wind generation, fuel cell and tidal energy, are rapidly growing and their share of load demand is increasing. Based on end user/load requirement, different concepts like standalone renewable systems and hybrid power systems for AC grid and DC Distributed Systems (DCDS) were proposed. Among these, DC grid distributed systems are gaining popularity because most of the commercial spaces, sports complexes and conference halls are offering DC loads like LED lighting, computers, printers and induction stoves. In comparison to AC grid, DCDS shows a significant improvement in energy efficiency, reliability and economic savings, especially, with the integration of renewable energy sources to the distribution systems [1], [2].

Unlike the common light sources: Incandescent light bulb, compact fluorescent lamp etc, LED light bulbs last longer and exhibit high efficacy. Currently LED fixtures can save consumption of energy between 20% up to 80% of compact fluorescents, halogens, fluorescent tubes, and incandescent bulbs. As per prediction given in [3], by the year 2030, most existing lighting technologies will be replaced by Solid State Light and the savings will be in the range of 190 Terawatt per Hour.

Furthermore, LEDs work directly on DC power supplies and this DC power is often obtained by using AC-DC converter resulting in extra circuitry, increase in components count, power loss and injection of harmonics on the AC power utility grid. So, a typical DC distribution system is adopted to power the DC loads and to help integrate renewable energy sources and battery systems in a very efficient way [4]. A DC regulated grid voltage system, with centralized controller, prioritizes the use of solar PV panel (renewable energy), battery system and a centralized AC-DC rectifier. The DC grid voltage level will be regulated according to end load or application. In the literature 48V, 220V, 380V, 400V and 540 V DC grids are proposed [1]. A 48V DC voltage level for utility grid is not suitable because the load current requirement will be high, resulting in oversizing of cables, increased power losses and higher overall cost. It is worth to note that lighting loads, IT loads (consisting of mobile/laptops charging stations and IT servers) and home appliances with minor modifications are well suited for 220V DC

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grid [5]–[8], while HVAC (Heating, Ventilation and Air Conditioning) loads require higher voltages of 380V/400V DC. Unlike AC loads, DC loads do not draw reactive power, so the current rating will be less in delivering the same amount of power [2]. Office spaces and commercial buildings have 40-50% lighting loads and sports complexes and stadiums have more than 50% of lighting loads [3]. Thus, powering these loads with dc grid system is highly suitable.

LED driver is an electrical DC device which regulates the power flow to a single LED or string of LEDs. LEDs typically work in 2 to 4V range for low DC voltage applications. LED drivers need to convert AC into DC, while protecting the LEDs from power surge. LED drivers ensure LED safety, as it protects the LED from damage when forward voltage (V_f) exceeds breakdown voltage (V_b) [9]. As forward voltage changes with temperature and finally leads to thermal runaway. Thus, to protect from thermal runaway, the electrical characteristics of the LED should match the corresponding driver design. Thus, for optimum energy efficiency of the whole system, the appropriate driver circuit plays rather quite significant role.

There are two types of LED drivers: Constant Voltage and Constant Current. Detailed review is presented recently in [9]. The constant voltage drivers are used when the LED needs a constant DC voltage. They are also used in applications where the LEDs are formatted in strips and connected in parallel to the driver. Here, due to parallel connection all LEDs receive the same amount of voltage from the driver. In case of constant current drivers, the drivers handle same current passing through the LED. This type of driver adjusts the amount of forward current. The excess of this forward current may overheat the LED and cause problems. This type of driver is used when the LED product doesn't have an inbuilt driver. It keeps a constant current flowing through a series or string of LEDs.

Traditionally, LED systems are based on either single-stage or two-stage driver. Single-stage LED driver consists of DC – DC converter controlled to achieve power factor correction and constant output current. However, the two-stage system consists of a PFC circuit along with a DC-DC converter. This DC-DC converter is controlled to give controlled LED current. Control of LED current controls the brightness of LED. The single stage converters use a high storage capacitor thereby increasing the driver's volume. Cost of two-stage system is higher, and reliability is rather low (due to large number of devices) [10], [11]. Recently, many integrated topologies are designed to improve the efficiency along with the cost. Preferred topology must perform power factor correction to ensure high PF and low THD [5]. The integration technology has enabled the simplification of this process by merging both the Power Factor Correction stage and the DC-DC stage into to one stage. This is possible by sharing not only the control circuits but also the active power switches [12], [13]. Therefore, higher efficiency, higher reliability and fast output dynamics are all attained while maintaining low cost and small size [14].

LED driver of switch mode type offer better regulation of output current with high power density; however, it uses passive elements (LC). Mostly, driver circuit topologies depend on the range of LED power rating. For instance, when the power in the LED lamp is less than 5W then PFC is no longer required. Practically, LED driver topology can be chosen based on THD, galvanic isolation, PF, efficiency and cost. Presently, LED drivers are based on two stages conversion: AC-DC conversion followed by switched mode DC-DC. With this configuration, dimming operation for every light fixture is difficult to achieve. In addition to this, these drivers have low efficiency and they inject harmonics into the AC grid by drawing non-sinusoidal current via diode-based bridge rectifiers. Moreover, the utilization of capacitors, inductors, MOSFET drivers and current controller ICs in the design of switched mode LED drivers will further increase the size and cost [15], [16].

