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Automatic Illuminance Controlling System with Processing and Analyzing Unit for Energy Saving Purpose*

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ABSTRACT

This paper presents the approach for energy saving in lighting system by controlling the illumination in a classroom at a particular intensity automatically during 08.00 am. to 04.00 pm. based on IES as a case study. The electric lighting used to compensate the natural daylight is obtained from 72 Watt fluorescents that are controlled by photo sensor as well as PID controller and PWM circuit. Photo sensor will transform the illumination value as electrical signals to ADC circuit and then transmit these data via RS-232 serial port to computer to create Visual Basic-based database. Finally, the yearly average natural illuminance will be processed and analyzed. Moreover, the estimation of electric lighting use in the future will be also calculated in order to control and reduce the electricity cost.

Keywords : Illuminance, Lighting, Daylight, LDR, Energy and Database

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Introduction

Solar energy is one of the renewable energy resources that is expected to be an alternative way to reduce the use of fossil fuels. Daylight is one form of solar energy that can be used to lighten the buildings in daytime. However, the illuminance in each work area should be considered when lighting system is designed based on environment and nature of work to meet IES (Illuminating Engineering Society of North America) standard. In this research, the combination use of daylight and electric light for illuminating a classroom is examined. The illumination will be set and controlled automatically at a particular level (8 to 3,600 lux). Fluorescent lamps will be used to compensate the light in the room to meet the requirement if only daylight is not sufficient.

Method and Theory

Normally, solar radiation is not stable during daytime due to altitude angle, cloudiness, turbidity and environment, as shown in Figure 1. According to Figure 1, the solar radiation reaching the atmosphere is dependent on time hourly as illustrated in Eq.(1).

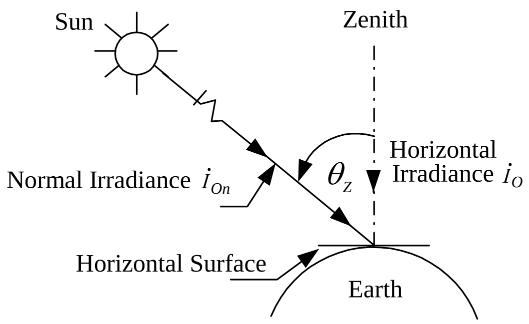

Figure 1. *Relationships of direct solar radiation and altitude angle*

$$\dot{I}_{On} = \dot{I}_{SC}(r_O/r)^2 \quad (1)$$

$\dot{I}_{On}$ is the extraterrestrial irradiance (W/m^2) and $\dot{I}_{SC}$ is the solar irradiance at the average distance between the sun and the earth or solar constant, 1,367 W/m^2. The irradiance respected to the period of time is illustrated in Eq.(2).

$$\dot{I}_O = \dot{I}_{On} \cos\theta_Z \quad (2)$$

The time in hours can be converted to the hour angle as shown in Eq.(3).

$$\Omega = \frac{2\pi \text{ rad}}{24\,\text{h}} = \frac{d\omega}{dt} \qquad (3)$$

Where Ω is the rotational speed of the earth, *dt* is the period of time and ω is hour angle respected to the incident angle of the earth to the sun in degrees. Consideration of the electric illuminance diffusing on the work plane based on Zonal cavity method is the lighting system design in building. The average illumination is demonstrated in Eq.(4).

$$lx = \frac{L}{A} \qquad (4)$$

Where *lx* is the illuminance (lm/m^2), *L* is the luminous flux from lamps (lm) and *A* is the area. In practice, the ratio of luminous flux on work plane and the total luminous flux from lamps should be taken to calculate.

$$lx = \frac{L(CU)}{A} \qquad (5)$$

Where *CU* is the coefficient of use

System Design

In this research, the system is divided into 2 main parts: hardware and software. Hardware consists of the summing amplifier, interface circuit, microcontroller, driver, and computer. For software, Visual Basic is chosen to setup database for analyzing, processing and forecasting the lighting load in future.

