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Load current, dropped voltage and size considerations in LDR based light control system

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Load current, dropped voltage and size considerations in LDR based light control system

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Abstract. Energy consumptions are dominated by lighting and air conditioning. Automatic controlling is the solution as human awareness is unreliable. Lighting and air conditioning can be automatically controlled by employing light sensor as well as human existence sensor. Light bulb and street lighting have been widely equipped by light sensor such as the light dependence resistor (LDR). LDR sensor circuit can be made transformer less and transformer based. Transformer less LDR circuit can be integrated into light bulb while transformer based LDR circuit is designed as a standalone device. This paper examines power consumption, load current and circuit size of both LDR circuits. Experiments show that transformer less LDR circuit consumes higher power with limited load current. However, its size is smaller. On the other hand, transformer based LDR circuit consumes less power and provides larger load current. But the challenge is the transformer size to overpower the transformer less circuit.

1. Introduction

Energy availability is continuously being a concern of international development. Electrical supply crisis has been demonstrated by scheduling blackout as well as discontinuing distribution network development. There are more than 3 thousand villages in Indonesia are not served by the electrical network [1]. Meanwhile the alternative source is far for the emerging demands. In fact, energy availability is lagged behind the economic development and the population growth [2]. Solar cell is the most prospective solution as sunlight is available whole the years, however, high temperature in the tropical country increases heat on surface so that the solar cell efficiency is lower [3] besides its high production cost. Other sources like micro-hydro generators are limited for local services.

The promising step is consumer efficient behavior such as by using low energy electrical and electronics equipment as well as energy efficient awareness. Efficiency step is not only performed in high current equipment [4, 5], but also in small current application [6]. However, since human is forgetful, automatic solution is preferred. Sensors assist human in reducing energy consumption by providing automatic detections and disconnections. Human presence detector helps controlling electricity usage [7]. Infrared detection has been widely used [8]. Light depending resistor is one of light sensing devices that are widely used in many applications as it has low price and is easy to use [9].

This paper focuses on the use of the light depending resistor (LDR) as the sensor for controlling light dependant circuits such as light bulb. The main problem when applying the circuit for automatic controlling is to provide DC voltage that drives the controller circuits. It was transformer based power

supply be the main circuit for DC supply. However, transformer size is considered as the main disadvantage that makes circuit size is not preferred. DC supplies focuses on transformer less circuit. However, study shows that such circuits make controller efficiency deteriorates. On the other hand, commercial small size power transformer has been available [10], so that size will no longer be matter. This study compares efficiency on transformer and transformer less LDR circuit for controlling light based automatic device. The two circuits are taken as samples of analysis and compared parameters are power consumption and efficiency [12].

2. Materials and Method

Figure 1 shows a transformer-less LDR controller circuit. This circuit contains of a full bridge rectifier, light sensor, comparator and switching circuit. The system employs LDR, resistors, capacitors, diodes, a mosfet and an operational amplifier.
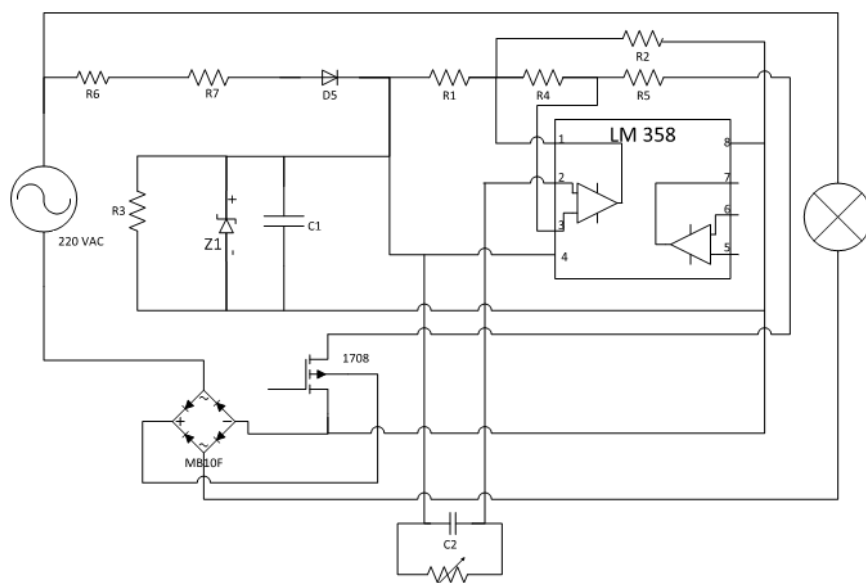
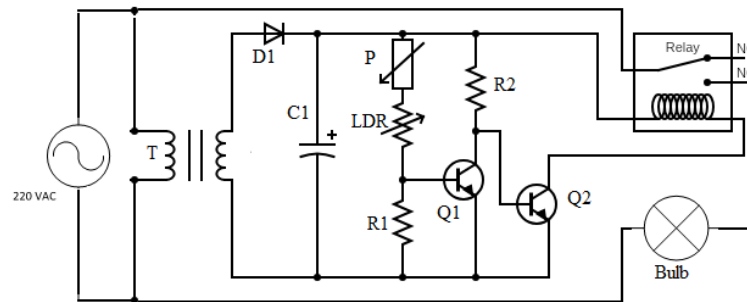**Figure 1.** A sample of transformer less LDR circuit