Thus, a linear regulator-based LED driver is preferred especially with the recent introduction of DC grid systems. However, linear regulators suffer from lower efficiency when the drop-out voltage is high and only buck mode of operation is possible. Hence to overcome these drawbacks the selection of the output voltage should be very close and slightly less than the DC grid voltage. In this paper, a robust, highly reliable and low-cost LED driver is proposed. A passive component-less topology based linear regulated dimmable LED driver, for distributed DC grid, is proposed. Using a simple load current sensing technique, dimming from 5% to 100% brightness is achieved. The effects of dimming and input DC grid voltage variation on the efficiency of the system are discussed. The proposed topology of LED driver is suitable for a wide range of applications ranging from sports complex to commercial tech parks etc.

II. PROPOSED LED DRIVER

High brightness LEDs are usually less than one watt rated power. Manufactures are constantly trying to improve the power rating of single LED output. Due to this small rated power values, when an application requires high light output multiple LEDS are connected in series to give high power brightness. Both chromaticity and luminous intensity are directly proportional to forward current. Hence, the fact that an LED is driven at a required constant current by a driver circuit.

Fig. 1 shows the proposed diagram of the LED's driver based on linear regulator concept. It is powered from DC voltage grid at the input. The proposed schematic of linear regulated dimmable LED driver is shown in Fig. 2. This proposed driver has three major sections: Selection of pass devices, Driving (biasing) circuit of pass devices and compensator. As this regulator is being designed for high voltage 220V DC or more standard Darlington [17] type pass devices are selected. Here standard NPN-PNP structure acting as pass device provides high voltage blocking and the Darlington structure provide the current boosting with very less ground current which in turn leads to high efficiency of

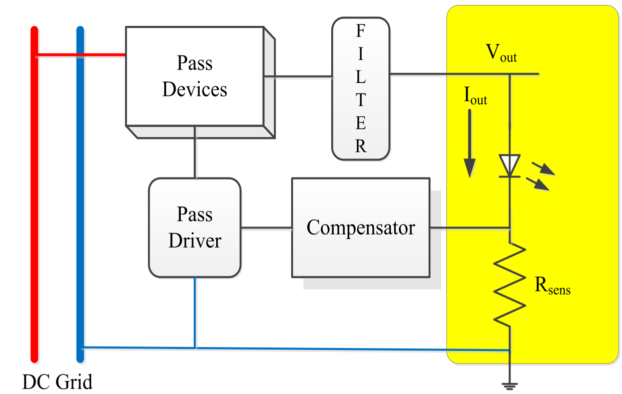


FIGURE 1. A LED's driver based on linear regulator concept and powered from DC grid.

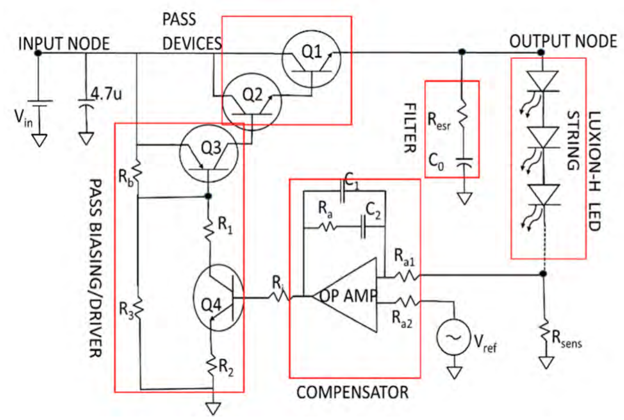


FIGURE 2. Schematic of linear regulated dimmable LED driver.

the driver. Biasing circuit's main function is to set the base current of the PNP transistor (Q3). To achieve current, a NPN transistor Q4 is powered from the input voltage and its biasing is controlled from the compensator. A low cost OPAMP based type II compensator is selected, which is discussed in section V.

A comparison between switching and linear LED drivers is given in Table 1. It is seen that the proposed linear regulator does not require inductors and capacitors which is a major advantage resulting in lower volume, weight and cost.

III. STEADY STATE ANALYSIS

The steady state analysis circuit of the proposed linear LED driver is given in Fig. 3, with all the branch currents shown. Transistors Q1 and Q2 forms the Darlington connection of the main pass components of the driver to provide high current gain and consequently lower ground current [18].

Since ground current flowing in the driver circuit is reduced significantly, high load current can flow, and hence high efficiency is achieved. The transistors Q3 and Q4 form the driver circuit for the main pass transistors (i.e. Q1 and Q2). Biasing of Q3 and Q4 transistors is needed in such a way that required base current for the main pass devices (Q1 and Q2)

TABLE 1. Comparison of different types of DC-DC regulators for LED driver application.

