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Intelligent Control of Electrical Power Consumption and Wastage in University of Benin Lecture Theatres

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ABSTRACT

This paper investigates electrical power consumptions and wastages in lecture theatres (LTs), drawing offices (DOs) and laboratories of the University of Benin, Benin City, Nigeria. It identifies one major source of electrical energy wastage; lightings and fans in the lecture theatres and laboratories remaining on in the absence of students, technicians, technologists and lecturers. The aim of this work is to design an intelligent system to control the lightings and fans in the lecture theatres and laboratories, analyse the amount of electrical energy consumed with and without the intelligent system and calculate the energy wastage. The system turns on lightings and fans within the section in the LT where there are persons while lightings and fans in other areas remain turned off. The intelligent system was designed using PIC16F877A microcontroller, Passive Infra-Red (PIR) motion sensors, relays, energy saving bulbs and the code was written using MicroC Pro.

1. Introduction

The Nigerian power sector which was formally pivoted by The Power Holding Company of Nigeria (PHCN) was fully privatized and ceased to exist on the 30 September, 2013. In its stead, the Nigeria Electricity Regulatory Commission (NERC) with the authority for the regulation of the electric power industry in Nigeria was formed. With this recent privatization of the Power Holding Company of Nigeria by the Federal Government, and subsequently unbundling it into eighteen (18) successor companies of power generation (Gencos) and power distribution (Discos), Nigeria's power sector is expected to benefit from a major paradigm shift of constant power supply service [1]. At this point one can infer that these private companies who now run the power sector would need to come up with an avenue to recoup their investments with interest and the best way to do so is via increases in their tariff plan. Moreover, electricity-generating capacity in Africa with respect to the population is low [2] and Nigeria's energy demand has increased much more rapidly than its population [3], consequently there is need for an efficient power management system to manage electrical power consumption, minimize power wastage and reduce cost of electricity tariffs. A power management and control system such as the intelligent control of electrical power consumption and wastage in lecture theatres, University of Benin will save the day by reducing the pinch of this tariff on our pockets. This intelligent system can also be applicable in our homes, industries, offices, halls and factories since sufficient and constant energy providing is an important condition of national economy development [4]. In general, energy efficiency in Nigeria is very poor both in domestic and commercial usage [5]. Electrical energy utilization in Nigeria is far from being efficient [6]. A lot of energy is wasted in Nigeria because households, public and private offices and industries use more energy than is actually necessary to fulfill their needs [7]. Having this in mind, the Intelligent Control of Electrical Power Consumption and Wastage in Lecture Theatres, University Of Benin was conceived, designed and implemented as it removes the need for manually switching on/off of lighting points and fans on entry/exit into a particular lecture theatre or laboratory. Most consumers are unaware of their electric power consumption and this leads to electric energy wastages in their daily life. The focus of this study is to bring to the awareness of the consumers the use of smart and intelligent systems in the reduction of electricity tariff, and also to find alternative ways in reducing the wastage of electrical power consumption. This research is based on the reason that if all the electrical appliances (lightings and fans in lecture theatres as case study) in all the consumers' premises in the country were to be turned on at the same time, it would be impossible for the utility companies like the Discos to supply enough energy necessary to run all these appliances. This makes it more imperative for proper control of consumers' loads to avoid energy wastage and excessive tariff billing. Intelligent control of electrical power consumption and wastage in lecture theatres conditions power supply to the lighting points and fans in lecture theatre, home, hall or office. It manages power consumption with the following functionalities: turns on fans and lighting points in a particular location in the lecture theatre where there are individuals, turns off fans and lighting points in any location in the theatre where there is nobody and eventually turns off all fans and lighting points in the absent of no one in the lecture theatre or hall.

2. Materials and Method

This study is about power management at lecture theatres within the Faculty of Engineering, University of Benin, Nigeria. The old 1000 lecture theatre (old 1000LT) measuring 39.62m by 20.11m, new 1000 lecture theatre (new 1000LT) measuring 34.14m by 20.42m, drawing office one (DO1) and drawing office two (DO2) and both measuring 27.74m by 12.80m will be used as case study.

2.1 Hardware Module

In the control system, once any person enters the lecture theatre (LT) or DO, the infrared (IR) light radiating from the person's body is detected by the PIR sensor within the range where the individual is. The PIR sensor outputs a TTL value of 3.3v [8]. This value is compared with a reference value of 2.5v via LM358. Once the output from the PIR sensor is greater than a set reference voltage of 2.5v, the comparator outputs a logical one (5v) to the microcontroller unit (MCU). Once this is done, the microcontroller therefore activates the corresponding relay which turns on the appropriate lighting and fan within the lecture theatre or DO. The MCU continues to monitor the sensors' outputs through LM358 and triggers the necessary relays that eventually turn on the necessary lightings and fans base on the presence of individuals in the LTs or DOs.

