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Development of Vehicle Lighting System Using LED Application

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Abstract: A Light Emitting Diode (LED) is a semiconductor device which converts electricity into light. LEDs are preferred over incandescent lamps because of their long life and their availability in various colors and brightness levels. The aim of this paper is to present the development of vehicle lighting system using LED application. In this system, high power LEDs type is chosen as automobile headlight model and controller circuit using microcontroller is considered. The LEDs are driven using buck converter circuit with appropriate Pulse Width Modulation (PWM) signal whereby the PWM signals are generated by microcontroller. The system is divided into 2 modes of operation, manual and automatic. The automatic mode of operation will be operating when the LDR senses the level of light brightness whereby the level of brightness is proportion to duty cycle of PWM. Meanwhile, for the manual mode of operation, 3 switches which are SW2 with 20% duty cycle, SW3 with 40% duty cycle and SW3 with 80% duty cycle are developed. The result shows that the maximum brightness of LED is about 127.6 Lumen at 80% of duty cycle for manual operation mode. Besides, by varying the duty cycle of PWM signal for both modes of operation, manual and automatic, LED brightness can be controlled.

Keywords: LED, lumen, LED brightness, PWM, buck converter.

1. Introduction

In 1994, Hewlett-Packard increased the efficiency of the LED in ten times the efficiency of a red filtered light bulb [1]. The efficiency of 25 lm/W enabled the earliest LED stop lights on automobiles, LED red traffic signals and single colour outdoor signs. But at 3 lm LED uses were still inadequate to those applications. In 1998, the pioneering work on high power LEDs started at Lumileds lighting. This company introduced the earliest commercial power LED. The Luxeon 1 W LED operates at power level 20 times larger than the traditional 5 mm indicator LED, with efficiency of 50%. Automotive designers are beginning to project LEDs headlights. In January 2004, the Hyundai Company showed at Detroit Automobile salon its concept car HDC-8, which used LEDs not including a reflector [2]. This was possible due to development in this technology over years. The new generation of high-power LED modules represents a significant development in LED design. Ranging from 1 watt to 10 watts, current high-power LED modules are capable of delivering between 10 and 50 Lumens/watt of light output. This level of light output is comparable to almost all incandescent lamps and even halogen bulbs in single-colour applications.

The LED current should be limited to avoid the device overheating. A resistor is not a proper answer as LED current limiter. The reason is the battery voltage that changes with time. The output voltage value a 12 V battery car may change from 10 V to 15 V depending on external temperature and electric load. Besides this fact, voltage spikes may disappear in battery power source generated by motors and relays. This unregulated power supply will reduce the LED useful life. Moreover, the resistor losses decrease the system efficiency. The present work proposes a DC-DC current controlled converter to control a LED headlight [3].

2. Literature Review

Table 1.1 shows four types of lighting sources that are incandescent bulb, tungsten halogen, halogen and the LED (ASMT-MW22). The power needs by the LED (ASMT-MW22) to produce 150 lm is only 3 W with about 50 lm/W efficiency.

Table 1.1: Lighting sources in automotive applications

Lighting Source	Power (W)	Luminuos Flux (lm)	Efficiency (lm/W)
Incandescent Bulb	60	865	14.4
Tungsten Halogen	50	590	11.8
Halogen	55	1500	27
LED (ASMT-MW22)	3	150	50

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Researchers from [4-6] have been developed and proved that LED lighting system are able to replace traditional or high electric consumption lamp without comprises the quality of output light brightness. Some LED types with suitable controller and driver circuits are able meeting automotive lighting standards [4,6]. Therefore LED can be used for automotive lighting system with suitable controller and driver circuits and also only consume low power as compared to typical automotive lighting bulb. The important electric circuits involve in controlling LED brightness are DC to DC converter as a LED driver and PWM circuit as an output power controller.

Most of the DC converters are suitable for power LED application. Many researchers agreed that principle of Buck and Boost converters or combination both of them in controlling power LED brightness are useful, [7-11]. Buck or Boost converter is most suitable [7] if low voltage DC source is considered for the main source. In this system Buck converter is considered because author [11] claimed that Buck converter offer high efficiency power conversion for automotive lighting applications.