Elements	Switching Regulator [16,17]	Linear Regulator
Capacitor	Required	Not Required
Power switch	Required (MOSFET)	Required (Darlington NPN BJT)
Power diode	Required	Not Required
Inductors	Required	Not Required
Controller IC	Required	OP AMP
Gate driver	Required (efficient)	Only transistors

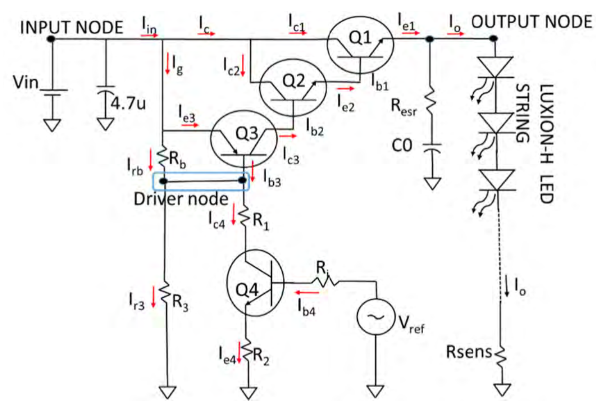


FIGURE 3. Linear regulator with various branch currents.

must be sufficient to draw desired load current. It is known that the light output is directly proportional to the current in the LED, hence variable LED current provides the dimming characteristic. This current can be directly varied by varying the biasing voltage of Q3 and Q4, which in turn controls the base current of the power transistors (Darlington). A large resistance, R_3, is selected to limit the current flowing into the ground as it is directly connected to the supply input (DC grid) and creates a DC supply for the Diver circuit. Load current can be sensed by R_{sens} in series with the load and this sensed voltage is used for control. This voltage is input to the error amplifier-based compensator. From transistor steady state model, the following equations are derived.

$$\left.\begin{array}{c} I_e = I_c + I_b, I_{c1} = \beta_1 I_{b1}, I_{c2} = \beta_2 I_{b2}, \\ I_{c3} = \beta_3 I_{b3}, I_{c4} = \beta_4 I_{b4} \\ I_{c1} = I_{e1}, I_{c2} = I_{e2}, I_{c3} = I_{e3}, I_{c4} = I_{e4} \end{array}\right\} \tag{1}$$

where I_{e1}, I_{c1} and I_{b1} represent the emitter, collector and base currents of the transistor Q1, respectively. Similarly $I_{e2}, I_{c2}, I_{b2}, I_{e3}, I_{c3}, I_{b3} I_{e4}, I_{c4}$ *and* I_{b4} are emitter, collector and base currents of the transistors Q2, Q3 and Q4, respectively. $\beta_1, \beta_2, \beta_3 and \beta_4$ are current gains of the Q1, Q2, Q3 and Q4 transistors respectively. Applying KCL at the Darlington collector node, the following relation is obtained;

$$I_c = (\beta_1 + \beta_2 + \beta_1 \beta_2)\, \beta_3 I_{b3} \tag{2}$$

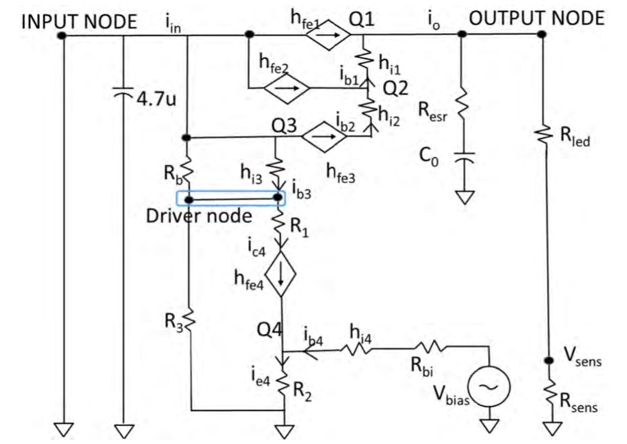


FIGURE 4. Small signal model of the proposed circuit.

From (1), the load current is directly proportional to the ground current flowing in the driver circuit. So, efficiency of the system can be significantly improved by reducing the ground current.

$$I_{in} = I_c + I_g \tag{3}$$

$$I_g = (1+\beta_3) I_{b3} + \frac{0.7}{R_b} \tag{4}$$

$$I_{b3} = \frac{1}{\beta_3}\left(\frac{I_{c1}}{\beta_2\beta_1}\right) = \frac{1}{\beta_3}\frac{I_o}{\beta_2\beta_1} \tag{5}$$

Applying KCL at the driver node (Fig. 3), the following relations are obtained;

$$I_{b3} + \frac{V_{be3}}{R_b} = I_{c4} + \frac{V_{in} - V_{be3}}{R_3} \tag{6}$$

Substituting (5) in (6):

$$I_{c4} = \frac{I_o}{\beta_3\beta_2\beta_1} + \frac{V_{be3}}{R_b} - \frac{V_{in} - V_{be3}}{R_3} \tag{7}$$

Applying KVL at Q4 base emitter biasing loop, the following is obtained

$$V_{ref} = V_{be4} + \left(\frac{R_i}{\beta_4} + R_2\right) I_{c4} \tag{8}$$

Substituting (7) in (8):

$$V_{ref} = V_{be4} + \left(\frac{R_1}{\beta_4} + R_2\right)\left(\frac{I_o}{\beta_3\beta_2\beta_1} + \frac{V_{be3}}{R_b} - \frac{V_{in} - V_{be3}}{R_3}\right) \tag{9}$$

Equation (9) gives the biasing voltage necessary for the driving the load current for the LED light fixture. Cumulatively V_{ref} is the operation of the pass devices in the active region, which can be obtained by properly selecting the BJT devices. This V_{ref} is controlled by the TYPE-II controller to achieve the stability in the circuit (section-IV deals the stability). Using (9), the necessary values of R_i can be chosen.

