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Design, Implementation and Development of an Intelligent Floodlight Control System

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Abstract

This paper considers the design, implementation and development of an intelligent floodlight control system based on P1C18F4520 microcontroller. Unlike traditional floodlight systems that simply use a sensor to determine when to switch on or switch off, the system is designed to automatically switch on and off at a predetermined time or with daylight. Also an intelligent back-up to cater for the possible failure of any one of the main floodlights is provided to ensure guaranteed coverage. The back-up floodlight is positioned at a centralized location and mounted on a moving shaft that is controlled by a stepper motor. The system monitors the light sensors attached to the lighting points and sends drive pulses to control the stepper motor. The system worked satisfactorily as it was able to put the lights on at the preset time and move the backup light to the position of a failed light source.

1.0 Introduction

Floodlights or outdoor lights are installed to serve two purposes; firstly, they serve as a means of ensuring security as they dissuade unwanted visitors by keeping entryways bright at night, and secondly, as a source of illumination making it easier to navigate drive-ways and paths in the dark. Traditional floodlight system designs employ switches that need to be operated by a user [1], [2], [3], [4]. However, when the user is not available to fulfill this function, the goal of having the floodlight is defeated. In addition, a common problem with floodlight system is lamp (light) failure which may mar proper lighting of the intended area. Hence, arrangements must be put in place for backup in the event of any floodlight failure. Most homes, company premises, campuses and public areas lack good floodlight switching and backup system, which has led to unwanted crime in such areas.

This work considers an automatic floodlight control system that eliminates the need for an individual to always be present in order to switch on or switch off the floodlight units. A noteworthy advantage of the automatic switching is the illusion of constant presence by homeowners even when the homeowner is not present, thus serving as deterrents to unwanted visitors. In addition, so as to always ensure full light coverage, a centralized floodlight with intelligent motion control, which can automatically switch on/off and focus its light in the direction of a failed floodlight is employed improving the overall efficiency and reliability of the system. The floodlight system design incorporates four floodlight units arranged at four corners of a rectangular shaped premise with a fifth light source as backup placed at the center of the premise. Figure 1 shows the block diagram for the system.

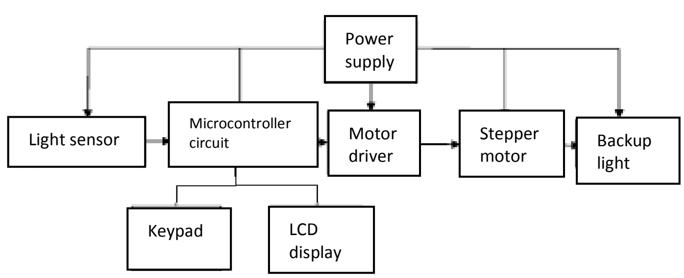

Fig. 1. Block diagram of the back-up floodlight system

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2.0 Design Analysis

A. Design Specifications

The design is categorized into the following stages:

1) **Power supply:** The circuit needs a power supply of +12V to drive the stepper motor and +5V for the microcontroller circuit [5]. The circuit employs a transformer with a root mean square voltage (V_{rms}) of 24V. Thus the rectified output voltage of the circuit and the peak inverse voltage (PIV) rating of the silicon diodes to be used in the rectification circuit can be calculated from eq. (2) and eq. (3). The forward voltage drop (Vb) for the silicon diodes is 0.7V.

Peak voltage (V_p) = $\sqrt{(2)}$ x V_{rms} = 33.9V (1)

Rectified output voltage = $V_p - 2V_b$ = 32.5V (2)

Diode PIV rating = $V_p - V$ = 33.2V (3)

2) **Microcontroller:** The microcontroller handles the control stages of the circuit. The microcontroller monitors all the other components and whenever it receives a light-off signal from any sensor, it sends pulses to control the stepper motor [6] so that the bach up light source can illuminate the dark region. The microcontroller used for the design is the P1C18F4520 by Microchip [6], [7], [8], [9].

3) **Keypad:** The circuit uses a 3x2 matrix key arrangement.

