

Development of Light Control and Motor Speed Control by Smart Phone

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Abstract

Wireless monitoring and control is the new technology that most of the nations are interested in since majority of the people are now using the cellular phone. Smart phone can now control many of the appliances of electric goods or lights as well as the motor speeds at the factories or workshops. The phone can also monitor the values of most of electrical or mechanical variables or even the human body functions like blood pressure, heart beat or oxygen. This technology is based on an automatic electronic and programming switch that can be built in a receiving circuit connected to any load, which detect the wireless transmitted signal and translated into an operating signal. The transmitted signal is generated from the mobile phone either by push button (touching a key) using DTMF (Dual-Tone Multi-Frequency) or by SMS (Short Messaging Service). This is preceded by dialling the number of the SIM card (Subscriber Identity Module) of the receiving circuit. This circuit consists of GSM board (Global System for Mobile Communications) and Arduino Uno microcontroller board plus other components such as resistances, capacitances, inductances, relays, transformer, decoder, transistors and converters. These electronic circuits are supplied by 3 to 5 volt or sometimes 12 volt, so adapter device is also involved with the components. This technology is only used the mobile functions, not the internet features, but depends on the mobile networks which allow the objects to be controlled from very far distance (from country to another country, from home to workshop or hospital). Unlike the other technology which works at small distance such as remote infrared Bluetooth, Wi-Fi, or line communication. In this paper, this technology will be highlighted showing the hardware circuits of light and speed control of AC and DC motors with their process and security system on the phone keys.

Keywords: Mobile phone; GSM; SMS; DTMF; Arduino; Program code; Converter; Decoder; AC and DC motor

Introduction

Wireless control of the appliances is to control the switch by using mobile phone from far distance or any other places and to help the user to switch ON or OFF. The goal of this paper is to control the light and motor speed easily by using SMS or touch a key of a cellular phone. As the technology grows, SMS technology has been widely accepted as a part of medium of communication [1]. The main objective of this paper is to design a smart system that allows remote control characteristics in easing the controls of home appliances. This will require the integration of the latest wireless technologies such as Bluetooth, SMS and Wi-Fi components into the system's concept and application. Also, another objective is to allow the system to portray a two-way communication system between the house-hold appliances and user's controlling device. This allows the implementation of a feedback mechanism in the system.

This technology is based on the principle of GSM network, which enables the user to remotely control the operations of the light and motor speed by using a mobile phone [2]. With the trend of huge growing usage of GSM during the past decade, network services are extended beyond speech communication to many other custom specified applications, machine automation and machine-to-machine communication

A GSM is a modem that works with a wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through fixed telephone line while a wireless modem sends and receives data through radio waves [1,3]. Like a GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate. To control the motor speed, SMS is transmitted where the GSM will receive the signal to be interpreted by the microcontroller.

This work is to use the idea of wireless communication between a

mobile phone, microcontroller and switch or motor drive. Basically, the control switch is connected directly to the light or to the motor circuit. In order to control the motor speed, user normally needs to be at the place where the control switch is located to the machine. However, in this work paper, a push button dialling method or SMS are used to control the motor speed or light from very far distance of the location of the switch or machine. For controlling the appliances, GSM board and Arduino UNO board with its microcontroller are used. Additionally pulse width modulation (PWM) and transistor H-bridge are used to control the DC and AC motor speed using SMS, while DTMF decoder associated with computer TC35 and IC MT8870 are developed to control both motors by touching button keys.

Description of the Components

Global System for Mobile communication (GSM)

GSM is one of the popular and reliable wireless communication systems which is accessible and user friendly. It is one of the factor highly concern with market survey, survey result shows cost effective the price of its transceiver module (a simple cellular phone) or the subscription fees [4]. The paper is based on the principle of GSM network, which enables the user to remotely control the operations of the appliances by using a mobile phone. The controlling circuit is the most important component in communication and interface between home appliances.

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It is implemented by using Arduino interfaced to mobile phone. The user sends GSM data in the form of SMS message to switch ON or OFF any appliance at home such as lamp, air condition, fan and any other switch.