Figure 2 shows the compared transformer based LDR circuit with half bridge rectifier and three transistors. The switching system uses a magnetic relay. For Figure 1, if zener diode has 4.5 volt, if D_5, bridge diodes and zener diode Z_1 are assumed to have zero internal resistances, then the current flows through resistor R_6 and R_7 is 1.4 mA, taken from Kirchhoff law:

$$I = (E_1 - (V_{D5} + V_z + V_D))/ (R_6 + R_7)$$

In order to compare the performances, circuit implementations, direct measurements as well as mathematical analysis are performed as shown in Figure 2 and Figure 3. Meanwhile for Figure 2, by using a 220 V/12 V transformer, the rectified voltage has been analyzed intensively in [11]. The output voltage can be simplified as:

$$V_{DC} = V_m - V_m/fRC$$

Where Vm is the maximum voltage, f is AC voltage frequency, C is a smoothing capacitor and R is the total load. If the transformer is lossless, than only VDC is taken account into loss calculation.

Figure 2. Sample of transformer based LDR circuit
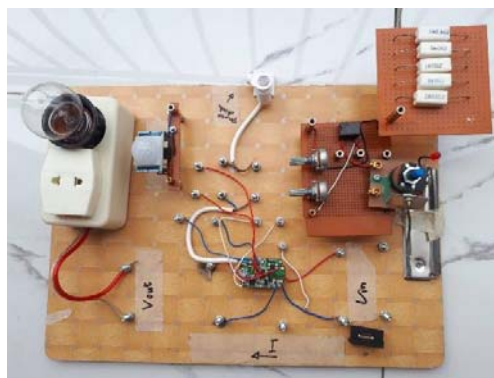
Figure 3. Sample of circuit implementation

Consider that in the worst case, V_{DC} is close to V_m, driving resistance is R_1, Q2 work in maximum relay current, the power consumed by the LDR circuit is given by:

$$P_d = V_m(\frac{V_m}{R_1} + I_{Q1} + I_{relay})$$

3. Results and Discussion

The root mean square (rms) of voltage source is 216 volts, results a peak voltage of 305.5 volt with DC voltage of 97.15 volt for half rectifier. Measurement determines that for LDR resistance higher than 81.80 kΩ, current flows through the controlled device, but does not if resistance is lower than 16.62 kΩ. The operational amplifier produces low voltage if pin 6 has higher voltage than pin 5. During daylight, $V_{pin\ 6}$ is 3.43 V and R_{sensor} is 20kΩ and output voltage is 0.02 volts. During dark hour, Vout is 3.59 V with R_{sensor} 350 kΩ. Operational amplifier output voltage controls mosfet switch. When $V_{control}$ is 3.59 volts, current flow through R_5 causes gate voltage drops to Vg = Vout – I.R_5.

Measurement gets Vg = 0.74 volt, so the current, I_{RS}= (3.59-0.74)/47k=0.06 mA. This current generates higher current flows through from drain to source, activating the controlled device, but cannot flow in the opposite direction. This means the forwarded voltage to load is half wave. The losses on R_6 and R_7 achieve 129.38 mW. Mosfet is the most consuming within transformer less LDR circuit. Its power consumption depends on I_D, which is determined by the load current. Mosfet IRF9540 has internal resistance R_d 0.2 Ohm. With 220 V source and a 20W light bulb as load, mosfet will have current about 1.5 A, which means dropping power up to 466.8 mW in mosfet. The total load resistance is approximately

the parallel combinations of driving resistors (P, LDR, and R_1 in series), current source R_2 and current source of relay. The transistor of Q1 and Q2 is able to work with 2 mA current. Transistor 2N2222 has maximum current 800mA, so that it can work with any types of relay. For instance, 12 V output transformers with 1MOhm R_1, 1000 μF capacitor, Q1 work with 2 mA and relay 12 V has winding resistance of 500 Ohm, the LDR circuit will consume maximum dissipated power of about 312.14 mW. This value has included all components within LDR circuits. This value is still lower than R_6, R_7 and mosfet power consumption in transformer-less LDR circuit (596.18 mW in total). Besides smaller power consumption, load current is fully AC with maximum current limited by relay specification.

4. Conclusions
The analysis and measurement shows that transformer less LDR controller is small enough in size, but only able to drive load with half wave AC and limited current. The circuit consumes power about 596.18 mW for R_6, R_7 and mosfet, not includes other components such as LM358, diodes, and other resistors. Maximum drain to source current of mosfet limits the current flows to load. The advantage is size reduction that makes circuit is small enough to be inserted in controlled devices such as the light bulb. On the other hand, transformer based LDR controller consumes less power about 312.14 mW for all components. The current flow to load is fully AC, limited only by the relay specification. The primary challenge is transformer and relay sizes.

Acknowledgement

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