4) **Light sensor:** A light dependent resistor (LDR) with resistance values listed in Table I is used as the light sensor [5]. As shown in figure 3, the LDRs are

TABLE I
LDR VALUES

Dark resistance	2.3MΩ
Light resistance	380Ω (at full day light)

connected in series with variable resistors to form voltage dividers. This results in output voltages (V8) that depend on light intensity as shown in eq. (4).

$$V_s = \frac{R}{R_s + R} V_{cc} \tag{4}$$

Where V_{cc} is the supply voltage to the voltage divider circuit, R8 is the sensor resistance and R is the resistance of the variable resistors as in figure 3. By choosing R = 10K, V_s = 3.5V (minimum voltage for a TTL logic high), and V_{cc} = 5V, the sensor resistance required to produce a TTL logic high can be computed as shown in eq. (5).

$$R_s = \frac{V_{cc} - V_s}{V_s} R = \frac{5 - 3.5}{3.5} 10000 = 4284\Omega \tag{5}$$

5) **LCD screen:** The output utilizes a GYM16O2A liquid crystal display (LCD), which is driven by the microcontroller using ASCII information [8]. The GYM1602A model is a 16x2 character screen type and is powered by a +5V power supply [5].

6) **Motor driver/actuator:** The circuit incorporates a unipolar stepper motor and a set of N-channel mosfets (1RF3205) in the motor control circuit. The function of the mosfets is to switch current through the coil of the stepper motor [10].

7) Power control: This stage consists of a transistor and relay circuit that switches power to the backup light whenever darkness is detected.

B. Operational Principles

The flowchart and complete circuit diagram of the automatic floodlight control system are presented in figure 2 and figure 3, respectively. The circuit is controlled by the P1C18F4520 microcontroller [11], which uses the transistor-relay switches, Trl-RLY1 and Tr2RLY2, to switch the backup light and the security lights respectively by sending control pulse to them. The microcontroller sends the control pulse based on two conditions which are [9]:

- presence of darkness.
- pre-programmed time for switching the lights.

The microcontroller monitors LDR5 voltage divider network with R5 for a low level or zero logic state that is indicative of darkness or low light intensity [12]. When the microcontroller detects a zero logic state, it checks the