3. Methodology

The design concept of the system in controlling brightness of LED is shown in Fig. 1.2. The system consists of three main parts which are controller circuit, gate driver and LED driver. These parts are used to build up the system of automotive lighting.

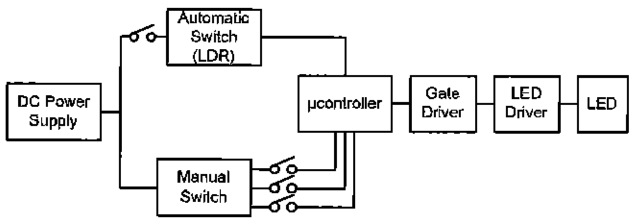


Fig. 1.1: Block diagram of the system

4. Results and Discussion

4.1 Simulation Results

Circuit design and simulation processes have been done and conducted. DC-DC converter Buck type as a LED driver has been used and basic circuit of the driver is shown in Fig. 1.2(a). PWM switching scheme has been considered as an input switching for LED driver circuit. Microcontroller and MOSFET driver circuits are shown in Figs. 1.2(b) and 1.2(c) respectively. The system consists of 3 main circuits and the circuits are Controller (microcontroller), MOSFET driver and LED driver circuits.

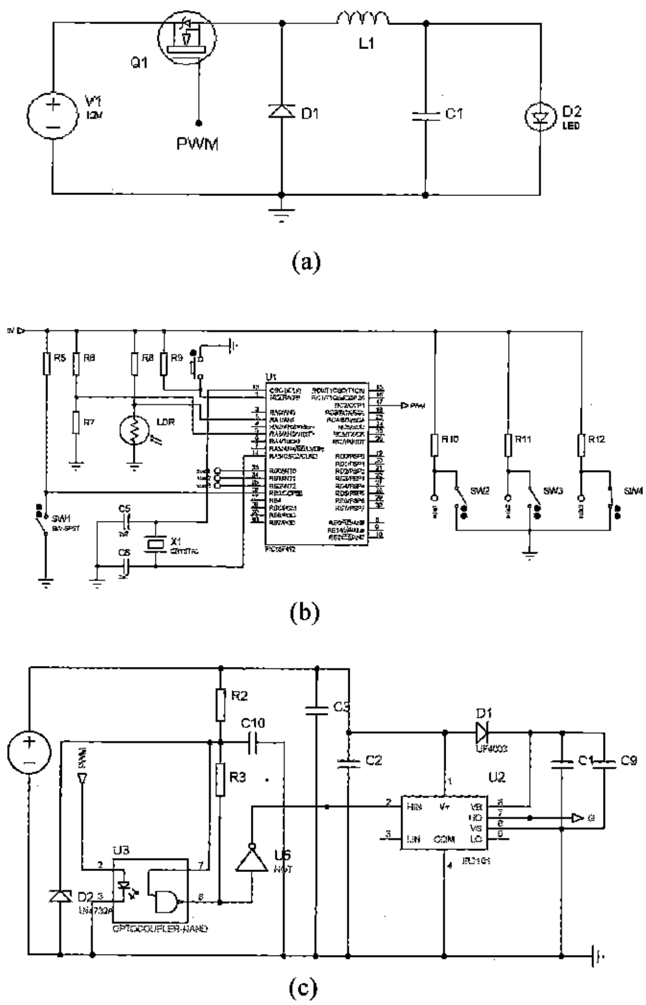
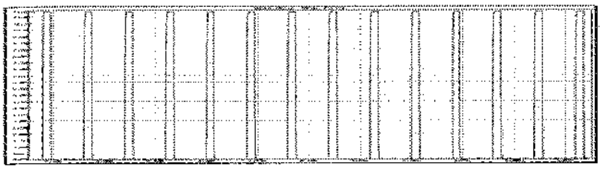


Fig. 1.2: (a) LED driver circuit using Buck converter circuit, (b) Controller circuit (microcontroller), (c) MOSFET driver circuit