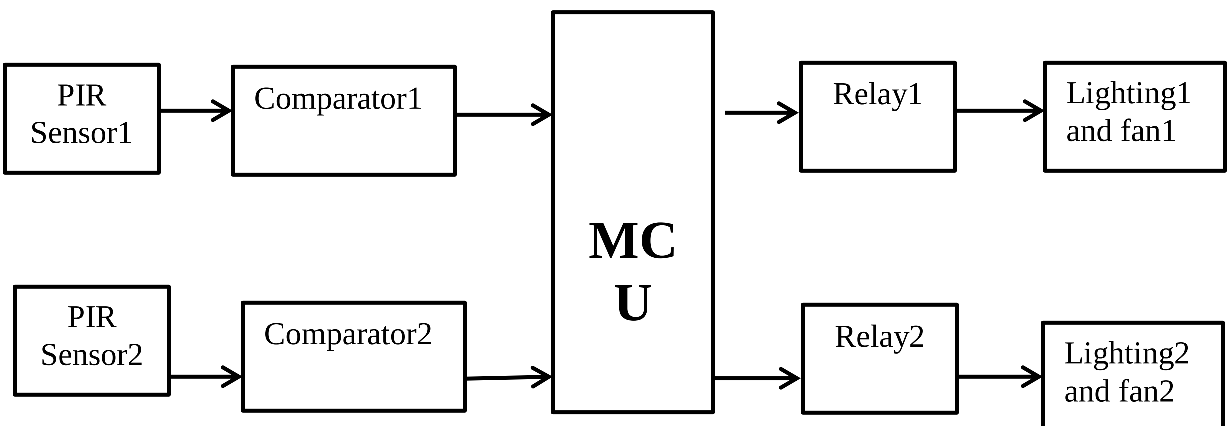

Fig. 1: Block Diagram of Hardware Module

2.2 Power Supply Circuit Design

This is the circuit that will supply power to the sensory unit, control unit and relays. The sensory and control units require 5volts dc and the relays require 6volts dc input supply. The circuit diagram is as shown in Fig.2.

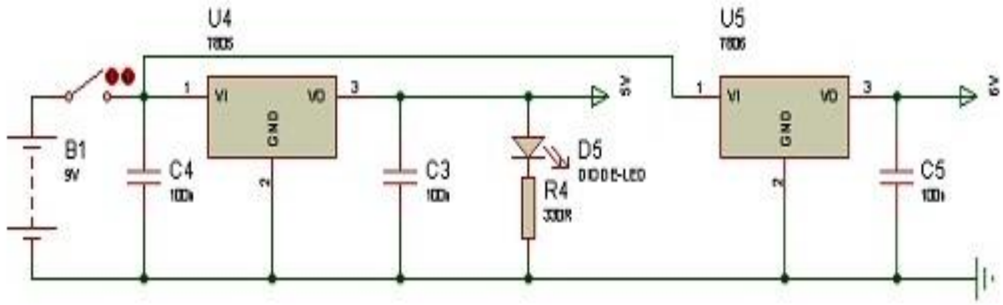

Fig. 2: Power Supply Circuit Diagram

U4 (7805) and U5 (7806): LM78xx voltage regulator specifications from datasheet:

- Input voltage range for 7805: V_{in} = 7.5v~20v and for 7806: V_{in} = 8.5v~21v
- Output voltage range for 7805: V_{out} = 4.75v~5.25v and for 7806: V_{out} = 5.7v~6.3v

The 9v battery is enough to supply the minimum input voltage for the system. C_3 and C_5 are transient capacitors and their rating as stipulated in the 78xx voltage regulator's datasheet as 0.1uf [9]. These capacitors help for smoothening of the output from the voltage regulators.

Current limiting resistor calculation:

$$R_4 = \frac{V_{out} - V_D}{I_D} \quad (1)$$

V_{out} = Output voltage of regulator

V_D = Voltage drop across diode

I_D = Forward current of LED

Light emitting diode (LED) characteristics:
Forward current of LED = 10mA and voltage drop = 2v [10]. Therefore

$$R_4 = \frac{5 - 2}{10 \text{ x } 10^{-3}}$$

$$R_4 = 300\Omega$$

Therefore, resistor value used is: 330Ω

2.3 Sensor Detection Circuit Design

The sensory unit is composed of the PIR, comparator (LM358) and a 10kΩ potentiometer. The PIR motion sensor is an electronic sensor that senses or measures infrared light radiating from objects in its field of view. It has a sensing range of less than 120 degree within a distance of 7 meters maximum. This distance can be adjusted with the distance potentiometer to a minimum of about 3 meters [8]. It has three pins; the middle pin is the output, the right positive pin (pin1) is Vcc while the left negative pin (pin3) is ground (Gnd). The PIR sensor detects infrared wavelengths which are emitted by any object with a temperature above absolute zero. This infrared is a form of radiation which is invisible to the human eye. The sensor outputs a high voltage level of 3.3v when infrared is detected and a low voltage of 0v in the absent of infrared radiation [11]. The 10kΩ potentiometer is used to set a reference voltage for the comparator. The inverting input of LM358 is set at the middle of the 10kΩ potentiometer such that the reference voltage is giving as:

$$V_{ref} = \frac{5 \text{ X } V_s}{10}$$
$$V_{ref} = \frac{5 \text{ X } 5}{10}$$
$$V_{ref} = 2.5V$$

Once the sensor detects or senses the presence infrared wavelength emitted from persons within the set range in the LT or DO by adjusting the distance potentiometer on the sensor. This distance can be set to 3-7 meters. For proper range management within the LT, the distance potentiometer will be adjusted so the sensor can accommodate a range of 5meters. The high voltage level output of 3.3v is fed to the non-inverting input of the comparator LM358, which compares it with the reference voltage of 2.5v fed to the inverting input of LM358. As long as the 3.3v output from the PIR sensor is greater the reference voltage of 2.5v, the comparator outputs a logic one (5v) to the PIC16F877A.