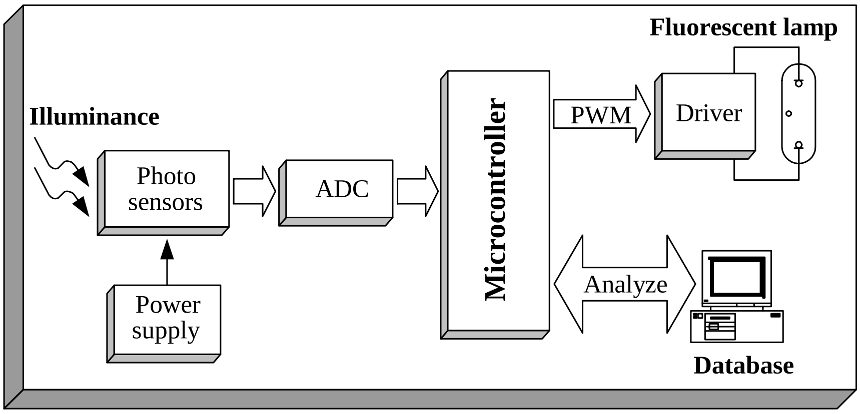

Figure 2. *Block diagram of the system*

Photo Sensor

Due to its high sensitivity, linearity, low price and applicability with electronic circuit, LDR (Light dependent resistance) photo sensor (shown in Figure 3.) is used to measure the intensity. LDR is the passive transducer that requires external supply. The resistance of LDR is varied inversely with the illuminance.

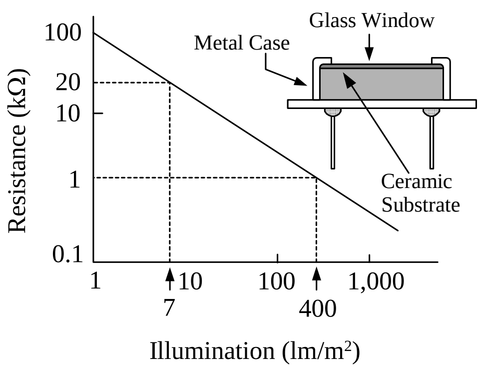

Figure 3. *Characteristic graph and structure of LDR*

Average Illuminance Detector

In order to control intensity effectively, four LDRs are installed in four points of the room to obtain four intensity values. These values will be taken to calculate the average illuminance of the room by using invert summing amplifier as shown in Figure 4.

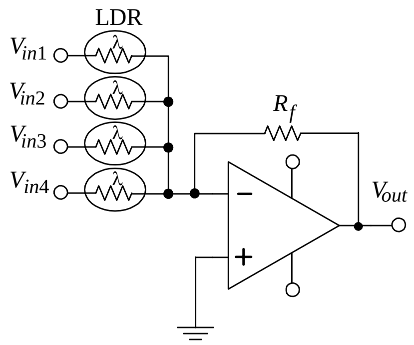

Figure 4. *Invert summing amplifier used with LDR*

The input power supply (V_{in}) is set at 5 Volts. Thus, the output voltage (V_{out}) from this circuit can be written as follow:

$$V_{out} = -\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right] R_f V_{in} \tag{6}$$

Where R_1, R_2, R_3 and R_4 are the resistance values of LDR

Processing Unit

The output voltage from the summing amplifier will be converted to digital signal (ADC) 8 bit 255 levels and then transmitted to microcontroller under two tasks:

- Generate PWM signal (shown in Figure 5.) with 30 % to 100 % Duty cycle and 10 kHz frequency. The 4.5 to 15 volt DC will be supplied to driver in order to increase the current by using TIP142 transistor. DC Ballast is used to drive fluorescent lamp to obtain the suitable intensity respected to the natural daylight illuminance in the room.

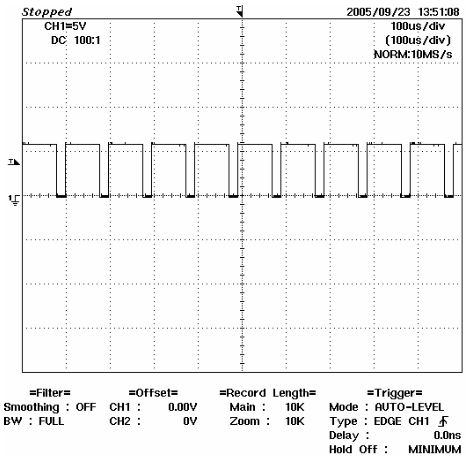

Figure 5. *PWM signal with Duty Cycle 80 % and 12 Volt*

- Receive and Transmit data via RS-232 serial port by setting a required value from computer and send back to microcontroller to process and compare with the voltage from LDR. Then, PWM signal will be generated to control the fluorescent lamp illumination to be constant as specified. Figure 6 is illustrated the use of RS-232 serial port and MAX-232.