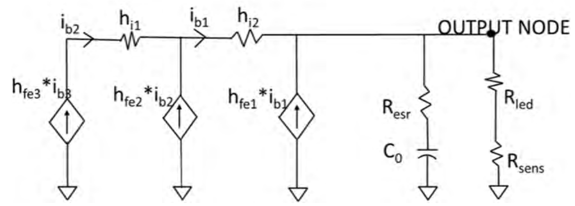


FIGURE 5. Exact sub-circuit -a- of the output node.

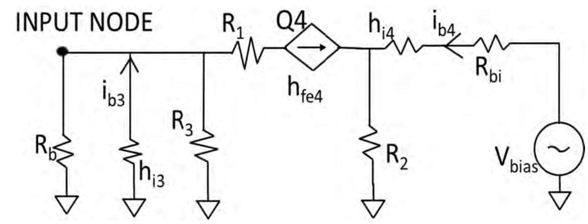


FIGURE 6. Exact sub-circuit -b- of input node.

IV. SMALL SIGNAL MODEL OF PROPOSED CIRCUIT

The small signal model is derived to investigate the stability of the proposed driver circuit. It also helps to design the controller to achieve desired output current for proper dimming of the LED luminaires [20]–[22]. The small signal model of the proposed driver circuit is presented in Fig. 4 and sub-circuits (illustrated in Fig. 5 and Fig. 6) are used for analysis purpose. Current relationships are derived as follows;

$$I_o = \frac{(1+h_{f1})}{1+\frac{R_{led}+R_{sens}}{R_{esr}+\frac{1}{sc}}} I_{b1} \tag{10}$$

$$I_{b1} = \left(1+h_{f2}\right) I_{b2} = K_2 I_{b2} \tag{11}$$

$$I_{b2} = h_{f3} I_{b3} = K_3 I_{b3} \tag{12}$$

$$I_{b3} = \frac{R_b R_3 h_{f4}}{R_b R_3 + h_{i3}\left(R_{bi} + R_3\right)} I_{b4} = K_4 I_{b4} \tag{13}$$

$$I_{b4} = \frac{1}{R_o + h_{i3} + \left(1+h_{f4}\right) R_2} V_{bias} = K_5 V_{bias} \tag{14}$$

By simplifying the above equations, the following is obtained;

$$I_o = K_1 K_2 K_3 K_4 K_5 V_{bias} \tag{15}$$

$$where\ K_1 = \frac{\left(1+h_{f1}\right)}{1+\frac{R_{led}+R_{sens}}{R_{esr}+\frac{1}{sc}}}, K_2 = \left(1+h_{f2}\right), K_3 = h_{f3}$$

$$K_4 = \frac{R_b R_3 h_{f4}}{R_b R_3 + h_{i3}(R_{bi} + R_3)},$$

$$K_5 = \frac{1}{R_o + h_{i3} + (1+h_{f4}) R_2}$$

$$I_o = G_{plant} V_{bias}, G_{plant} = K_1 K_2 K_3 K_4 K_5 \tag{16}$$

$$\frac{V_{sens}}{V_{bias}} = G_{plant} R_{sens} \tag{17}$$

R_{sens}, R_{led} and R_{esr} are the load current sense resistor, LED equivalent load and series equivalent resistor, respectively.

The h-parameter model of the devices $h_f and h_i$ values are forward current gain and input impedance, respectively.

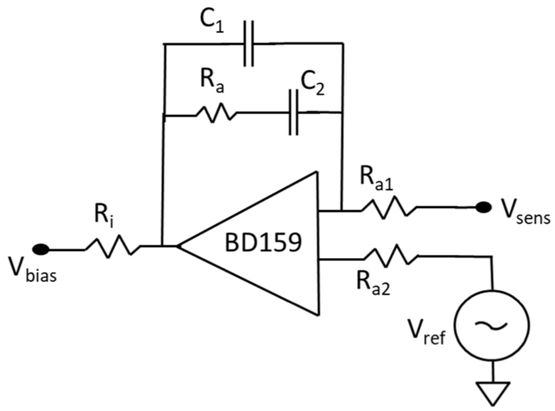


FIGURE 7. Selected Type compensator.

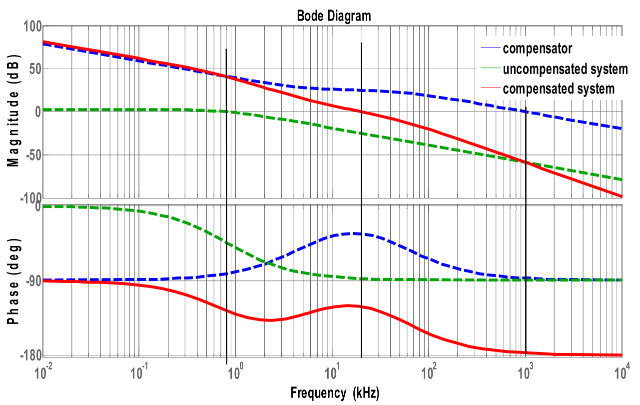


FIGURE 8. Bode diagram of the system describes the steady state stability.

From these h-parameter and component values (R_o, R_b), the plant transfer function can be determined.