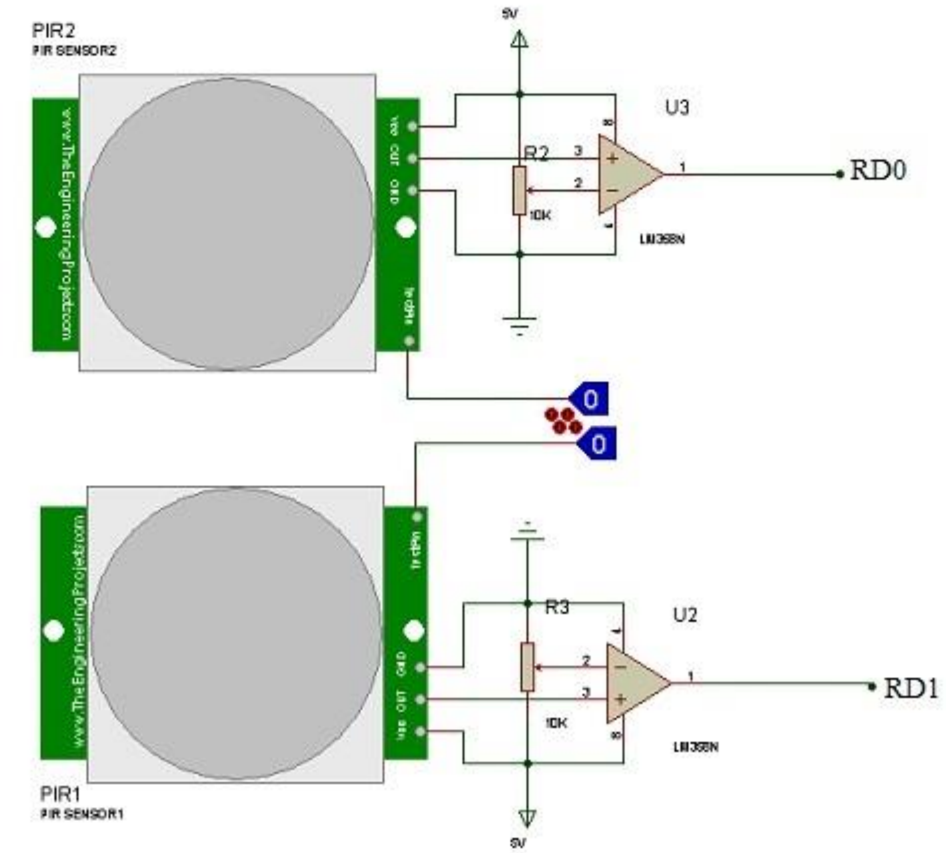

Fig. 3: Sensor Detection Circuit Design

2.3 Control Circuit Design

This is the heart of the Intelligent Control of Electrical Power Consumption and Wastage in Lecture Theatre and it is design using PIC16F877A. The PIC microcontroller hardware circuit is usually very flexible and all the surrounding components are given a recommended range of values from the datasheet. The ranges of values given for the PIC microcontroller hardware are as follows [12]:

- Reset resistor: 8.2KΩ to 15 KΩ
- Crystal oscillator: 4MHz to 32MHz
- Crystal capacitors: 20pF to 47pF

For the design, the following values were chosen:

- Reset resistor (R_1): 10 KΩ
- Crystal oscillator: 12MHz
- Crystal capacitors (C_1 & C_2): 33pF

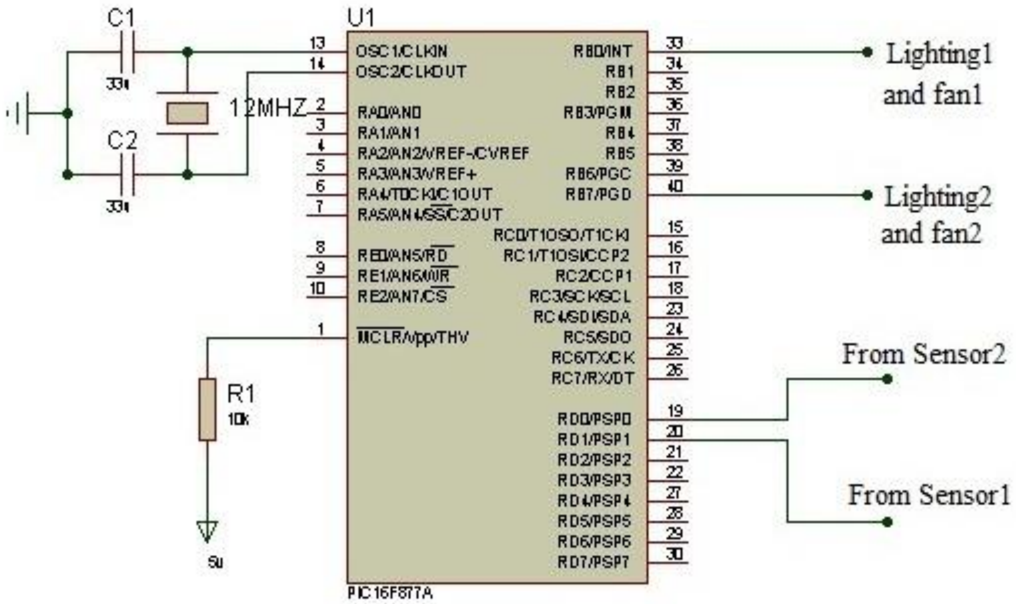

Fig. 4: Control Circuit Design

The control unit receives a logic one from either sensory unit 1 or unit 2. If the logic one is from sensory unit 1, lighting1 and fan1 are turned on while lighting2 and fan2 are turn on when a logic one is received from sensory unit 2. It is worth noting that when the person within the range of the sensory unit 1 leaves that section and goes to the another section within the LT covered by sensory unit 2, lighting1 and fan1 associated with sensory unit 1 go off and lighting 2 and fan 2 associated with sensory unit 2 come on. The MCU continues to monitor both sensory units to determine whether there is any person in the LT or not.

