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Design of an Automatic Window Using a PIC Microcontroller and Stepper Motor

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Abstract- In this paper, the design of an automatic window is presented. The proposed window closes and opens automatically during and after a rainfall. The automatic system was developed with a focus on hospitals in order to allow medical staff and other supporting staff to concentrate on their primary responsibilities of taking care of patients. The system design includes a PIC16F877A microcontroller which gets activated when a moisture detector sensor sends a high logic signal to it. The microcontroller executes its embedded program by activating the stepper motor through a ULN2003 current-dependent integrated circuit (IC) chip resulting in stepwise control of the window. Hence, the window is automatically closed when rainfall is detected but opens and remains open when no rain is detected. We intend to extend our design to automatic opening and closing of the windows at others times in addition to during and after rainfall; for instance, window opening and closing every day at specific times in the morning and evening respectively.

Keywords: Microcontroller, automatic window, hospital management, stepper motor

1 Introduction

The windows within hospitals are typically left open for easy air circulation and proper ventilation within the offices and wards, especially in the tropical countries such as Nigeria. However when rainfall occurs with no prior signs, it will take the hospital staff some time to close all windows within the hospital depending on the type and location of the windows. During heavy rainfall, rain water might drop into wards and offices where open windows cannot be closed quickly. Such raindrops within the hospital rooms through the window can cause damage to medical equipment, furniture and even patients. The major disadvantage with manual operation of windows within hospitals is that lots of manpower time is lost during rainfall when staff have to go round the wards and offices confirming all the windows are closed and opening them when the rain has stopped. Therefore, there is the need for automatically controlled windows to allow hospital staffs concentrate better on their primary responsibilities (Adegbenjo et al, 2012) of saving life as well as preventing unnecessary accidents from spilled water on the floor from rainfall.

Automatic control has played a vital role in the advancement of engineering and science. It is essential in such industrial operations as controlling pressure, temperature, humidity, viscosity and flow in the process industries (Hausila, 1991). The first significant work in automatic control was James Watt's centrifugal governor for the speed control of a stream engine in the eighteenth century (Khan et al, 2015). Other significant works in the early stages of development of control theory were due to Minorsky, Hazen, and Nyquist, among many others (Katsuhiko, 1997; Auger, 2013).

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This work focuses on the design of an automatically controlled window opening and closing system for hospitals based on the detection of a rainfall. The system uses a microcontroller to activate a stepper motor to drive the windows which makes it different from currently available similar systems such as that developed by Ucar et al (2001). The remainder of the paper is as follows. Section 2 reviews previous related works on microcontroller and stepper motor applications while our methodology is explained in Section 3. The implementation of a prototype for the proposed design and conclusions are presented in Sections 4 and 5 respectively.

2 Related Work

Dharmadhikari et al (2014) presented an automatic wiper system during rain. The system was designed with ease of operational ability, which eliminates the stress on the driver's effort especially when it rains. The data processing unit contains the microcontroller. The motor control module is composed of the DC motor and its control circuit. The rain detection unit uses two types of sensors whose outputs are normalized by an input signal module. The data processing is performed by a microcontroller and its results are fed into an output signal module which is the input to the motor control box (Javanmard et al, 2009). The two signal modules were needed for interfacing between all the units. This system performs well but has precise feedback limitation due to the DC motor.

Khan et al (2015) presented a work on a design concept and zone wise vehicle parameter control. The fluent performance was applied to the entire system design, which enables reliable signal processing, transfer and control to manage delicate vehicle interconnected systems. The system used AT89C51 microcontroller which has no in-built analogue to digital converter and comes under complex instruction set computer (CISC) architecture that makes the programming more complex. Our work uses PIC microcontrollers which are more flexible.

Mazidi et al (2006) worked on a design that will assist in door operational management, the approach is based on the application of motion detecting sensor (PIR sensor) and 8051 microcontroller to create an automatic door opening and closing system in assisting shopping malls and other commercial buildings. The system uses infrared detectors to detect images based on the temperature variants of the objects. However, they cannot detect differences in the objects which have a very similar temperature range which can lead to high inaccuracy.