V. COMPENSATOR DESIGN

Since light output is directly proportional to the current, the main purpose of the controller is to regulate the current flowing in the LED fixture to get the desired light output (lumens or light intensity or illumination). A type II compensator is selected to make the overall closed loop transfer function satisfy the stability criteria. The current through the LED will be controlled based on the output of the error amplifier. The type II compensator offers a pole at origin, one zero and a high frequency pole. The phase shift angle can vary from 0^0 to 90^0 [21]. The proposed compensator is illustrated in Fig. 7 and the corresponding Bode plot is given in Fig. 8. Transfer function of the proposed compensator is obtained as;

$$G(s) = \frac{V_{bias}(s)}{V_{sens}(s)} = -\frac{1 + R_a C_2 s}{R_{a1} s (C_1 + C_2 + R_a C_1 C_2 s)} \quad (18)$$

With assumptions of $C_2 \gg C_1$ and for middle frequencies $\omega_z \ll \omega \ll \omega_p$, compensator's transfer function has a zero at $\omega_z = -\frac{1}{R_a C_2}$ and a pole at $\omega_p = -\frac{1}{R_{a1}(C_1+C_2)}$.

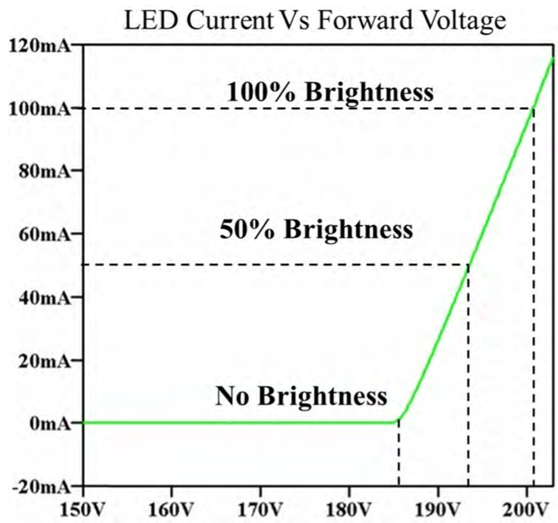


FIGURE 9. Characteristics of LUXEON – H high voltage LED.

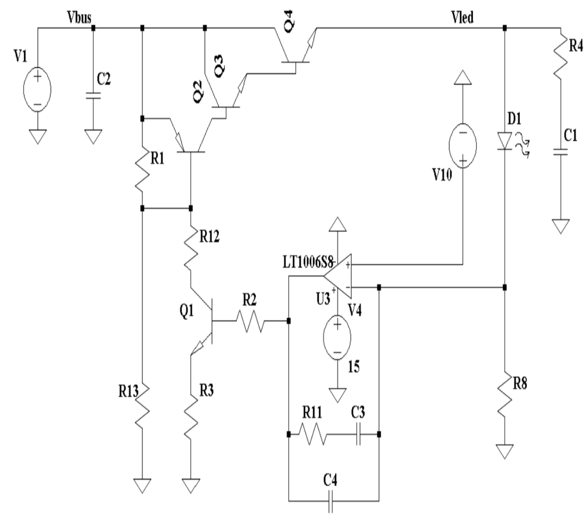


FIGURE 10. Simulation schematic in LT spice software.

The gain at maximum phase of the compensator is

$$|G(s)| = \left|\frac{R_a}{R_{a1}}\right| \quad (19)$$

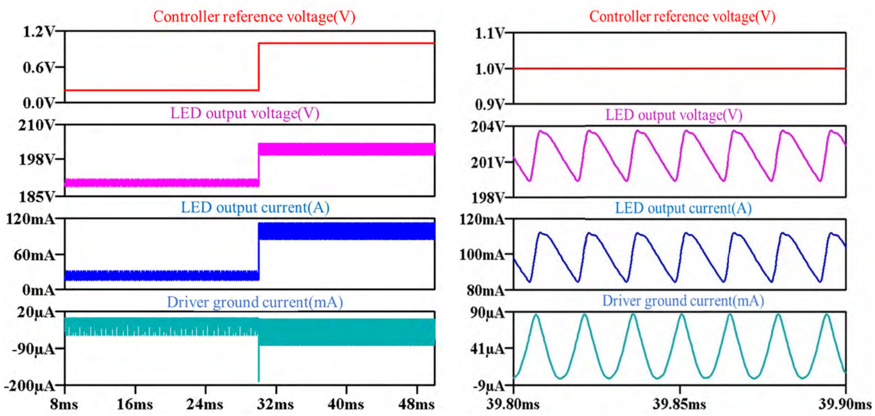
The gain crossover frequency of the compensator is

$$\omega_{co} = \sqrt{\omega_z \omega_p} \quad (20)$$

The phase of the compensator is given in (21)

$$\emptyset = -180 + \tan^{-1}\frac{\omega}{\omega_z} - 90 + \tan^{-1}\frac{\omega}{\omega_p} \quad (21)$$

From the bode diagram of the uncompensated system, phase of 45° is observed at crossover frequency of 820 Hz and at 20 kHz, gain of -25dB and phase of 88^0 is observed. The compensator is designed to achieve overall compensated systems phase margin of 55^0 at 20 kHz crossover frequency.