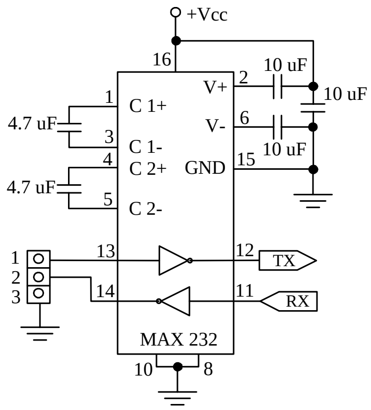

Figure 6. *Interface unit with MAX-232 serial port*

Results

When the light strikes LDR, the resistance of LDR will change inversely respected to the striking light. Figure 7. shows the reduction of resistance when the light strikes LDR by random in the range from 50 lux (≈ 6.9 kΩ) to 2,360 lux (≈ 800 Ω).

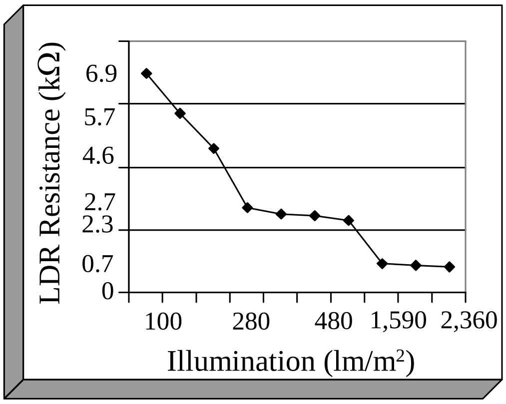

Figure 7. *Relationships of resistance and illuminance*

The output voltage is obtained by measuring average illuminance randomly from invert summing amplifier as shown in Table 1. Constant input voltage is supplied at 5 volts with 5.5 gains and provides the maximum output voltage equals to 5 volts at 3,600 lux. Table 2 represents the relationships of output voltage from control unit and driver used to control the intensity of a fluorescent lamp. From table 1 and 2, the relationships graph at 8 to 3,600 lux with 0.55 to 4.95 volts of average output voltage from summing amplifier and the fluorescent lamp illumination at 80 to 479 lux that uses 1 to 5 volts from control unit are created as shown in Figure 8.

Illumination (lux)	Output LDR (Volt)	Output Summing Amp. (Volt)
3,600	0.900	4.95
2,060	0.820	4.51
1,200	0.814	4.47
800	0.780	4.29
660	0.750	4.12
399	0.720	3.96
250	0.700	3.85
138	0.670	3.68
80	0.640	3.52
32	0.590	3.24
19	0.450	2.47
8	0.100	0.55

Table 1. *Intensity VS Output summing amplifierVoltage*

Output Controller (Volt)	Output Driver (Volt)	Illumination (lux)
5.00	14.58	479
4.50	13.80	455
4.00	11.78	440
3.75	10.76	418
3.50	9.76	409
3.25	8.79	389
3.00	8.06	367
2.75	6.93	325
2.50	6.00	297
2.25	5.00	262
2.00	4.21	225
1.50	2.28	180
1.00	1.25	80

Table 2. *Output voltage VS Fluorescent lamp illumination*

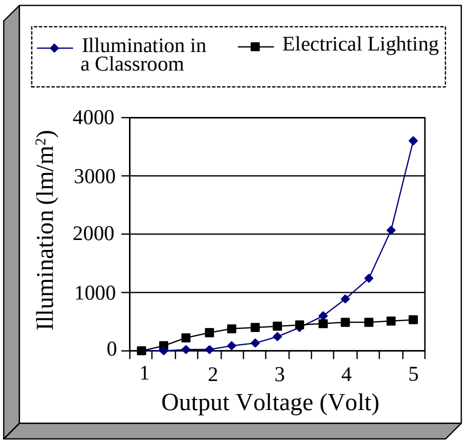

Figure 8. *Relationships of output voltage and intensity*

Summary

From experiments, it is found that the electric light from fluorescent lamps can compensate fluctuating daylight to meet the requirement automatically. Thus, the room illuminance remains constant during work period. Also, annual illumination of natural daylight, the analysis of electricity use, and the forecast of lighting load will be kept and examined that contributes to energy saving in the whole lighting system further when the program is more developed.

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