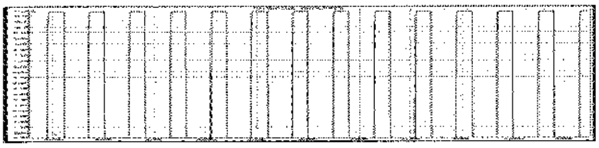
Fig. 1.3 shows the timing diagram of the different PWM duty cycles to switch the MOSFET in order to control the brightness of the LED. The controller goes through 4 conditions in each generating PWM signal, i.e. SW2 ON, SW3 ON, SW4 ON or automatic mode.

For condition 1, SW2 ON, PWM signal with 20% of duty cycles is generated and the signal is being as an input to MOSFET in LED driver circuit to control output power in turning ON LED. Then process is followed by condition 2, SW3 ON, PWM signal with 40% of duty cycles is generated and condition 3, SW4 ON, PWM signal with 80% of duty cycles is generated. Equation (1.1) shows the formula to determine duty cycle, D.

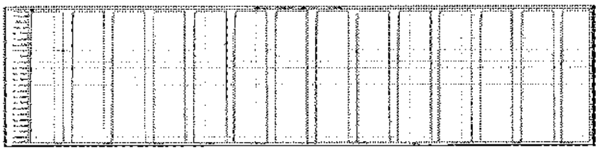
$$D = \frac{T_{ON}}{T_{ON} + T_{OFF}} \tag{1.1}$$



a) PWM signal when SW2 is ON (D=20%)



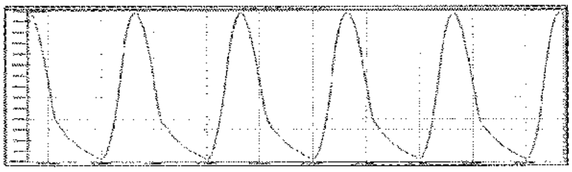
b) PWM signal when SW3 is ON (D=40%)



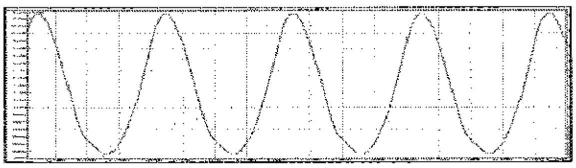
c) PWM signal when SW4 is ON (D=80%)

Fig. 1.3: Timing diagram for MOSFET switching

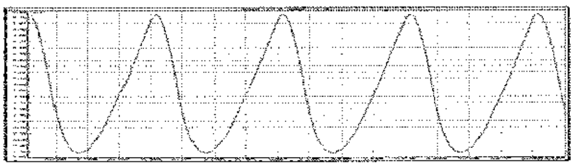
Fig. 1.4 shows the average output power waveforms from the LED. Because of switching phenomenon, ripple is produced for every condition.



(a) when SW2 is ON (D=20%, 748 mW average power consumed by diode)



(b) when SW3 is ON (D=40%, 2.22 W average power consumed by diode)



(c) when SW4 is ON (D=80%, 5.19 W average power consumed by diode)

Fig. 1.4: Output waveforms of SW2, SW3 and SW4

The automatic operation mode is depends on LDR signal. If the environment is dark, duty cycle of PWM will increase to generate maximum output power for the maximum brightness and if the environment is bright, duty cycle of PWM will decrease to generate minimum output power for the minimum brightness.

4.2 Hardware Results

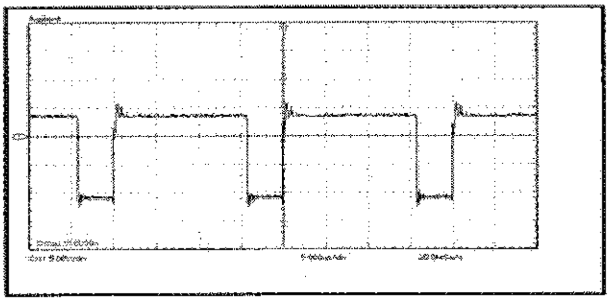
The measurement was conducted both for manual and automatic operations. For manual operation, 3 duty cycles have been set, switch 1, 2 and 3 are 80%, 40% and 20% respectively. For automatic operation, duty cycle is depends on the input from LDR.