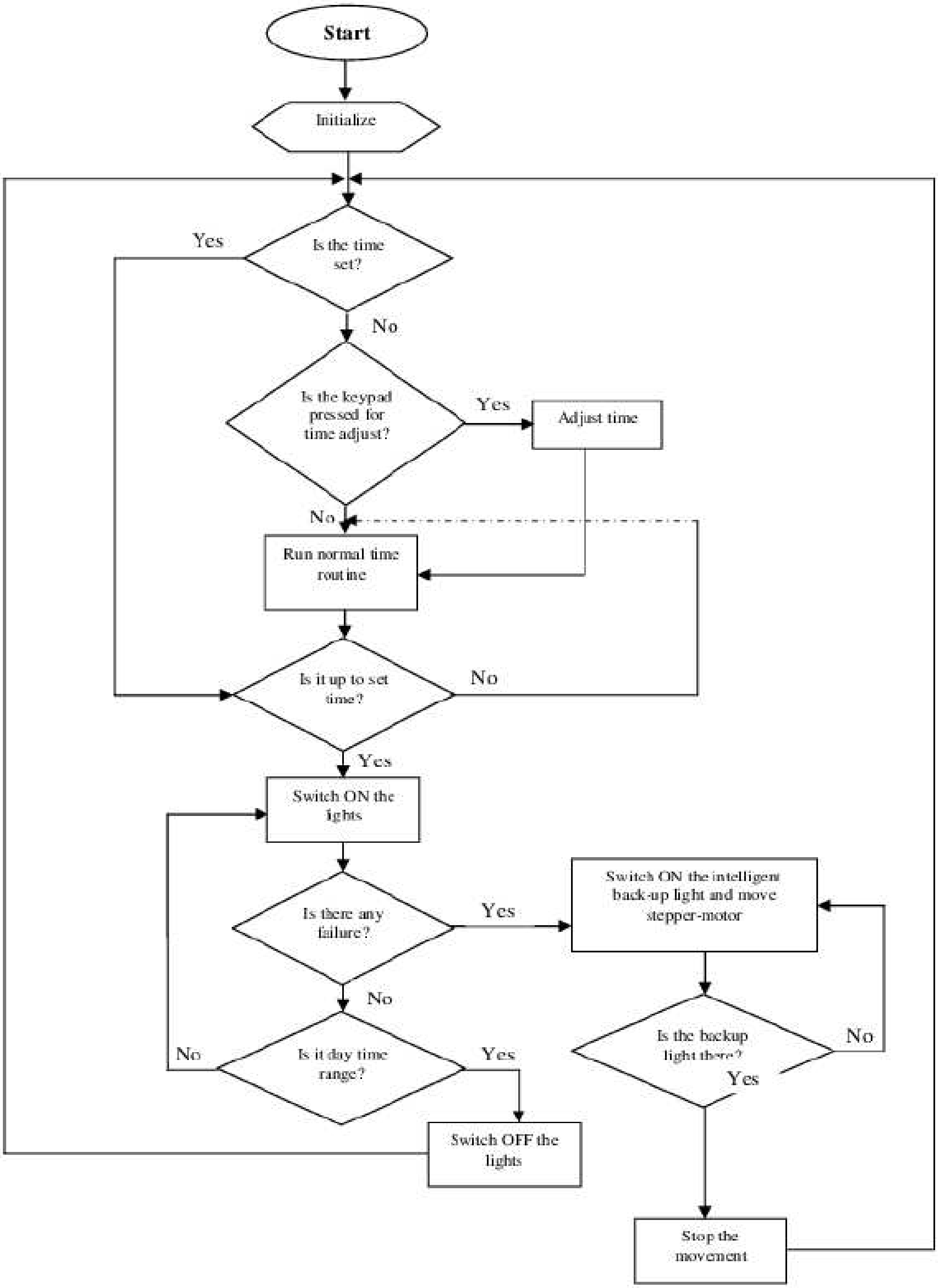

Fig. 2. Flowchart of the floodlight control system

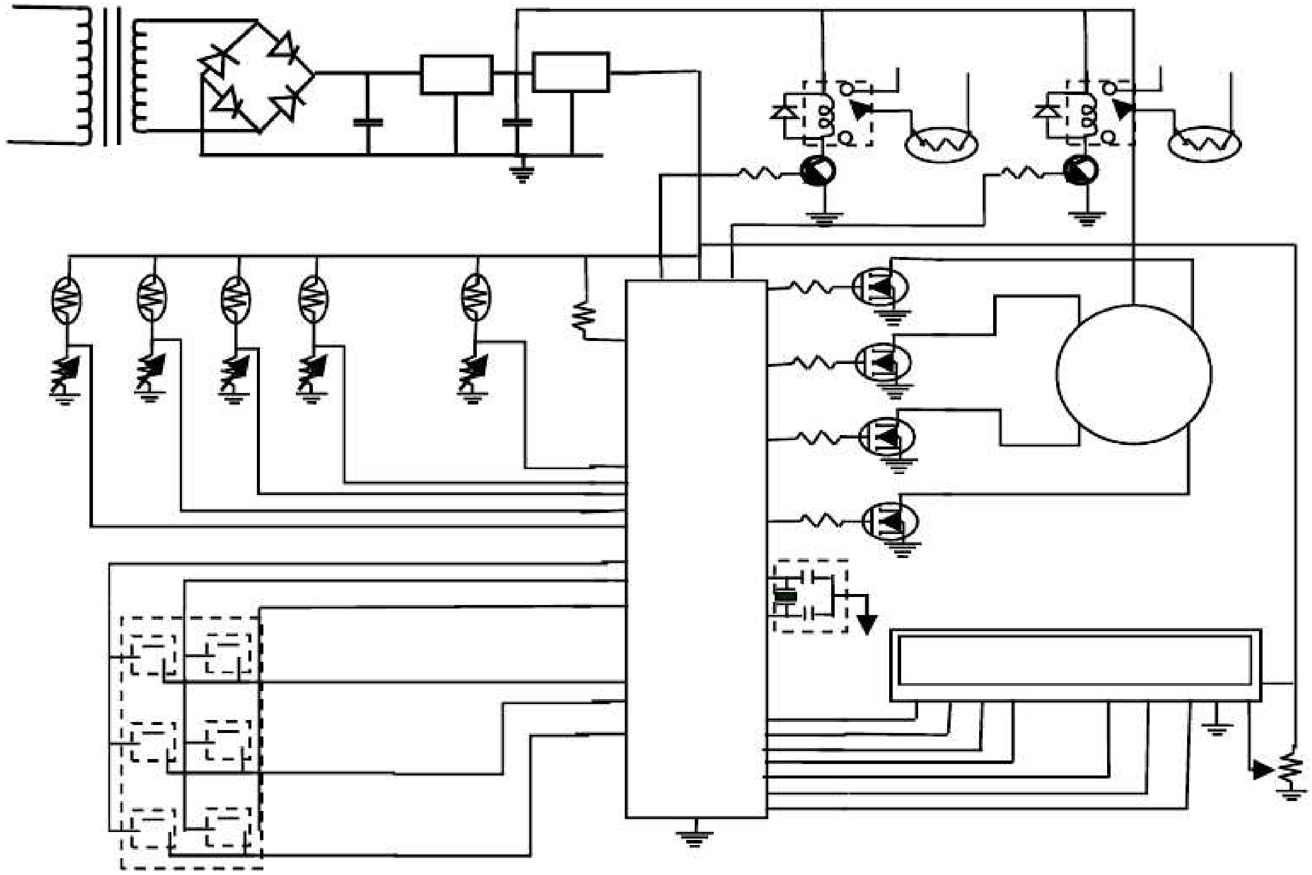

Fig. 3. Circuit diagram of the back-up floodlight system

preprogrammed time to ascertain if the user desires the lights to be on. If the preprogrammed time condition is met, the microcontroller sends a pulse to Tr2 and R1y2 to switch the security lights on. This usually happens in the evening period of the day. The microcontroller uses only the output of LDR5 for detecting daylight, which happens in the morning periods. When sufficient light is detected, the microcontroller receives a high logic level and switches off the security lights. During the darkness periods (nighttime), the microcontroller monitors the security lights to ensure that they are on or working by their luminance using the light sensors LDR1 to LDR4 (there are four lights used for the work, hence the four LDRs). When a light failure occurs in any light source, the LDR assigned to it will not receive light and through the output voltage of the circuit attached to that particular LDR, the microcontroller will detect the light failure. As a result, a pulse is generated by the microcontroller and sent to Trl and Rlyl to switch the backup light on. Then, drive pulses are sent to the mosfets, Ml to M4 to drive current through the stepper motor, which in turn operates and moves the backup light towards the area the light failure was detected. The keypad is used to adjust the preferred switch on and switch off time. The LCD screen/display is used for displaying time and for displaying the adjusted information.

3.0 Design Implementation and Testing

The construction was done in stages starting with circuit set-up on project board to check for workability of the design and to ascertain what stages may require adjustment since tolerance effect on components may cause some deviation from expected performance. For this reason the construction was carried out in stages since it is more convenient to assemble large systems in stages from independent modules. The program codes were written in assembly language, compiled using MPLAB and the microcontroller was then programmed with the hex flies containing the machine language codes. The LDR sensors for light detection were connected to the microcontroller and tested. The following precautions were strictly adhered to in the course of the construction:

- The wiring was neatly done during power off to prevent short-circuit.
- Component leads were kept as short as possible.
- All ICs were mounted on appropriate IC sockets.
- To ensure that voltages would not exceed nominal values the stipulated power supply was adhered to.

The circuit was tested after all stages have been coupled. The responds to the lighting points was tested by putting off each lighting point and then checking the response of each section of the circuit to the change at night time. The microcontroller output ands input programmed ports were carefully monitored for the right pulse pattern to ensure the system is working properly. The following instruments were used to test the circuit:

1) Digital multimeter
2) Digital frequency meter
3) Pulse tracer

4.0 BILL OF QUANTITY

The construction of the automatic backup lighting system was done with the materials listed in Table II. The price per unit and total amount per item is also given in Nigerian Naira (N).

Table II: Tables of Engineering Materials And Evaluation.

Item	Unit Price (N)	Quantity	Amount (N)
Diodes	5	2	10
Resistors	5	12	60
Vero-board	120	1	120
Wires	-	-	800
Soldering lead	-	-	1000
Bridge Rectifier	80	1	80
12V transformer	350	1	350
Soldering Iron	150	1	150
7805	40	1	40
LDR sensors	200	5	1000
I.C socket	100	1	100
Mica capacitors	10	2	20
Stepper motor	2000	1	2000
Casing	3000	1	3000
Power plug	50	1	50
Screws and nails	400	-	400
Transistor C945	10	3	30
PIC18F4520	1800	1	1800
Variable resistors	20	5	100
12V relay	200	2	400
Power switch	50	1	50
100W light bulb	100	5	500
Lamp-holder	50	5	250
Super glue(pack)	500	1	500
LCD screen	1500	1	1500
Touch switches	40	6	240
Masking tape	150	1	150
TOTAL			17,550

5.0 Conclusion

The principles involved in realizing an automatic intelligent lighting system that improves on the generic security floodlight control by implementing an intelligent backup to cater for the failure of any of the main lighting points have been highlighted. The microcontroller was used for the design because of its multitasking and fast operational capability. The circuit uses the microcontroller to monitor light sensors that are connected to each lighting point to detect if the lights are on or off. When the system detects that a lighting point is off, it automatically turns the to the direction of the worked as expected backup source on and moves it failed light source. The circuit

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