2.4 Lighting Circuit Design

The section is composed mainly of 10k resistor, BC547 transistor, relay, energy saving bulbs and a 220V main supply.

From relay datasheet:

- Maximum switching current is 10A
- Maximum switching voltage is 250VAC
- Coil resistance = 160Ω
- Operating voltage = 6V

Therefore relay coil current:

$$I = \frac{6}{160} = 0.0375 = 37.5\text{mA}$$

From BC547 Datasheet:

$I_C > 37.5\text{mA}$, $V_{CEO} > 6V$ and $h_{fe} = 75$

$$I_b = \frac{I_c}{h_{fe}} = \frac{0.0375}{75} = 0.0005 = 0.5\text{mA}$$

$$R_1 = R_2 = R_b = \frac{v}{I_b} = \frac{5}{0.5\text{mA}} = 10{,}000 = 10\text{k}\Omega$$

Where (v = 5) is the output voltage from PIC16F877A. Either from pin 0, port b or pin 7, port b.

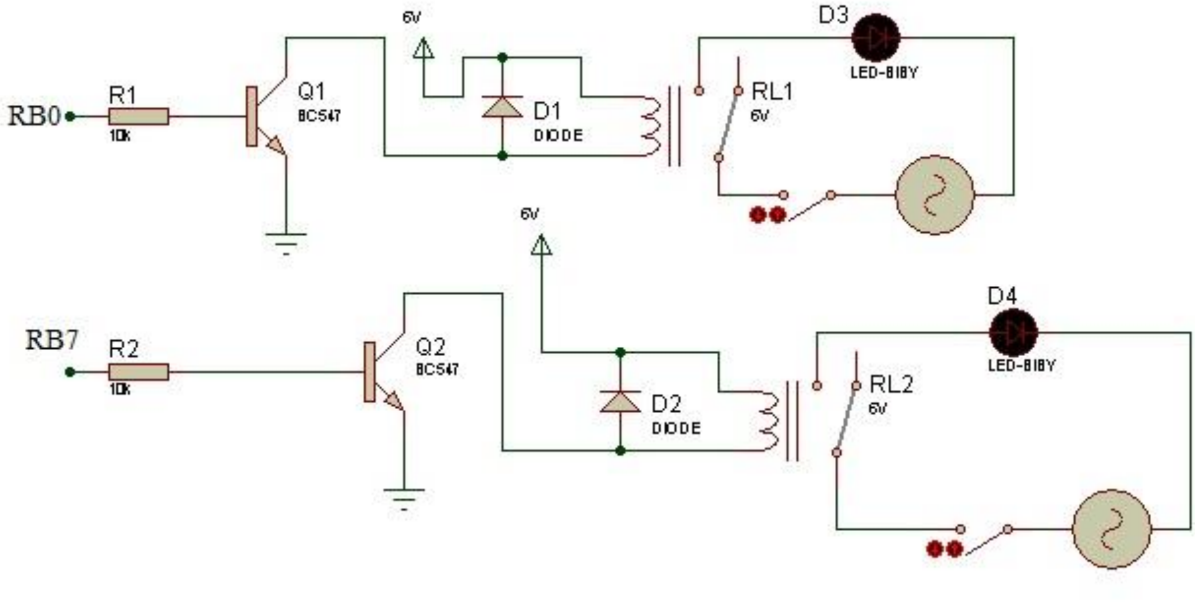

Fig. 5: Lighting Circuit Design

The relay is activated or deactivated with the aid of BC547. All switches in the LT are closed and as far there is no person in the LT, the energy saving bulb remain turned off. Once the intelligent system detects human motion with the LT, the MCU triggers the relay via the BC547. This equally turns on the energy saving bulb within that section.