Sai and Sivaramakrishnan (2009) worked on the design of a self-adjusting window shade with a computer terminal that acts as a remote to broadcast instructions to the window shade via radio frequency (RF) signals. Manual adjustments are stored into the microcontroller system along with the room's current ambient light and temperature settings. When these lighting and temperature conditions are found in the room, the window shade will automatically re-adjust itself to that previous level. This system will automatically raise, lower, open, and close your blinds by itself. The implemented work was tested experimentally and the results show high efficiency performance.

Okomba et al (2015) worked on the design and prototype implementation of an Arduino microcontroller based liquid crystal display (LCD) system that uses a light dependent resistor (LDR). The Arduino microcontroller was connected (hard-wired) to the pins of an LCD programmed to display a list of names continuously but one at a time. The developed system was tested and found to meet the required specifications.

Joan et al (2003) described a radio frequency communication for controlling stepper motor through a PIC16F877 microcontroller. For remote communication, DTMF (Dual-Tone Multi frequency) signal can replace RF signal for the advantage of simplicity and audibility. Stepper motors, due to their positional accuracies and fast response, are now finding applications in computer peripherals, process control, machine tools, robotics and various surveillance systems (Aye, 2008). Stepper motors are especially being used in robotics and process control like silicon processing, integrated circuits bonding and laser trimming applications where it is necessary to control the stepper motor from a remote place (Andrew et al, 2009).

Adeyanju et al (2015) worked on the design and prototype implementation of a multi-powered uninterruptible power supply system using a microcontroller. The system consisted of three basic units: the battery charging unit, the automatic switching unit and the inverter unit. The automatic switching unit includes the micro-controller and MOSFET switches to regulate the charging from multiple sources as well as switching from the power supply from AC to battery and vice versa. Evaluation showed that charging the battery with AC power was much faster than with solar power.

Sagarika et al (2011) worked on the angular position of a stepper motor being controlled remotely using DTMF signal through a microcontroller. Wireless position control can also be achieved through RF transmitter and receiver. However in case of RF communication, devices using similar frequencies such as wireless phones, scanners, wrist radios and personal locators can interfere with transmission (Alice, 2014).

3 METHODOLOGY

The methods that have been employed in this work include design of circuit diagrams for the system as well as development of required firmware for the prototype. The system block diagram is shown in Fig. 1 and has five main components: stepper motor, current driver, rain detector, microcontroller and power supply unit.

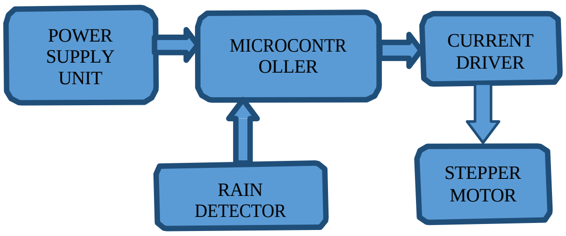

Fig. 1: Micro-controlled Window Opening/ Closing System

3.1 Stepper Motor Unit

A stepper motor is a brushless and synchronous motor which divides the complete rotation into a number of steps. Each stepper motor will have some fixed step angle and motor rotates at this angle. The internal schematic of the stepper motor is given in Fig. 2.

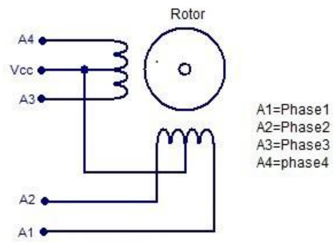

Fig. 2: Internal schematic of stepper motor

The stepper motor is rotated by switching on individual phases for a given time one by one. Each step position is an equilibrium position since without further excitation, the rotor position will stay at the latest step. Thus continuous rotation is achieved by the input of a train of pulses, each of which causes an advancement of one-step. This, it is not really a continuous rotation, but a discrete stepwise rotation.

The rotational rate is determined by the number of steps per revolution and the rate at which the pulses are applied. A driver circuit is necessary to convert the pulse train into proper driving signals for the motor. A microcontroller is then used to control the rotation of the stepper motor by sequentially activating one transistor at a time (thus, energizing one motor coil at a time). With each step in the sequence, the motor rotates a fixed number of degrees, typically 1.8 degrees per step. Each motor coil draws a relatively heavy current when energized, necessitating transistors to interpose between the microcontroller outputs and the motor coils thereby identifying what type of logical signal (high or low). Fig 3 is the circuit diagram of a four phase stepper circuit. The microcontroller output lines are connected to an NPN transistor. The transistor used is actually an NPN Darlington and it act like switches, activating one stepper motor coil at a time.