i. Hardware Measurement Result for Manual Operation

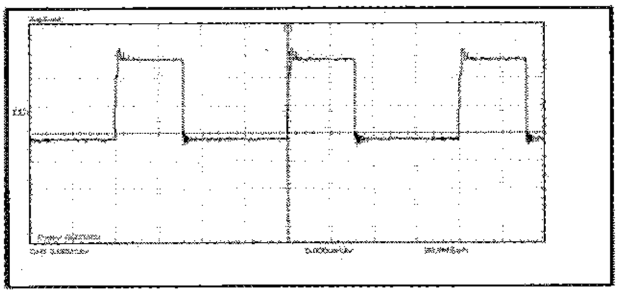
Figs. 1.5(a), 1.5(b) and 1.5(c) show the measurement results of manual operation for D = 80%, D = 40% and D = 20% respectively. From the observation, when D = 80%, the LED is more bright than D = 40% and D = 20%. The LED is dim when D = 20%. Table a shows output results.

Table 1.2: Output results

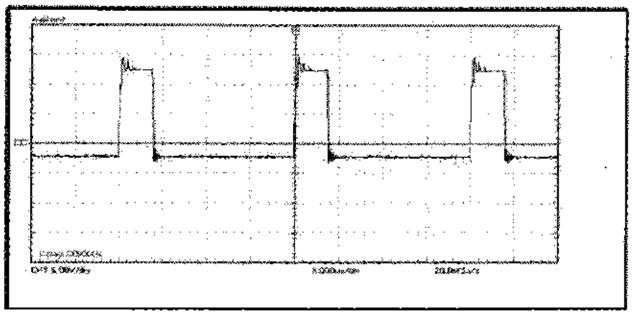
Duty Cycle	t_{on}	t_{off}	Period, T	LED Brightness
80%	15.8 μs	4.2 μs	20 μs	more
40%	7.8 μs	12.2 μs	20 μs	less
20%	3.8 μs	16.2 μs	20 μs	dim



(a) SW1 ON with 80% duty cycle



(b) SW2 ON with 40% duty cycle

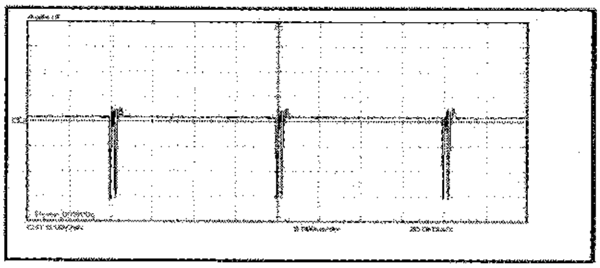


(c) SW3 ON with 20% duty cycle

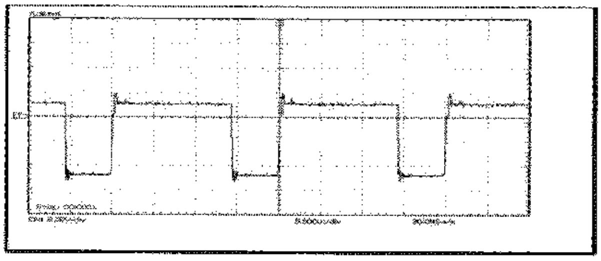
Fig. 1.5: Measurement results for manual operation mode

ii. Hardware Measurement Result for Automatic Operation

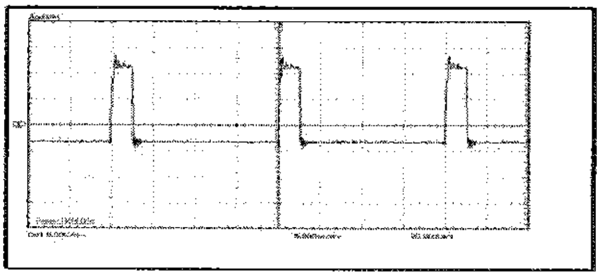
In this system, LDR is used to sense the existence of light or as a light sensor. Figs. 1.6(a), 1.6(b) and 1.6(c) show the measurement results of automatic operation and three duty cycles are captured during operation. Those captured duty cycles are D = 100% (LDR senses dark environment), D = 75% (LDR senses dark environment but brightness still in partial) and D = 12.5% (LDR senses less dark environment) with respect to Figs. d, e and f respectively. From the observation, when D = 80%, the LED is more bright than D = 40% and D = 20%. The LED is less bright when D = 20%.