(a) (b)

FIGURE 11. **(a) Simulation results of analog dimming at rated conditions. (b). Zoomed Version of operation for reference voltage of 1.0 V.**

From the bode diagram, at 20 kHz the gain of uncompensated system is 25dB, and hence gain margin is obtained as:

$$\emptyset = PM - \emptyset = 55^{\circ} - \left(-88^{\circ}\right) = 143 \qquad (22)$$

PM is the phase margin and Ø is the gain margin of the system. After solving the equations (20-22) at $R_{a1} = 1\ k\Omega$, the values of $C_1 = 159nF$, $C_2 = 1.59uF$ and $R_a = 17.7k\Omega$ are obtained. The bode plot of the compensated system shown in Fig. 8, having high gain, infinite gain margin and phase margin of 57^0 at 20kHz.

VI. REAL TIME SIMULATION RESULTS

Actual LUXEON-H high voltage LEDs are modeled in LT spice software to get the V-I characteristics given in the data sheet [22]–[24]. Unlike normal diodes, the LED itself acts as a load having nonlinear characteristics as shown in Fig. 9. LED starts conducting at 185V and reaches the rated current of 100mA at 200V. The proposed LED driver is simulated in LT spice software and the schematic is shown in Fig. 10.

Fig. 11(a) shows the simulation results of the analog dimming of the LED driver. Here the current flowing through the load is constant throughout the operation of the driver to give the fixed light output. To vary the light output, the reference signal to the compensator can be changed. The simplicity of this driver is the fact that reference voltage can be easily generated by the low-cost tiny microcontrollers. In the proposed driver, 1V reference voltage at the error amplifier, drives rated current through the load. This means to reduce the current or light output to the desired level; this reference voltage must be reduced. Steady state zoomed version of the analog dimming of LED driver is shown in Fig. 11(b). Here ripple in signals is due to controller action. By appropriate tuning (trial and error method), this ripple can be minimized.

In analog dimming, the continuous current through the LED load will be according to the preset light levels. Analog dimming is also identified as Continuous Current Reduction Dimming (CCRD) [23], [24].

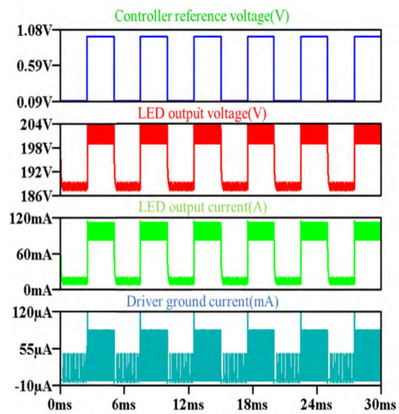


FIGURE 12. **Simulation results at PWM current dimming at rated conditions.**

Since the extent of brightness is proportionate to the current flowing through the LED, the current is reduced to decrease the brightness of LED. The ground current flowing in Fig. 11, is about 50uA which is negligible and leads the driver to reach maximum efficiency as shown in Fig. 13 and Fig. 14. Applications suitable for analog dimming are as follows:

(a) to achieve high-performance dimming when lengthy cables exist between driver and light engines, (b) applications where low EMI is desired, such as medicinal equipment, and (c) with motion application or spinning equipment.

The switching of current between zero and the rated output current is called PWM Dimming (PWMD). The simulation results with PWMD are shown in Fig.12. Here, brightness of LED is dependent upon the average value of reference signal. Reference signal in Fig. 12 is generated for 2kHz frequency. In PWMD, LED load is either off or running at its rated current (full load). The ratio of on time to off time determines the LED brightness. This is also called as "Average Current Dimming". By controlling the duty ratio, the average current

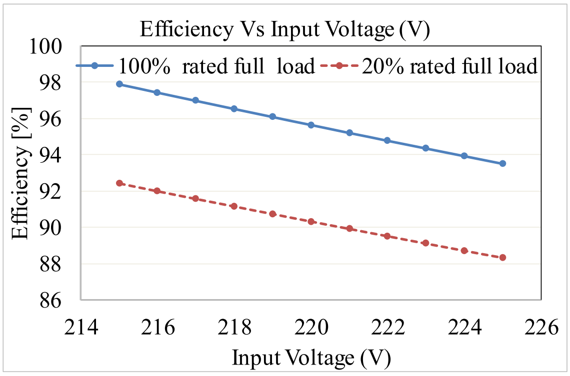


FIGURE 13. Variation of efficiency with input voltage variation.

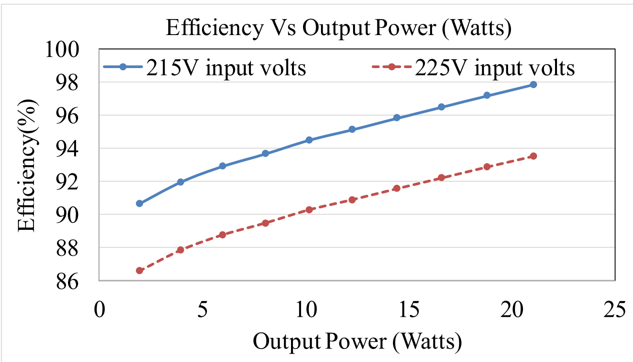


FIGURE 14. Variation of efficiency with output power variation.