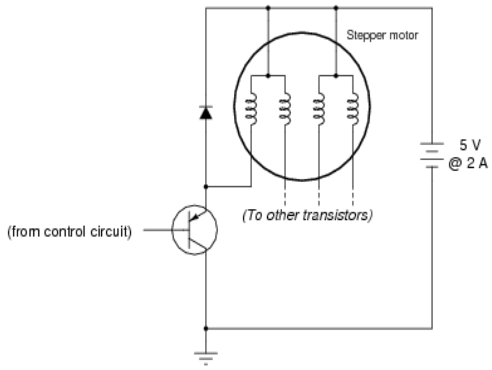

Fig. 3: Stepper motor drive circuit

Due to an inductive surge created when a coil is toggled, a standard 1N4001 diode is placed across each transistor, providing a safe way of dispersing the reverse current without damaging the transistor. The ULN2003A is a current driver IC and do not need an external snubbing diode because they have a built in diode.

3.2 Current Driver

The ULN2003A is a current driver IC. It is used to drive the current of the stepper motor as it requires more than 60mA of current. It is a high voltage, high current array of Darlington pairs. It consists of seven pairs of Darlington arrays with common emitter. The IC consists of 16 pins in which 7 are input pins, 7 are output pins and the remaining are V_{CC} and Ground. The first four input pins are connected to the microcontroller. In the same way, four output pins are connected to the stepper motor. Each channel or Darlington pair in ULN2003A is rated at 500mA and can withstand peak current of 600mA. The inputs and outputs are provided opposite to each other in the pin layout. Each driver also contains a suppression diode to dissipate voltage spikes while driving inductive loads. Fig. 4 shows the schematic for each driver.

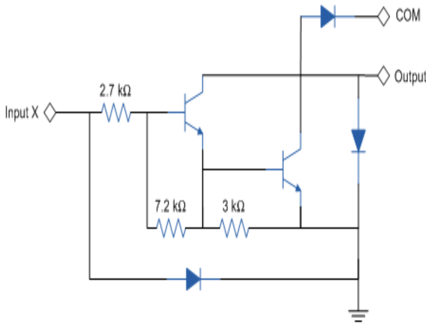

Fig 4: Schematic of the ULN2003 Current Driver

The main principle of this circuit is to rotate the stepper motor moves step-wisely at a particular step angle. The ULN2003 IC is used to drive the stepper motor as the controller cannot provide current required by the motor.

3.3 Rain Detector

Ceramic moisture sensors are calibrated over the full dew point range from -100 to +20 °C dew point using computer controlled humidity generators with mass flow controller operation. Modern impedance dew point sensors are typically constructed using state-of-the-art thin and thick film techniques. Operation of the sensor depends upon the absorption of water vapour into a porous non-conducting sandwich between two conductive layers built on top of a base ceramic substrate.

The active sensor layer and the porous top conductor, that allows transmission of water vapour into the sensor, are engineered very thinly. Therefore the sensor responds very rapidly to changes in applied moisture, both when being dried (on process start-up) and when called into action if there is moisture ingress into a process. Despite this extreme sensitivity to changes in moisture content, the impedance moisture sensor can be incredibly rugged due to the nature of its construction. Fig. 5 shows an exploded view of a ceramic impedance moisture sensor. The moisture sensor used in this work employed impedance as a predictor of moisture content.

