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Performance analysis of photoresistor and phototransistor for automotive's halogen and xenon bulbs light output

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Abstract. Illumination of any light is measured using a different kind of calibrated equipment's available in the market such as a goniometer, spectral radiometer, photometer, Lux meter and camera based systems which directly display the illumination of automotive headlights light distribution in the unit of lux, foot-candles, lumens/sq. ft. and Lambert etc.,. In this research, we dealt with evaluating the photo resistor or Light Dependent Resistor (LDR) and phototransistor whether it is useful for sensing light patterns of Automotive Halogen and Xenon bulbs. The experiments are conducted during night hours under complete dark space. We have used the headlamp setup available in TATA SUMO VICTA vehicle in the Indian market and conducted the experiments separately for Halogen and Xenon bulbs under low and high beam operations at various degrees and test points within ten meters of distance. Also, we have compared the light intensity of halogen and xenon bulbs to prove the highest light intensity between halogen and Xenon bulbs. After doing a rigorous test with these two sensors it is understood both are good to sensing beam pattern of automotive bulbs and even it is good if we use an array of sensors or a mixed combination of sensors for measuring illumination purposes under perfect calibrations.

1. Introduction

Headlamps are considered as “vision” of automotive vehicles. On considering safety riding, headlamps play an important role while driving during night times. Nowadays there are three types of bulbs used in automotive headlamps. They are halogen, Xenon or High-Intensity Discharge (HID) and LED Headlamps. Each bulb is having its own advantages like halogen is cheaper, xenon is too brighter and LED bulbs are having good power consumption and good brightness. Halogen bulbs are widely used bulbs globally because of low cost and fair illumination on road under latest reflector Lens technology. Halogen bulbs shown in figure 1 is available in the category called H1, H3, HB4, and H11 which has only one filament. It means single filament for used for low beam and high beam and also used for fog lamps [1]. At present, the H4 category bulbs are used in most of the automotive which has dual filament arrangement having the ability to lighting under high and low beam on the on the same bulb. The general information of halogen H4 is given below as per specification.

Power rating	: 55W
Filament temperature	: 3400K



Voltage rating	: 12V
IEC base type	: P43t [3 pin]

Xenon bulbs [8] shown in figure 2 are also more popular nowadays in automotive sectors which have good white illumination like daylight. Xenon bulbs look like halogen bulbs and their glass body is blue coated. The power consumption is the same as halogen or even less but the illumination is greater than the halogen [2].

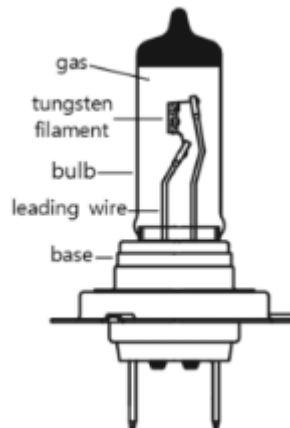


Figure 1. Halogen bulb [13]

The xenon gas in the bulb will produce light minimally on power up and within 20 seconds it reaches its maximum intensity [3][12]. The general information of Xenon H4 is given below as per specification.

Power rating	: 55W
Filament temperature	: 4000K
Voltage rating	: 12V
IEC base type	: P43t [3 pin]



Figure 2. Xenon bulb [14]

photo-resistor or light dependent resistor shown in figure 3 is a sensor used for detecting the lights. As the name itself implies resistance of the sensor varies with respect to light. The resistance decreases as the intensity of light increases and resistance increases as the intensity of light decreases. Generally, in the absence of light, the resistance of LDR is Megaohm. The LDR specifications are given below.

Power consumption	: 80 mW
Temperature	: -40 to 75 degrees C

No of pins : 2

The phototransistor is a transistor with an open base has small collector current consist of thermally produced minority carriers and surface leakage. By exposing the collector junction to light this transistor starts working for the light change which is generally more sensitive to the light than a photodiode. The phototransistor is differing from the photodiode in current gain. In another word if the same light falling in both photo diode and photo transistor more current in phototransistor than photodiode and it meant as increased sensitivity[9].