(a) PWM with 100% duty cycle



(b) PWM with 75% duty cycle



(c) PWM with 12.5% duty cycle

Fig 1.6: Measurement results for automatic operation mode

Table 1.3 shows data taken from circuit simulation and hardware measurement, there are differences between both conditions. This is because of the usage of several different components in simulation due to library limitation of the used software. With refer to Table 1.1, one Tungsten Halogen lamp is about equal to four LEDs in term of luminous and power consumed is about 12 W instead of 50 W for Tungsten Halogen. Therefore LED offer low power consumption as compared to the other option of automotive lamps. Luminous flux, F can be obtained by considering relative luminous flux versus forward current graph in Fig. 1.7 and equation 1.2 with regard of given typical value of LED brightness, 145 Lumen (from ASMT-MW22 datasheet). By referring Table 1.3, the maximum LED brightness obtained for 80% of duty cycle is about 127.6 Lumen.

$$F = \text{Relative Luminous} \times \text{DC Forward Current} \qquad (1.2)$$

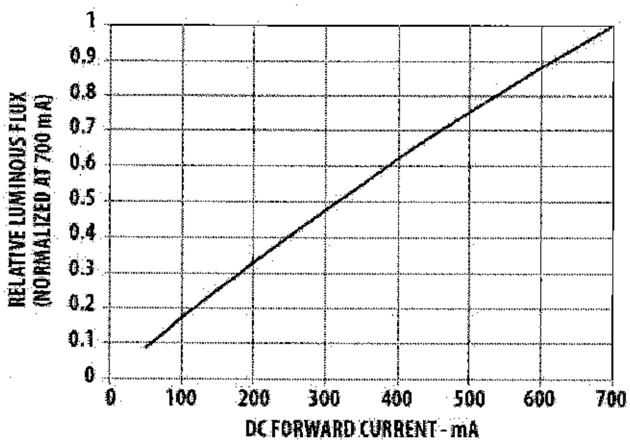


Fig. 1.7: Relative Luminous Flux vs. Forward Current

Table 1.3: Data from circuit simulation and hardware measurement

Circuit Simulation				
Duty Cycle	V_{LED} (V)	I_{LED} (A)	Power (W)	Luminous Flux (Lumen)
80%	5.16	0.98	5.12	N/A
40%	3.93	0.57	2.27	N/A
20 %	2.95	0.25	0.74	N/A
Hardware Measurement				
Duty Cycle	V_{LED} (V)	I_{LED} (A)	Power (W)	Luminous Flux (Lumen)
80%	3.44	0.59	1.84	0.88x145=127.6
40%	1.72	0.28	0.49	0.46x145=66.7
20%	0.86	0.15	0.13	0.22x145=31.9

Fig. 1.8 shows the picture of hardware constructed in prototype form of the system.

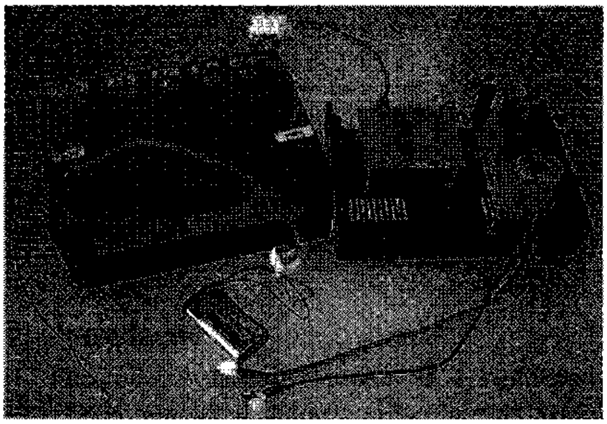


Fig 1.8: Prototype of the system

5. Conclusion

The designed of automotive lighting system using LED was succeed. The brightness of LED can be controlled by adjusting duty cycle of the generated PWM signal. In this system, LED driver circuit acts as a Buck converter and received the PWM signal to control output power whereby it reflects to the brightness of LED and the system can be controlled by manual or automatic modes of operation.