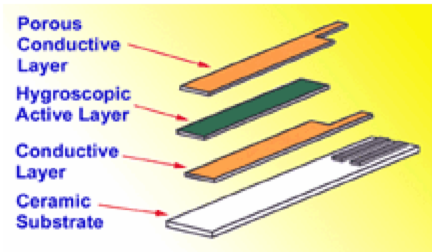

Fig. 5: Exploded view of a ceramic impedance moisture sensor (Hamid, 2014)

3.4 Microcontroller

The PIC microcontroller PIC16F877A is one of the most renowned microcontrollers in the industry. This controller is very convenient to use, the coding or programming of this controller is also easier and it uses flash memory which could be used multiple times. It has a total number of 40 pins and there are 33 pins for input and output. PIC16F877A also have many applications in digital electronics circuits. The first pin is the master clear pin of this IC which resets the microcontroller and makes it active low. This means that the microcontroller should constantly be supplied with 5V but when 0V is supplied, then it is reset. Resetting the controller will bring it back to the first line of the program that has been burned into the IC. Fig. 6 illustrates the pin configuration of the PIC16F877A.

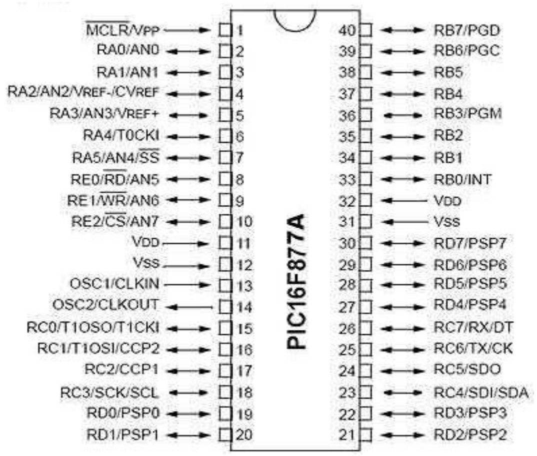

Fig. 6: PIC16F877A Pin Configuration (Broken, 2009)

PIC16F877A has 5 basic input/output ports. They are usually denoted by port A (RA), port B (RB), port C (RC), port D (RD), and port E (RE). These ports are used for input/output interfacing. In this controller, port A is only 6-bits wide (RA-0 to RA-5), ports B, C and D are 8-bits wide (RB-0 to RB-7, RC-0 to RC-7, and RD-0 to RD-7) while port E has only 3bits (RE-0 to RE-2). Port B and D are used in this design for interfacing the ULN2003A IC and the moisture sensor.

3.5 Power Supply Unit

This is the unit that transfers electric power from a source to a load using electronic circuits as shown in Fig. 7. It is required that power supply units in Microcontroller systems are small in size, light, cheap, high power conversion efficiency, possess electrical isolation between the source and load, low harmonic distortion of input/output wave forms and high power factor (PF) from an AC voltage source. Some power supplies require regulation of output voltages, especially conversion of utility AC input power into regulated voltage(s), required for electronic equipment.

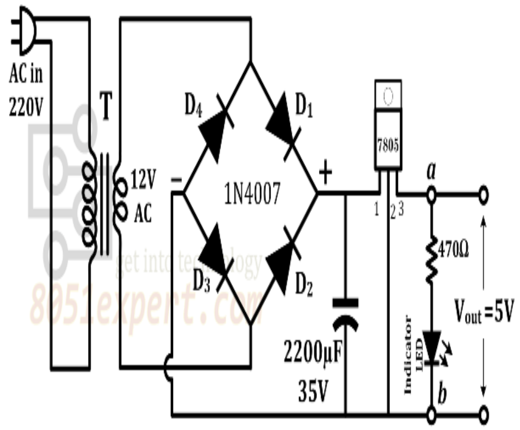

Fig 7: Power Supply Unit Circuit

The power supply unit supplies the required amount of electrical energy to the system. The voltage requirement for the design is a +5V, hence the power unit is designed such that it delivers a fixed and steady voltage of +5V. It consists of a 24V step down transformer on the input side, which supply the bridge rectifier system with the required energy. The bridge rectifier module has four diodes and converts the AC input voltage from the transformer into DC voltage. The output of the bridge rectifier consisting of ripples is passed through the 4700µF capacitor to filter off the ripples. The LM7805 regulates the voltage and ensure that its output does not exceed +5V at any moment.

4 Prototype Implementation

A stepper motor converts electrical pulses into mechanical movement. Unlike conventional motors, a stepper motor advances in steps. These steps of the motor are measured in degrees and can vary depending on the application. It takes one step at a time and the size of each step is equal to the other. The stepper motor in this work is connected to the ULN2003A current driver and the PIC16F877A microcontroller as shown on the overall circuit diagram in Fig. 8. The microcontroller is programmed to enable the stepper motor open and close the window as stipulated in the programmed firmware embedded on a ROM.