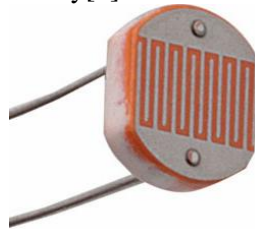


Figure 3. Light Dependant resistor [15]

So we have chosen phototransistor shown in figure 4 instead of the photodiode. The phototransistor is having the following specifications which commonly available in the market.

Power consumption : 250 mW
 Temperature : -40 to 100 degrees C
 No of pins : 2



Figure 4. Phototransistor [16]

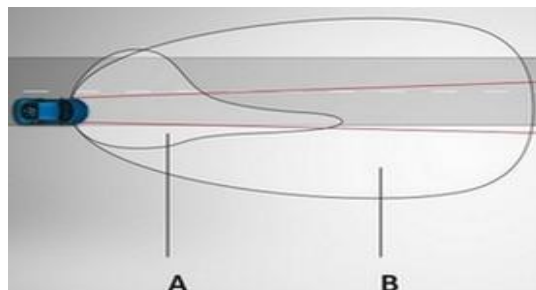


Figure 5. Light beam projection from headlight [17]

Usually, Headlamps [4][5] in automotive is operated in low or high beams depends on the situation. Low or dipped or passing or meeting beam (A) shown in figure 5 provides enough

illumination intended to use whenever the vehicles are present a head on oncoming or overtaken. High beam or main or driving beam (B) [11] provide full bright depends on the type of light with equal distribution of light from the center of the vehicle and need to use alone on the road which beam may give inconvenience to other drivers[6].

2. Hardware design

The following components are used to design the circuit in order to display the Analog to Digital conversion decimal values in liquid crystal display.

- Potentiometer -100K
- Liquid crystal display
- Light dependent resistor
- Phototransistor
- Arduino UNO

Hardware design for displaying ADC value of photoresistor and phototransistor requires LDR and photo transistor mentioned in mentioned in section 1, potentiometer about 100K, Arduino board consists of ATMEGA328 microcontroller, Liquid Crystal Display (LCD) and powering devices. The circuit shown in figure 6 is for phototransistor is same for LDR instead of the phototransistor, we need to replace LDR. The potentiometer R3 need to vary with respect to getting 3.3V under the full light which produces ADC value of 1024 which shown on LCD. The above-said settings are applicable for LDR and phototransistor.

The Arduino board is designed with an Atmel AVR Microcontroller (ATMEGA328), a crystal or oscillator (a clock that sends time pulses at a specified frequency to enable it to operate at the correct speed), and a 5-volt linear regulator. Depending on the type of Arduino we have, it may also have a USB socket to connect to a PC for uploading or retrieving data. The board exposes the microcontroller's I/O (input/output) pins so that you can connect those pins to other circuits or to sensors. We have used Analog pin 3 on the Arduino board for connecting the voltage output of voltage divider network consisting of the sensor which produces voltage is proportional to light and displayed in digital value (decimal) in the LCD after conversion. Basically, LCD is connected in two ways with Arduino. One we can connect all 8 pin of LCD to any 8 pins of Digital I/O of Arduino or we can connect any 4 pins (DB0 – DB7) of LCD to any 4 pins of Digital I/O. The remaining pins of LCD are E (Enable) to enable LCD, RS (Register Select) to select command or data and R/W (Read/Write) usually connected to ground for a write operation. The potentiometer connected to LCD used for varying contrast of LCD screen. The conversion of light (voltage) into a digital value does not only depend on hardware, it also involves software as explained in the following sub section.