2.5 Software Implementation of System

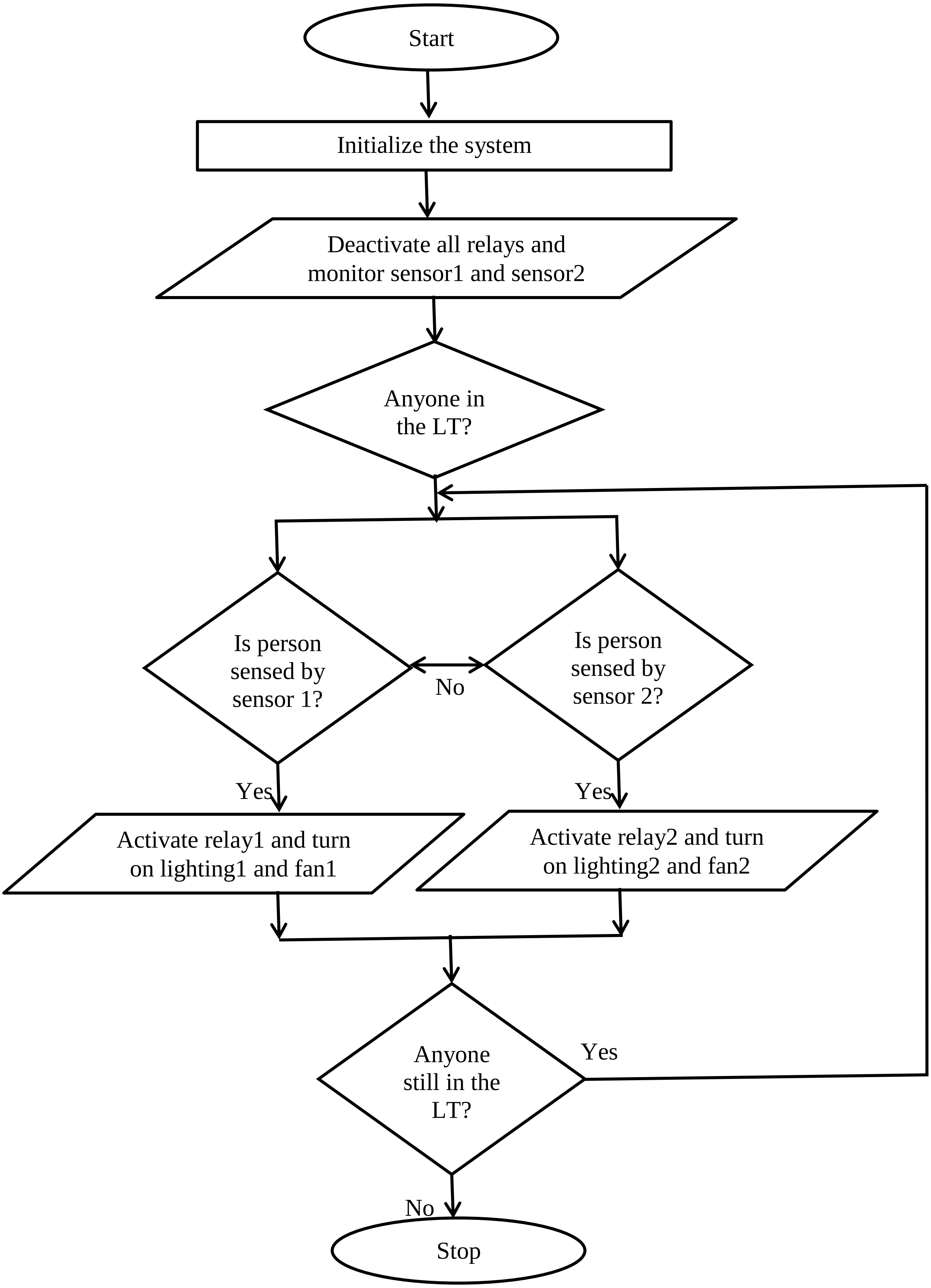

Fig. 6: Program flowchart

3. Results and Discussion

The complete design was first simulated in Proteus and found to be working satisfactorily before the final implementation. Fig. 7 shows the final hardware setup.