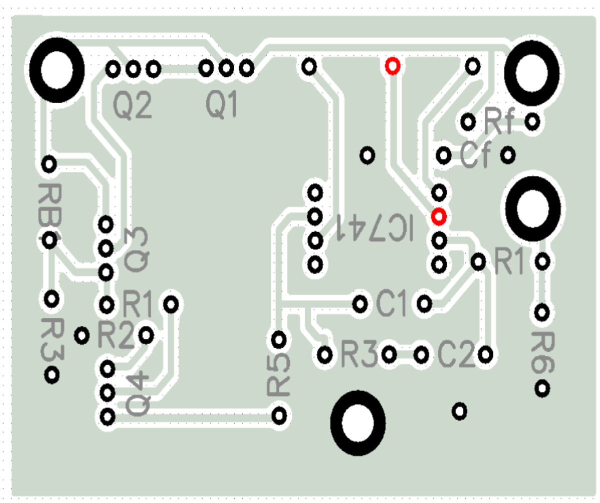


FIGURE 15. First prototype of the designed PCB.

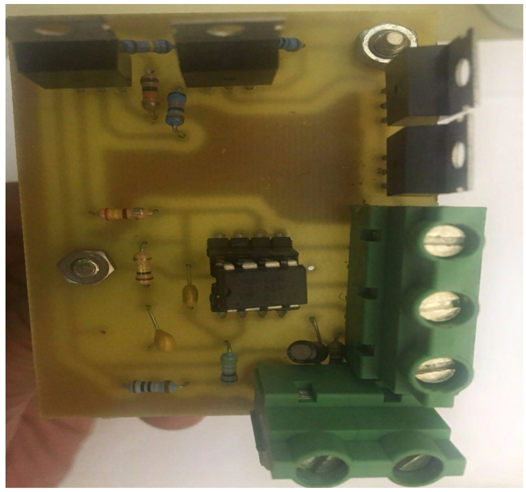


FIGURE 16. Proposed LED driver PCB with components soldered.

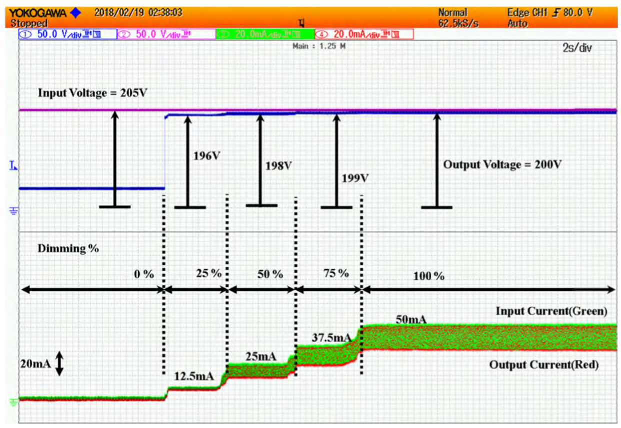


FIGURE 17. Dynamic performance of the LED driver for different load current (LED brightness) references.

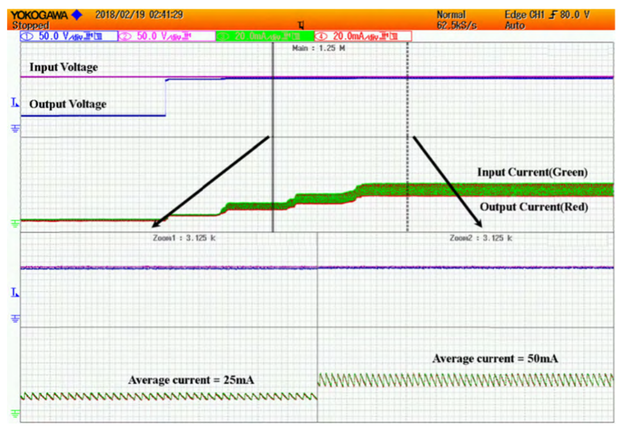
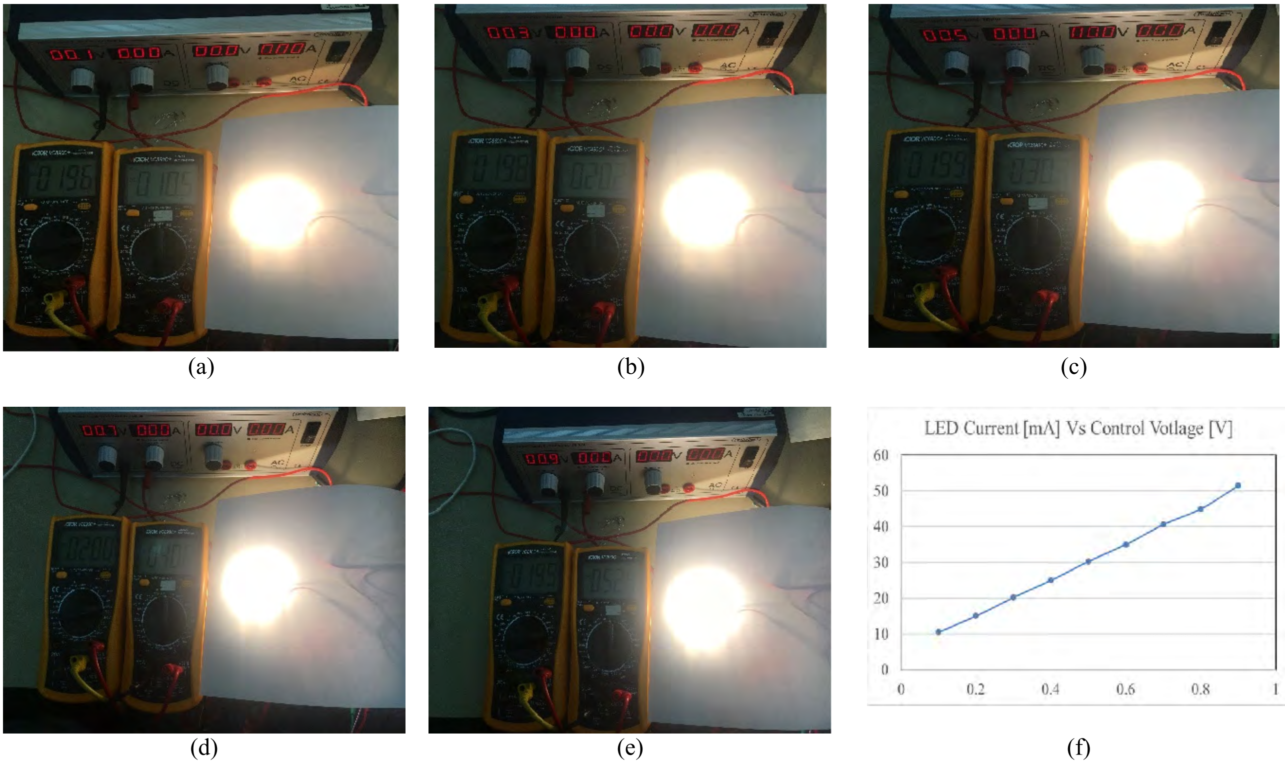