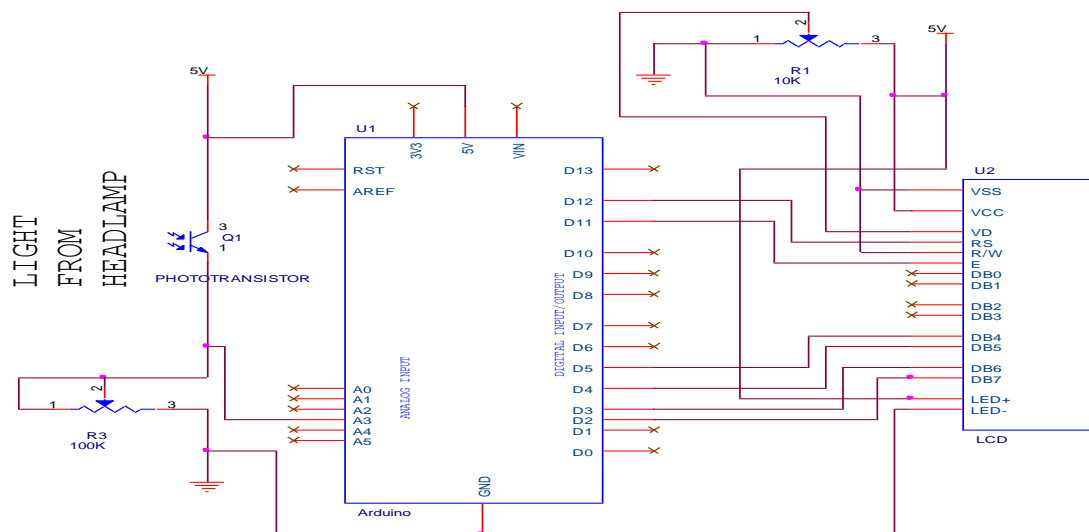


Figure 6. Circuit connection for sensor and ADC output display

3. Software design

As discussed in the above section 2, we have used Arduino board which is connected with LDR or phototransistor as an input device for light sensing and LCD as an output device to display the LCD values. So we are in need to design the coding in order to display the most accurate value of light sensing which is processed by ATMEGA328 available in Arduino board. LiquidCrystal is a header file used for the only Arduino for initializing the Arduino LCD operations. The LCD function which has 6 arguments implies that digital I/O pin 12 of Arduino board connected to RS of LCD, digital pin 11 of Arduino board connected to ENABLE OF LCD and remaining I/O pins 5,4,3 and 2 connected to LCD's DB4 to DB7 respectively. The digital output decimal value of proportional to the light beam is displayed after computing root mean square values as explained below.

We have computed the RMS value by taking 100 samples of output data at same test point (test points are shown in next section) and using a third variable called tmp_value the mean is calculated and then square root value is calculated for the mean value is the final analog to digital conversion value displayed on the LCD screen which is noted down for evaluation at all test points which is discussed in the next section.

4. Experimental setup

The evaluation of the sensors we have built the test points on the road and marked the points as the figure 7. We have measured the values from 0 to 67.5 degrees on which 33.75 is an exact center in our measurement. On each line, we have divided the entire 10 meters into 10 sections. That is measurement made on each angle as shown in the diagram at each meter. For example, observing data for low beam using halogen means, there are totally 8 levels of degrees on each degree 10 test points are observed. So totally for one beam, we need to observe 80 values totally. The headlight positioned from the center (zero degrees) to about 16-inch left and 16-inch right side and about 30-inch height from the ground which is measured and utilized from the TATA SUMO VICTA vehicle directly. The headlight is powered with 12V AMARON make battery which has maximum current 7A used for 4 wheelers especially in cars.