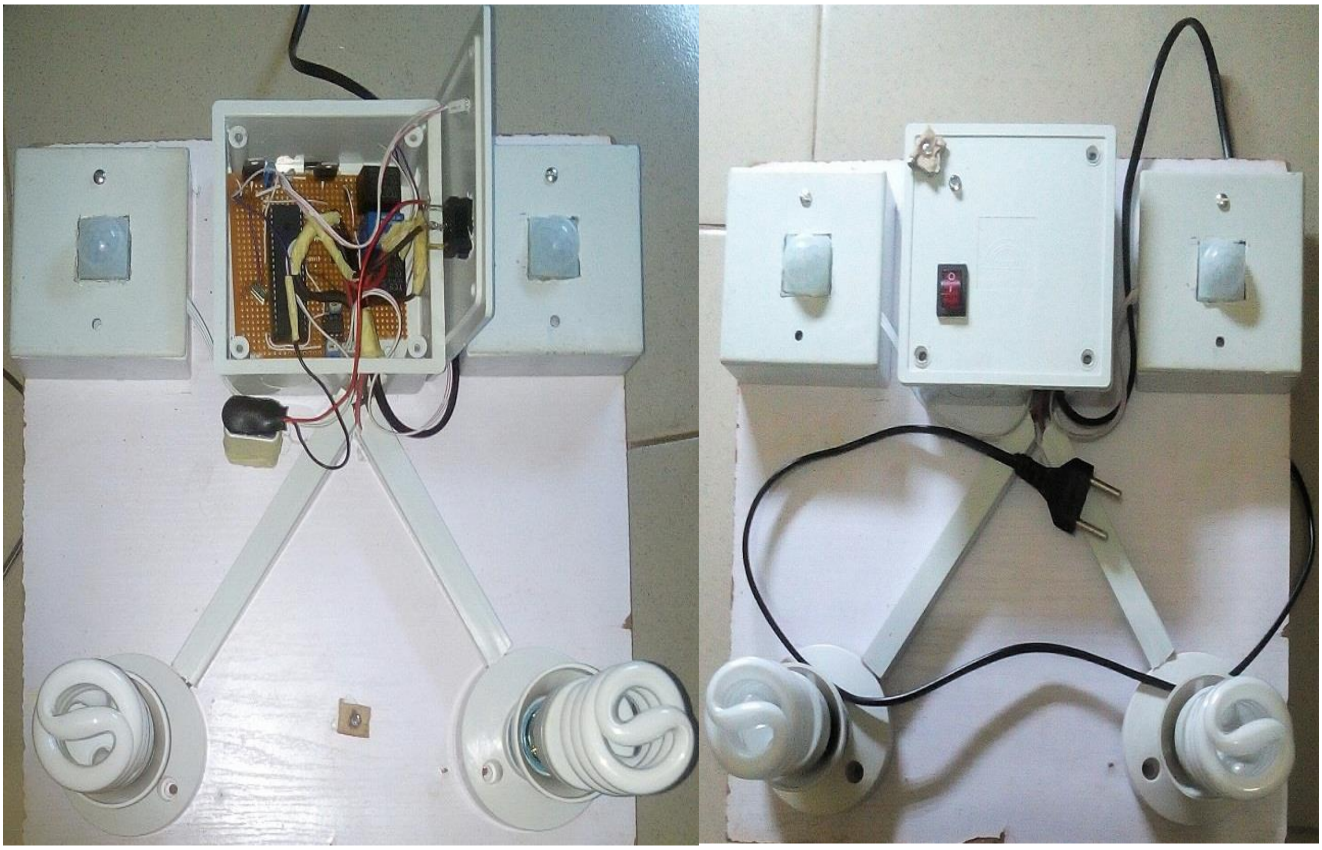

Fig. 7: Hardware setup

The prototype was tested with persons at various locations of the sensors and below are the results:

a) Someone at sensor location one and result: when someone goes close to sensor one, the light associated with sensor one turns on as shown in Fig.8.

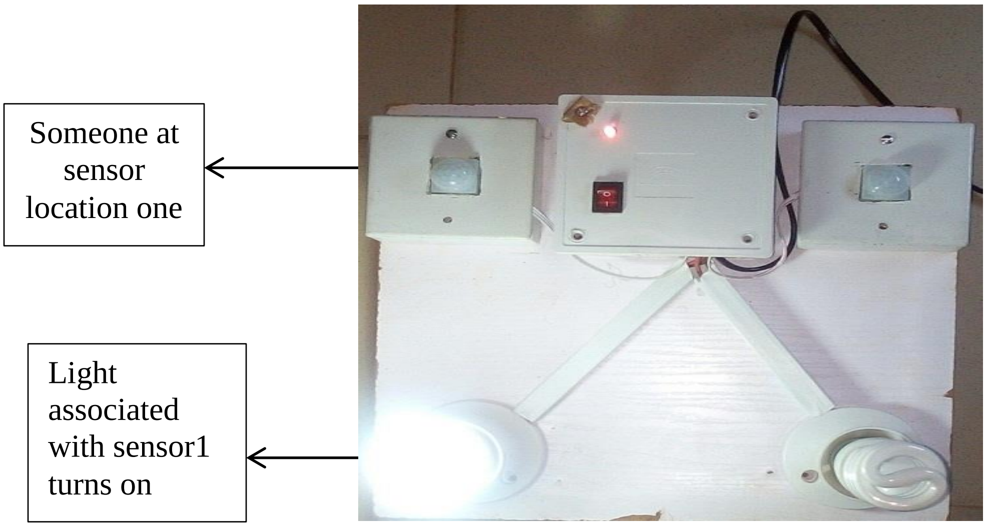

Fig. 8: Someone at sensor location one

b) Someone at sensor location two and result: when the person leaves the region covered by sensor one and moves to region covered by sensor two, the light associated with sensor one goes off and that which is associated with sensor two turns on as shown in Fig. 9.

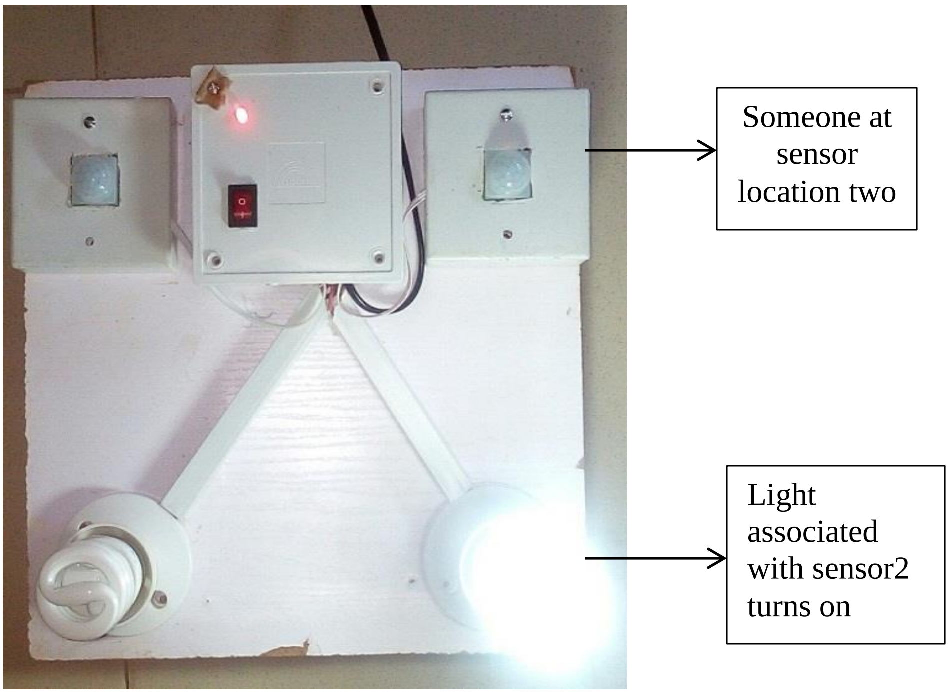

Fig. 9: Someone at sensor location two

c) Persons at sensor location one and two and result: when persons are within the locations covered by sensor one and sensor two, the lights associated with both sensors are turn on as shown in Fig. 10.