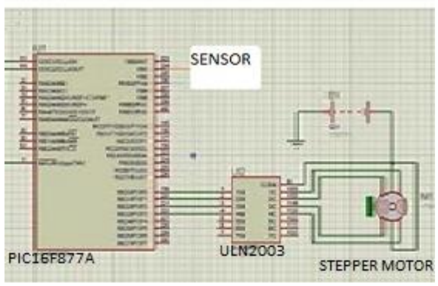

Fig 8: Circuit Diagram of Microcontroller Based Window Opening and Closing System

An implementation of the system was carried out using the necessary components situated at the respective positions on the breadboard as defined by the circuit diagram of Fig. 8. The VCC (5V) and GND (0V) are connected to the bread board in order to power the Microcontroller IC, ULN2003 current driver IC, and the stepper motor. The power source is not connected until all other connections are done. PIC16F877A microcontroller has a built in ADC (analog to digital converter) which is used to measure analog voltage. One of the ADC channel was used to measure moisture by connecting the impedance moisture sensor through pin 34 (RB1) of the microcontroller. Pin1 (MCLR) is always given +5V (VCC). If momentarily given a 0V, it will reset.

Pins 11 and 32 are connected to +5V (VCC), Pins 12 and 31 are connected to 0V (GND), Pins 13 and 14 (OSC1 & OSC2) are connected to a resonator /crystal oscillator ranging from 4MHz to 20MHz. The pins on ULN2003 are connected to the microcontroller with pin 1(1B) to pin 19(RD0), pin 2(2B) to pin 20(RD1), pin 3(B3) to pin 21(RD2), pin 4(B4) to pin 22(RD3), and the other side of ULN2003 is connected to the stepper motor with pin 16(1C) to phase 1(A1), pin 15(2C) to phase 2(A2), pin 14(3C) to phase 3(A3), pin 13(4C) to phase 4(A4). The impedance moisture sensor is connected by placing one terminal on VCC and the other terminal was connected to the analogue pin 39 (RB1) of the microcontroller, then tapped with a 1K resistor connected to the ground. Fig. 9 illustrates some of the components connection on the breadboard.

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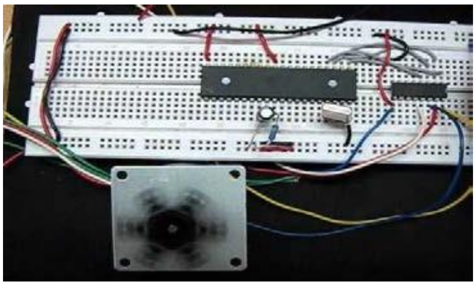

Fig. 9: Breadboard Connections of the Design Prototype

The moisture impedance sensor activates the circuit when it starts raining thereby sending an active high signal to the microcontroller which now executes the program embedded at different levels. On execution of the program, the stepper motor starts to rotate on a stepwise increment closing the window attached to it and system remains on this state while the moisture sensor continue to monitor the presence of rain. The sensor switches off the system once there is no sign of rain (moisture).

Fig. 10: Prototype of the Automatic Window

5 Conclusion

This paper discussed the design and prototype implementation of an automatic window using a stepper motor with a microcontroller. A PIC16F877A microcontroller was used in this work due to its ease of connectivity with the current IC (ULN2003). Although, conventional AC and DC motors could have been used for this work but such motors will required an external feedback mechanism which will not give a precise positioning of the motor. This makes a stepper motor a better option since the feedback mechanism is in-built in the software design of the microcontroller. Finally the voltage variations of the moisture sensor enables the movement of the stepper motor to either close or open an attached window having in mind that the voltage variation of the sensor depends on moisture.