FIGURE 18. Zoomed version of load current & input current for 50% and 100% LED brightness.

passing through the LED is controlled which in turn controls the brightness (light level). To reduce the electromagnetic interferences (EMI) generated by the frequent switching in the driver board, instead of turning OFF it can be operated at 2% to 5% of load current. So, from Fig. 9, it can be concluded that LED can operate at cut-in forward voltage of 185V at 2% to 5% of load current. This makes the voltage across the load to vary between 185 V and 220 V as shown in Fig. 12. Ripples in signal tracking (shown in Fig. 12) are due to controller action. Applications suitable for PWMD are: Fixtures that must be dimmed lower than 40% and still maintain consistent



Note: V_c = Control Voltage Magnitude in Volts, V_{out} = Voltage across LED string, I_{out} = Current through LED string

FIGURE 19. **(a) 20% brightness [V_c =0.1V, V_{out} = 196V, I_{out} = 105mA]. (b) 40% brightness [V_c =0.3V, V_{out} = 198V, I_{out} = 202mA]. (c) 60% brightness [V_c =0.5V, V_{out} = 199V, I_{out} = 303mA]. (d) 80% brightness [V_c =0.7V, V_{out} = 200V, I_{out} = 406mA].(e) 100% brightness [V_c =0.9V, V_{out} =199V, I_{out} =524mA]. (f) Control voltage Vs LED current.**

color, color mixing applications, because of their need for precise levels of each color.

Fig. 13 shows the efficiency variation versus input voltage variation. The designed LED driver depends performance on the DC grid voltage level; hence the regulation of the DC grid voltage is of paramount importance. Increase in input DC grid voltage reduces the efficiency of the driver as shown in Fig. 13. If the input voltage goes below the forward voltage of the LEDs, the driver circuit go idle and the light output becomes zero. Here the same light fixture can be used at different power levels or dimming conditions.

Fig. 14 shows the variation of the proposed driver efficiency with dimming (output power) variation. The driver efficiency is maximum at the rated condition and when the DC grid voltage is equal to the forward cut-in voltage of the LED. As the power output decreases (dimming increases), the efficiency of the system drops from 97% to 92%.

VII. DESIGN AND HARDWARE RESULTS

The proposed LED driver is designed using Dip Trace PCB design software, shown in Fig. 15. Components of the proposed driver are soldered on the PCB. The circuit after soldering is shown in Fig. 16.

The proposed LED driver is tested with 205 input DC voltage source. Using the proposed driver, brightness of the LED driver is varied from 0% brightness to 100% brightness in steps of 25%. Experimental results obtained are shown in Fig. 17. Current through the LED varies according to the luminous intensity or brightness of the driver. It should be observed that current through the LED varies linearly according to its brightness. Zoomed version of rated current are shown in Fig. 18 for 50% and 100% brightness cases.

Other set of experimental results for variation of LED brightness are shown in Fig. 19. Brightness of the LED is varied from 20% to 100% brightness (by varying control voltage reference) as shown in Fig. 19(a) to Fig. 19(e). It can be observed that current through the LED varies linearly with the LED brightness as shown in Fig. 19(f).

VIII. CONCLUSION

A linear regulated dimmable LED driver for distributed DC grid is proposed. Passive component-less (inductor and capacitor) operation is the key credit of this topology. Lifetime of the driver is very high because no electrolytic capacitors are employed in the proposed driver circuit. Power component biasing parameters determined by the steady state analysis and suitable Op-amp based type II compensator is designed based on the small signal model of the transistors. The performance of the proposed driver is verified in LT spice software simulation. Using the current sense resistor, the driver achieves dimming from 5% to 100% brightness.

Efficiency as a function of input DC voltage and output power variations are also studied. The proposed topology of LED driver is controllable, robust, highly reliable and economical. Thus, it can be used in wide range of applications from commercial spaces to household application.

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