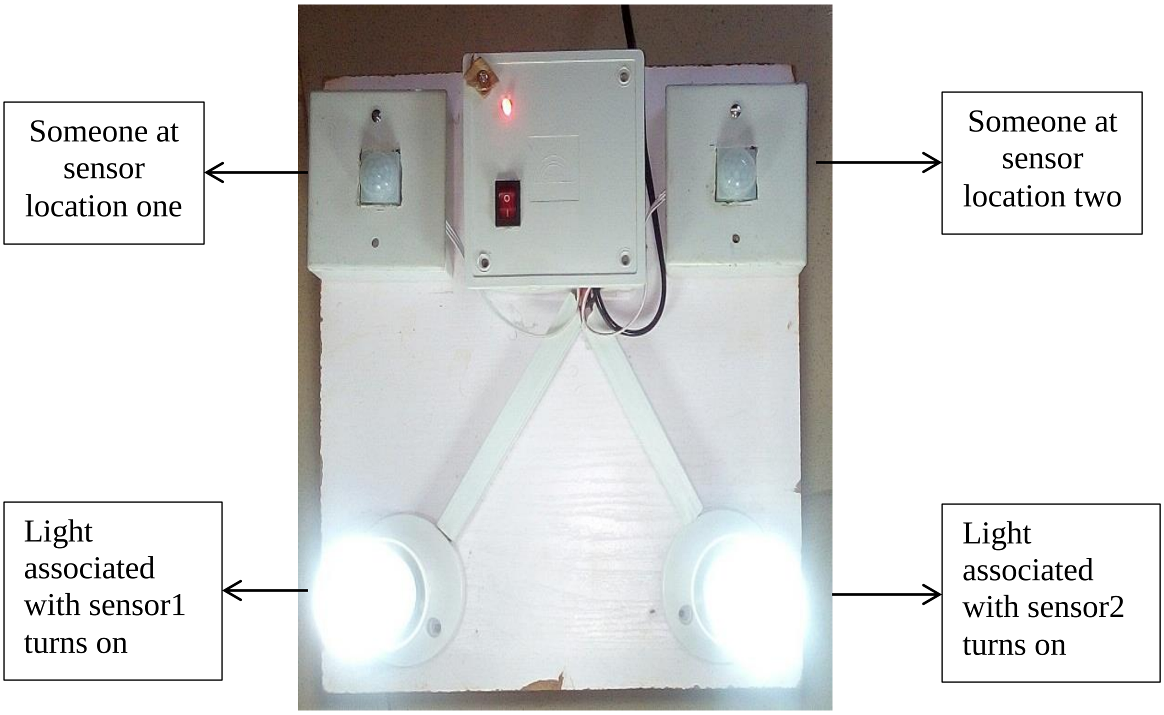

Fig. 10: Persons at sensor location one and two

Using the LTs and DOs as case study and analysing power consumed by the lightings and fans.

Number of energy saving bulbs in DO1 - 40

Number of ceiling fans in DO1- 12

Number of energy saving bulbs in DO2 - 40

Number of ceiling fans in DO2 - 12

Number of energy saving bulbs new 1000 LT - 72

Number of ceiling fans in new 1000 LT - 26

Number of energy saving bulbs old 1000 LT - 55

Number of ceiling fans in old 1000 LT- 56

Therefore total energy consume is analysed as follows:

According to the Environmental Protection Agency, typical wattage of bulb and fan are:

Energy saving bulb - 40watts

Ceiling fan- 100watts

Assuming the loads worked for a period of 10hours a day and the LTs and DOs are opened five (5) days a week. Therefore:

Energy consumed in each DO without the intelligent device:

$$\text{Energy} = [(40 \times 40 \times 10) + (12 \times 100 \times 10)]$$

$$\text{Energy} = 28{,}000\text{watt} - \text{hours per day}$$

$$\text{Energy} = 28\text{kWh per day}$$

Energy consumed in each DO for a period of one month,

$$\text{Energy} = 28 \times 20 = 560\text{kWh per month}$$

Energy consumed in new 1000 LT without the intelligent device:

$$\text{Energy} = [(72 \times 40 \times 10) + (26 \times 100 \times 10)]$$

$$\text{Energy} = 54{,}800\text{watt} - \text{hours per day}$$

$$\text{Energy} = 54.8\text{kWh per day}$$

Energy consumed in new 1000 LT for a period of one month,

$$\text{Energy} = 54.8 \times 20 = 1{,}096\text{kWh per month}$$

Energy consumed in old 1000 LT without the intelligent device:

$$\text{Energy} = [(55 \times 40 \times 10) + (56 \times 100 \times 10)]$$

$$\text{Energy} = 78{,}000\text{watt} - \text{hours per day}$$

$$\text{Energy} = 78\text{kWh per day}$$

Energy consumed in old 1000 LT for a period of one month,

$$\text{Energy} = 78 \times 20 = 1{,}560\text{kWh per month}$$

With the intelligent device and assuming there is an in/out flow of persons at different intervals within the 1000 LTs and DOs and this brings down the cumulative working time of all the loads to 6hours per day on an average.