References

Adegbenjo A.A., Kuyoro, S.O., Ogunlere, S.O., and Kanu, R.U (2012): Design and Implementation of Health Management System, *International Journal of Computer Science and Information Technology & Security (IJCSITS), ISSN: 2249-9555 Vol. 2, No.3.*

Adeyanju I.A., Omotosho O., Benjamen N.& Adegbola E.(2015): *Development of Micro-Controlled Multi-Powered Uninterruptible Power Supply System*, International Journal of Engineering Innovation & Research (IJEIR), 4(4), pp. 668-671

Alice L.A. (2014): An Automated Bed Positioning and Windows System Using MEMS accelerometer' International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol.3, Issue11

Andrew G., John I., and Richard B. (2009): Accurate Fusion of Robot, Camera and Wireless Sensors for Surveillance Application, IEEE 12th International Conference on Computer Vision Workshops (ICCV Workshops), Kyoto, pp1290-1297.

Auger F., and Hilairet M. (2012): Industrial applications of the kalman_lter: A review. IEEE Transactions on Industrial Electronics, PP(99): 1, ISSN0278-0046.

Aye T..S.,. And Lwin Z.M. (2008): Microcontroller Based Electric Expansion Valve Controller for Air Conditioning System, World Academy of Science, Engineering and Technology.

Broken A., (2009): Microcontroller PIC 16F877 Features, PIN diagrams and PIN description http://ugpro143.blogspot.com.ng/2009/06/microcontroller-pic 16f877-features-pin.html (accessed February, 2017)

Dharmadhikari S.N., Tamboli N.G., and Lokhande N.N., (2014): Automatic Wiper System, International Journal of Computer Technology and Electronics Engineering Vol.4, No.2, pp.15-18.

Hamid F., Rahman W., and Mohd N.H., (2014): Humidity Sensors Principle, Mechanism, and Fabrication Technologies: A Comprehensive Review. *Sensors*, *14*, pp. 7881-7939.

Hausila S., and Sudhansu, S., (1991): Some Novel microprocessor based configurations for controlling Remotely Located stepper Motors as Actuators of control valves, IEEE Transaction on industrial electronics, 38(4), pp. 283-287.

Javanmard M.K., Abbas A., and Arvin F., (2009): A Microcontroller-Based Monitoring System for Batch Tea Dryer, CCSE Journal of Agricultural Science, Vol.1, No.2, pp. 3-5.

Jegede O., Awodele O., Ajayi A., and Ndong M.A., (2007): Development of a Microcontroller Based Robotic Arm, proc. Of the 2007 Computer Science & IT Education Conference, Mauritius, pp. 16-18.

Joan N.M., Fernando D.M., Nuno M., and Rui E.A., (2003):

Progresses On The Design of a Surveillance System to Protect Forests from Fire, IEEE Conference on Emerging Technologies and Factory Automation, 2, 16-19, pp. 191-194, 10.1109/ETFA. 1248696.

Katsuhiko O., (1997), Modern Control Engineering third edition, pp.1-4.

Khan I.A., Jaitly P., Gupta R.K., and Kishor S., (2015): Zone wise Vehicle Parameter Control, in International Journal of Advanced Research in Computer Science and Software Engineering, Vol.5, No.3, pp.132-136.

Mazidi M.A., Mazidi J.G., and Mckinlay R.D., (2006): The 8051 Microcontroller and Embedded System, Prentice-Hall, India.

Okomba N, Adeyanju I., Adeleye O., Omodunb Bi, & Okwor C (2015): Prototyping of an Arduino Micro-Controlled Digital Display System, African Journal of Computing and Information & Communication Technologies (AJOCICT), 8(1), 61-66

Roderick L.S., and William S.Y., (2005): Low Cost Surface Mount LED Gas Sensor, IEEE King Tong Lau and Dermot Diamond, Sensors-00997, pp 4-6.

Sagarika P., Niladri S., Tripathy I., (2011): Remote Position Control System of Stepper Motor Using DTMF Technology in International Journal of Control and Automation Vol.4 No.2.

Sai K.V.S., and Sivaramakrishnan R., (2009): Design and Fabrication of holonomic Motion Robot Using DTMF Control Tones, International Conference on control, Automation, Communication and Energy Conservation, Perundurai, India, 4-6, pp.1-4.

Ucar M., Ertunc H., and Turkoglu O., (2001): The Design and Implementation of Rain Sensitive Triggering System for Wind shield Wiper Motor” In IEEE International Electric Machines & Drives Conference , pp. 329-336.