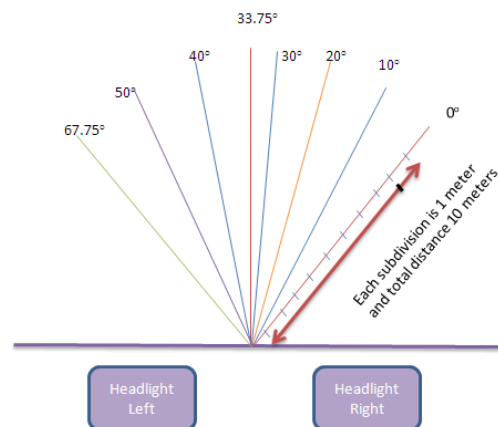


Figure 7. Test points (TP) locations and headlight projection

5. Experimental results

As mentioned earlier section we have conducted the experiments during night times for complete darkness. After a light beam is switched ON, we first collected the luminosity value in lux (unit of luminous) through lux meter available in the market called HTC LX-101A. Then as per the circuit is shown in section 3, we have used the circuit and software coding to collect the Analog to Digital conversion (ADC) value directly as displayed in LCD as defined above. This is applicable for both LDR and phototransistor. The reason for using the ADC value directly is, if we calibrate our design with any other lux meter there is a chance for getting an error. So, in order to analyze the LDR and phototransistor, we are comparing the values of Lux meters luminosity values and ours ADC value (displayed in LCD) directly as shown in figure 8a. The original light beam of halogen and xenon output is shown in figure 8.b and figure 8.c respectively

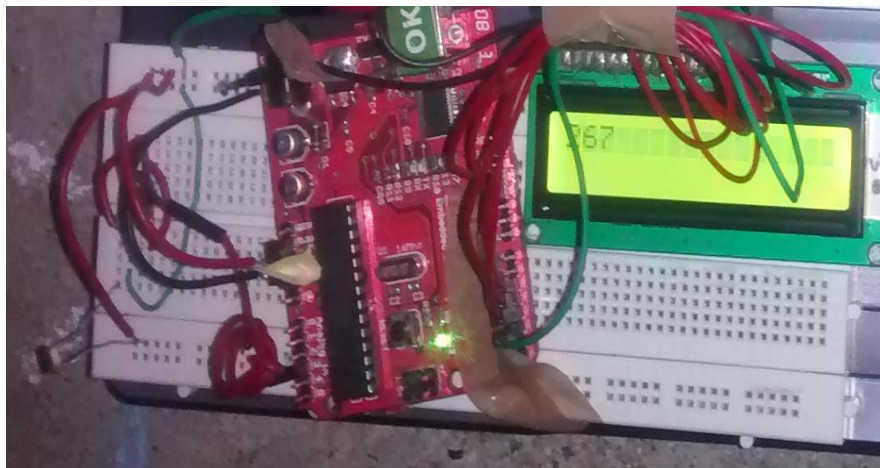


Figure 8 .a. Light intensity output as ADC value displayed in LCD



Figure 8.b. Halogen light beam



Figure 8.c. Xenon light beam

In figure 9, 10 and 11 the X axis is tested points and the Y axis is the ADC values as measured at each point. Figure 11 is direct LUX meter output data measured in the unit LUX. It was clearly shown in figure 9, 10 and 11, the Xenon bulb light output is brighter in many test points and also the phototransistor is efficient to detect the light output measurement [7][10]. The phototransistor is efficient to receive the color output from the Xenon bulb and from a Halogen bulb. But in the case of LDR, it is capable of receiving the yellow output as produced by the halogen.