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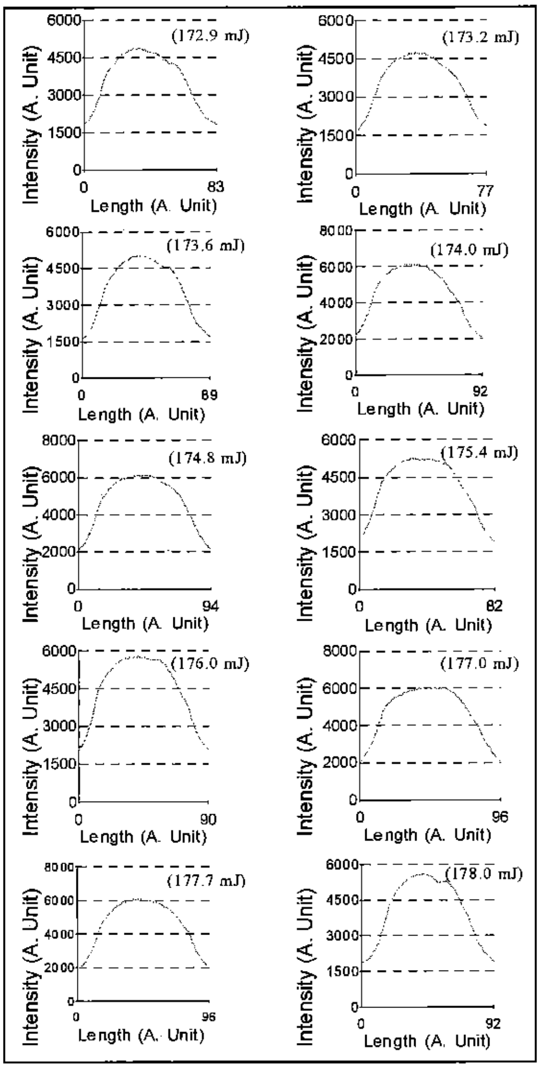

Fig. 7 The intensity profile of each frame in Figure 3.

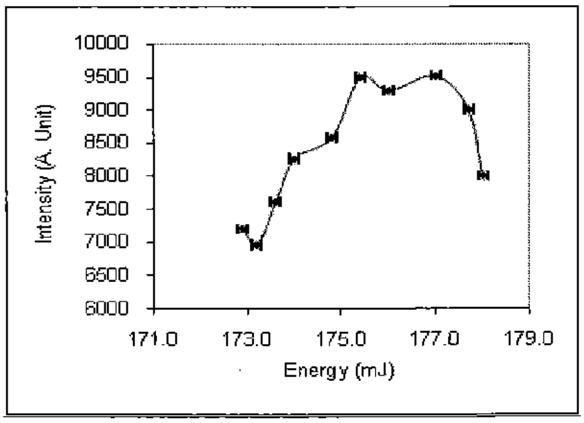

Fig. 8 The intensity of the plasma as a function of energy.

4. Conclusion

The plasma can be generated by focusing a Q-switched Nd:YAG laser in the air. Diagnostic of the laser plasma was carried in conjunction of high-speed photography technique with the aid of image processing system. The contrast of the image can be altered by using a binary morphological processes and binary contrast enhancement. The plasma size was found greater at higher energy. On the other hand the intensity of the plasma is unpredictable. From the experiment, we notice that there are instabilities in plasma expansion. The nonlinear force of the laser source mostly causes this phenomenon, besides the plasma beam also is unstable.

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