Therefore energy consumed in each DO with the intelligent device:

$$\text{Energy} = [(40 \times 40 \times 7) + (12 \times 100 \times 7)]$$

$$\text{Energy} = 19{,}600\text{watt} - \text{hours per day}$$

$$\text{Energy} = 19.6\text{kWh per day}$$

Energy consumed in each DO for a period of one month,

$$\text{Energy} = 19.6 \times 20 = 392\text{kWh per month}$$

Energy consumed in new 1000 LT with the intelligent device:

$$\text{Energy} = [(72 \times 40 \times 7) + (26 \times 100 \times 7)]$$

$$\text{Energy} = 38{,}360\text{watt} - \text{hours per day}$$

$$\text{Energy} = 38.36\text{kWh per day}$$

Energy consumed in new 1000 LT for a period of one month,

$$\text{Energy} = 38.36 \times 20 = 767\text{kWh per month}$$

Energy consumed in old 1000 LT with the intelligent device:

$$\text{Energy} = [(55 \times 40 \times 7) + (56 \times 100 \times 7)]$$

$$\text{Energy} = 54{,}600\text{watt} - \text{hours per day}$$

$$\text{Energy} = 54.60\text{kWh per day}$$

Energy consumed in old 1000 LT for a period of one month,

$$\text{Energy} = 54.60 \times 20 = 1{,}092\text{kWh per month}$$

Table 1: Results of the analyses of energy consumed with and without the intelligent device and energy conserved

Venue	Energy consumed without the intelligent device per month	Energy consumed with the intelligent device per month	Energy conserved in using the intelligent device per month
DO1	560kWh	392kWh	168kWh
DO2	560kWh	392kWh	168kWh
New 1000 LT	1,096kWh	767kWh	329kWh
Old 1000 LT	1,560kWh	1,092kWh	468kWh
Total	3776kWh	2643kWh	1133kWh

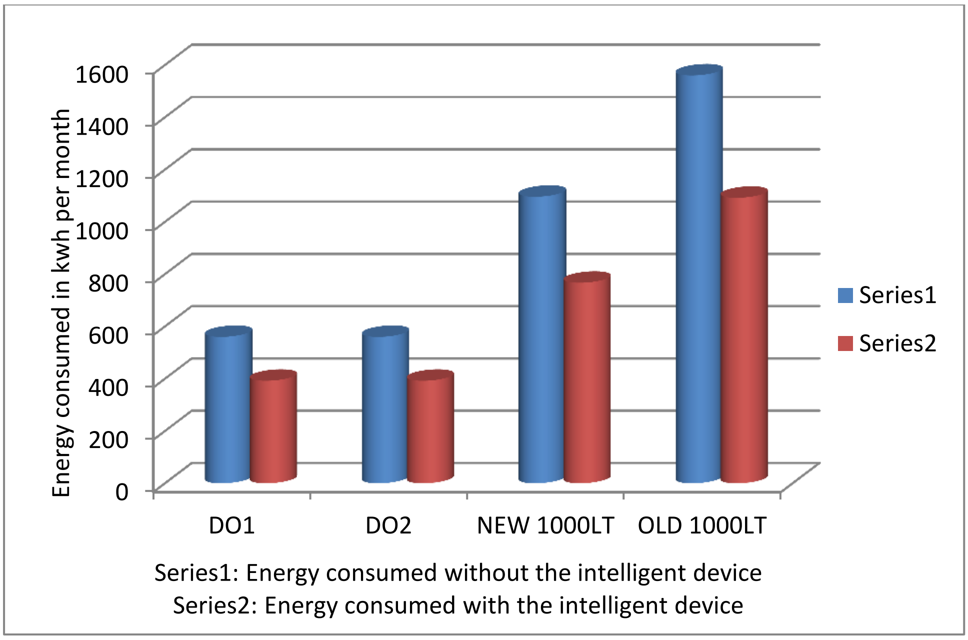

Fig. 11: Energy consumed with and without the intelligent device

The difference between the energy consumed without the intelligent device and energy consumed with the intelligent device is quite noticeable from Table 1, and one can infer the effectiveness of the intelligent device.

The strength of the proposed design lies in its ability to monitor each section of the LTs and DOs irrespective of their sizes. One major advantage it has over other designs is its ability to monitor a person in the region covered by sensor one and turns on the appliances in that region and once the person leaves that region for the region covered by sensor two, it turns off the appliances within the region covered by sensor one and turns on the appliances within the region covered by sensor two as observed in Fig. 9.

4. Conclusion

This paper presents the design and construction of a very low cost power management system that minimizes power consumption and reduces power wastages, thereby reducing electricity tariff. The system is also very efficient in automating ON/OFF of electrical appliances in theatres, halls, homes, churches and schools.
It is a kind of power management system that controls excessive power wastages. This device will be of immense importance in a country like Nigeria with epileptic power supply and rational in power distribution. At the present, the country is battling with power generation which has led to power rational in different metropolises, some with 3 hours on, 6 hours off and vice visa. So if homes and schools can apply the device, this will go in a long way to reduce power consumption and wastage, thereby maximizing power usage.

5. Acknowledgement

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6. Conflict of Interest

There is no conflict of interest associated with this work.

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