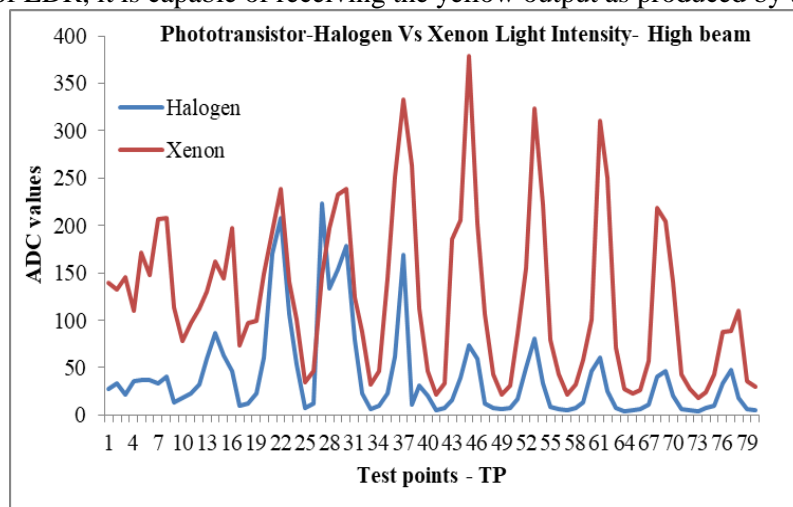


Figure 9. Light intensity comparison for halogen and xenon using phototransistor

The LUX meter output is the direct one presented in the unit of light intensity called LUX. By comparing the results of LDR and phototransistor, the light output values are greater for phototransistor as like LUX meter. This will help to confirm that the ADC values of our hardware design are helpful to measure light outputs.

6. Conclusion

By analyzing all results with these two sensors LDR and phototransistor, it is clear that both the sensors are good to sense the beam pattern of halogen and xenon lights. This conclusion is decided only because of strong correlation in between original lux meter values and sensor circuit values. Also, it is suggested if a lux meter is designed with both LDR and phototransistor under high calibration using sensor fusion technology, the light intensity values are measured with more accurate for halogen, xenon and even LED headlights.

Generally, the wavelength of LDR is 550nm which is considered to use for halogen bulbs and phototransistor's wavelength is 900nm which is good to measure even the headlight's having high intensity and even color radiations in the headlight light beam. Also, it is proven that Xenon is having high-intensity beam pattern under high beam compared to Halogen bulbs.

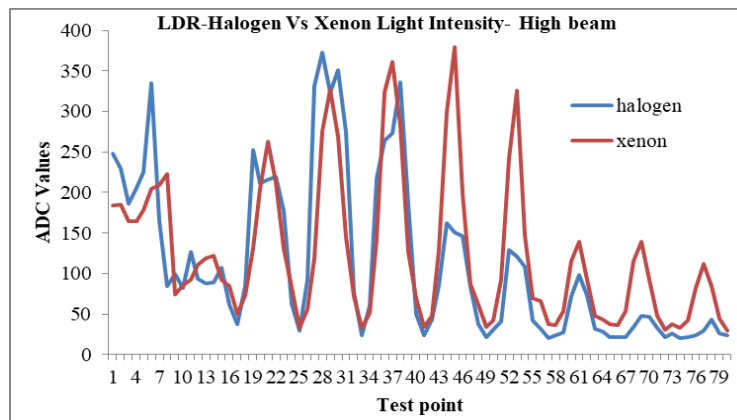


Figure 10. Light intensity comparison for halogen and xenon using LDR

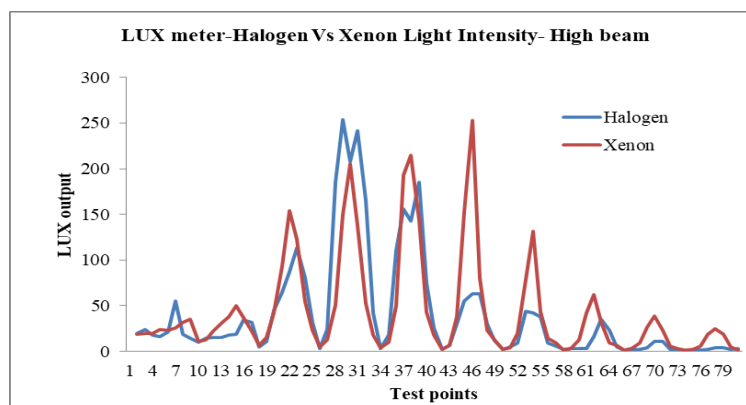


Figure 11. Light intensity comparison for halogen and xenon using LUX meter

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