GSM shown in Figure 1 is a specialized type of modem which accepts a SIM card and operates over a subscription to a mobile operator. From the mobile operator perspective, a GSM modem looks just like a mobile phone. It exposes an interface that allows applications such as Now SMS to send and receive messages over the modem interface. The mobile operator charges for this message sending and receiving as if it was performed directly on a mobile phone. To perform these tasks, a GSM modem must support as “extended AT command (attention) set” for sending/ receiving SMS messages as defined in the ETSI GSM 07.05 and 3GPP TS 27.005 specifications [3]. GSM modems can be a quick and efficient way to get started with SMS because a special subscription to an SMS service provider is not required. In most parts of the world, GSM modems are a cost effective solution for receiving SMS messages because the sender is paying for the message delivery.

For this paper, SIM900 GSM module is used. The SIM900 (Figure 1), is a complete Quad-band GSM solution in a SMT module which can be embedded in the user applications. Featuring an industry-standard interface, the SIM900 delivers GSM/GPRS 850/900/1800/1900 MHz performance for voice, SMS, Data and Fax in a small form factor and with low power consumption. With a tiny configuration of 24 mm × 24 mm × 3 mm, SIM900 can fit almost all the space requirements especially for slim and compact demand of design. SIM900 is designed with a very powerful single-chip processor integrating AMR926EJ-S core. The GSM is used to receive the signals send from the mobile phone. It contained a SIM card which acts as the mobile telecommunication to receive the required information from the other SIM card in the mobile phone [3,4].

Subscriber Identity Module (SIM)

One of the key features of GSM is the subscriber identity module (SIM). The SIM is detachable smart in appearance and is used for the subscription of information and phonebook. This allows the retrieval of information after switching handset on. The SIM card also enables users to link each other irrespective of different network operation [5]. For the purpose of this work to be achieved a SIM card on any network is required to establish a link between the user and his household equipment to squeeze 3.1 kHz audio between 5.6 and 13 kbits/s.

Software of Arduino

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for Processing programming language and the Wiring project It is designed to introduce programming to artists and other newcomers



Figure 1: SIM900a GSM modem.

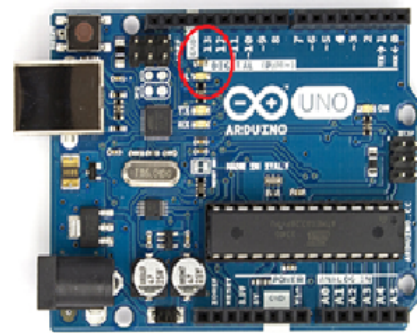


Figure 2: Arduino UNO board.

(PCINT14/RESET) PC6	1	28	PC5 (ADC5/SCL/PCINT13)
(PCINT16/RXD) PD0	2	27	PC4 (ADC4/SDA/PCINT12)
(PCINT17/TXD) PD1	3	26	PC3 (ADC3/PCINT11)
(PCINT18/INT0) PD2	4	25	PC2 (ADC2/PCINT10)
(PCINT19/OC2B/INT1) PD3	5	24	PC1 (ADC1/PCINT9)
(PCINT20/XCK/T0) PD4	6	23	PC0 (ADC0/PCINT8)
VCC	7	22	GND
GND	8	21	AREF
(PCINT6/XTAL1/TOSC1) PB6	9	20	AVCC
(PCINT7/XTAL2/TOSC2) PB7	10	19	PB5 (SCK/PCINT5)
(PCINT21/OC0B/T1) PD5	11	18	PB4 (MISO/PCINT4)
(PCINT22/OC0A/AIN0) PD6	12	17	PB3 (MOSI/OC2A/PCINT3)
(PCINT23/AIN1) PD7	13	16	PB2 (SS/OC1B/PCINT2)
(PCINT0/CLKO/ICP1) PB0	14	15	PB1 (OC1A/PCINT1)

Figure 3: ATMEGA328P pin configuration.

unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a sketch.

Arduino programs are written in C or C++. The Arduino IDE comes with a software library called “Wiring” from the original Wiring project, which makes many common input/output operations much easier. Users only need to define two functions to make a working cyclic executive program

Input and output of Arduino

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. Figure 3 shows the pin configuration. In addition, some pins have specialized functions, where:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. These are seen by the attachInterrupt () function [6].
- PWM: 3, 5, 6, 9, 10, and 11 pins. Provide 8-bit PWM output with the analogWrite () function.
- SPI: 16 (SS), 17 (MOSI), 18 (MISO), 19 (SCK). These pins

support SPI communication using the SPI library.

- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is of HIGH signal value the LED is on, and when the pin is LOW the LED is off. In digital sense the value is represented by 1 and 0.

