Design and analysis of the LDR-controlled device

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Abstract. Energy efficiency is important for sustainability. However, efficiency cannot rely on human being as human is forgetful. Many energy applications live on only at night. This paper extracted design and analysis of LDR-controlled device based on MXD-122 existing product. Circuits design contains power supply, sensors, comparator and switching device. As analysis performed, it is revealed that system works only for half wave output. The output current is limited by the maximum current of I_{DSS}. Many resistors cause dropped voltage, which means system efficiency is very low. In order to enhance system for controlling higher current device, it should be connected to contactor.

1. Introduction

Energy crisis is still an issue as increasing demand is not linear to the energy availability. This also happen in Indonesia even though this country has unlimited natural resources. According to major energy supplier, there are still more than 3660 villages unreachable by the electricity [1]. The nation energy body confirms the statement by denoting that the economy development rates about 6.2 percent per year with population increment about 1.49 percent per year requires energy development at least 6.2%. Without significant steps taken by the government and public, Indonesia may import the energy in 2027 [2].

Some reasons that triggering energy crisis indeed exist in this country. Customers hold the important role as many energy usages are inefficiently practiced. Even though the basic electricity price increased from Rp1,392 to Rp1,472.72 per kWh in 2006, and the subsidized price has been eliminated so that users should pay the bill fully, users are still unaware on using electricity efficiently.

On the other hand, energy efficiency cannot count on human awareness as human always forgetful. The efficiency should employ automation such as by using sensors or camera. The previous work examined the use of human presence [3] in order to control electricity usage. Other research also uses passive infrared for detecting human presence and controlling electricity based on the sensor response [4-6]. This paper concentrates on using light depending resistor (LDR) in controlling electrical devices. At this stage, paper observed the light bulb as the controlled device.

Research will explore the design and analysis the existing LDR-based circuit with the market name Muxin MXD-122, then modify the circuit for large current control. However, this paper covers only design and analysis of the observed circuit. This paper will be organized as follows, initial circuit identification is performed at first place, followed by mapping the circuit into blocks and then analyzing each block followed by experimental measurement. Some further steps for controlling larger current will be advised.
2. Circuit Design and Component Identification

Figure 1 shows the circuit design and component identification within the MXD-122 LDR based device controller driven by 220 Volt. Circuits contains of a power supply circuits, light sensor, comparator and switching circuit. The whole system employs electronic components including LDR, resistor, capacitor, diode, mosfet and operational amplifier.

Figure 2 shows the half wave power supply with zener diode as the regulator. Power supply generates sufficient DC voltages to supply operational amplifier and activate the mosfet as switching circuit. Figure 3a shows LDR and comparator circuits. LDR senses the light and adjusts its resistance accordingly. Resistance variation causes input voltage in comparator flipped, as results, operational amplifier produces opposite output voltage. This output triggers switching circuit which is performed by mosfet to either flow or stop current activating the controlled circuit (Figure 3b).

Figure 1. Circuit and component identification

Figure 2. Power supply
3. Circuit Evaluation and Analysis

In order to compare circuit analysis and circuit measurement, evaluation circuit is built as in Figure 4. Circuit contains lightbulb as the load, variable resistor to trim the LDR resistance values and resistors to increase load resistances.

For power supply circuit, the voltage regulator, Zener diode has 4.5 volt. If it is assumed that those diodes D5, D and Z1 has zero internal resistance, then the current flows through R6 and R7 is:

\[-E_1 + I(R_6 + R_7) + V_{D5} + V_z + V_D = 0\]

The measured root mean square (rms) voltage source is 216 volts, which means the peak voltage is \(V_p = \frac{V_{rms}}{0.707} = 216/0.707 = 305.5 \text{ volt}\). Half wave rectifier generates DC voltage \(V_{DC} = 0.318 \times V_p\) which gives 97.15 volt. So, the current flow can be determined by:

\[-E_1 + I(R_6 + R_7) + 0.7 + 4.5 + 0.7 = 0\]

\[I = 1.4 \text{ mA}\]

Based on LDR datasheet, the higher light intensity the smaller the resistance. Measurement shows that when resistance higher than 81.80 kΩ, current flows through the controlled device. If resistance is lower than 16.62 kΩ, the current is off.

Meanwhile, OpAmp produce low \(V_{out}\) if voltage on pin 6 is higher than voltage in pin 5 and so the opposite. Pin 6 input comes from sensor where:

\[V_{pin\ 6} = V_{CC} - V_{sensor}\]

Measurement shows that \(V_{pin\ 6} = 3.43 \text{ volts}\) and \(V_{pin\ 5}\) when \(R_{sensor} = 20k\Omega\) (daylight), so that OpAmp input current is:
The output voltage is 0.02 volts. Vout is 3.59 volt when sensor resistance 350 kΩ (dark). Output voltage is the control voltage for mosfet switch. When $V_{\text{control}}$ is 3.59 volts, current flow through $R_5$ causes gate voltage drops to $V_g = V_{\text{out}} - I.R_5$. Measurement gets $V_g = 0.74$ volt, so the current is:

$$I_{\text{RS}} = \frac{3.59 - 0.74}{47k\Omega} = 0.06 \text{ mA}$$

This current causes bigger current from drain to source activate the controlled device. In Figure 5, current turns to A (not B, ground) as A is more negative than B, but cannot flow in the opposite direction.

**Figure 5.** Control current flow

4. Conclusions
This analysis shows that, the control current is half wave, current flows in one direction as high as the mosfet $I_{DS}$. The maximum controlled device is $0.5 \ V_{\text{AC}} * I_{DS\text{max}}$. In order to control larger current, this circuit requires a contactor. This circuit has high loss. For instance, voltage drops at $R_6$ and $R_7$.

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