The Uno board of Figure 2 has 6 analog inputs, labeled A0 through A5, each of which provides 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though it is possible to change the upper end of their range using the AREF pin and the analog Reference () function.

Motor modules driver

Figure 4 shows the Motor module of driver circuit. The transistor is used as switches to electronically control the flow of current through other electrical components. This module is preferred to control a DC device that draws higher current. The base of the transistor (PIN 1) is connected to the Arduino output pin (Pin 9) through a 4.7 kΩ resistor by using Ohms formula $R=V/I$. The emitter (Pin 3) is connected to ground and the collector (Pin 2) is connected to one end of the DC Motor. The other end of the DC motor is connected to the +5V DC external power supply. It is very important to put a diode across the end of the DC motor being powered to protect the control circuit from the potential voltage spike that can be created when current is released from the device being powered. The circuit were build up with two diodes (HER304 and IN4007) for optimum protection of back emf voltages produced by any inductive loads when switched ON or OFF (DC motors were inductive loads that can cause important back emf currents) [7].

The motor used here is 3V Miniature Brushless DC motor shown

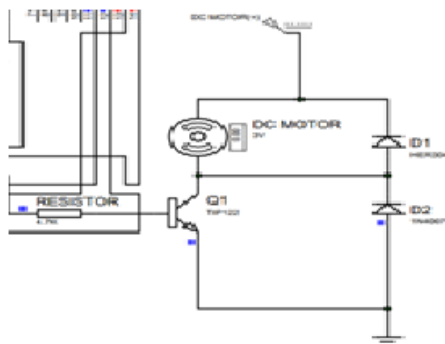


Figure 4: DC motors modules drive.

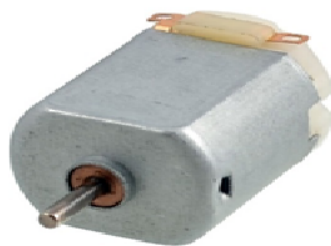


Figure 5: 3V Miniature brushless DC motor.

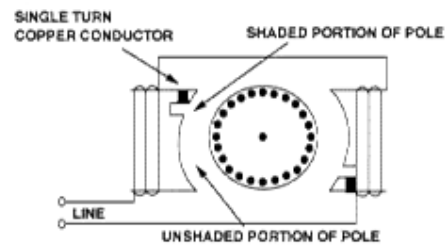


Figure 6: Configuration of shaded-pole induction motor.



Figure 7: Shaded pole AC motor.

in Figure 5. This DC motor has 13500 rpm maximum speed at no load and torque of 1.37 mNm. The minimum voltage for the motor to run is 3 V and maximum voltage is 6 V.

Shaded pole induction motor

A shaded pole motor Figure 7 uses no starting switch. The stator poles are equipped with an additional winding in each corner called a shade winding. These windings have no electrical connection for starting but use induced current to make a rotating magnetic field. Rotor torque initiates as the magnetic field sweeps across the face of the pole between the un-shaded and shaded portions. The rotor is highly resistant in order to maximize the torque.

From Figure 6, the pole structure of the shaded pole motor enables the development of a rotating magnetic field by delaying the build-up of magnetic flux. A copper conductor isolates the shaded portion of the pole forming a complete turn around it. In the shaded portion, magnetic flux increases but is delayed by the current induced in the copper shield. Magnetic flux in the unshaded portion increases with the winding current forming a rotating field [8].

Dual Tone Multi Frequency (DTMF) Signaling decoder technique

DTMF is a tone composed of two sine waves of given frequencies. Individual frequencies are chosen so that it is quite easy to design frequency filters, thus it can easily pass through telephone lines (where the maximum guaranteed bandwidth extends from about 300 Hz to 3.5 kHz). DTMF was not intended for data transfer; it is designed for control signals only. In GSM modules a DTMF encoder is included. The DTMF tones are controlled by AT commands.

The MT8870 monolithic DTMF receiver offers small size, low power consumption and high performance. Its architecture consist of a band split filter section, which separates the high and low group tones, followed by a digital counting section which verifies the frequency and

duration of the received tones before passing the corresponding code to the output bus. The DTMF technique presents distinct representation of 16 common alphanumeric (0-9, A-D, *, #) on the mobile phone as shown in Figure 8. The lowest frequency used is 697 Hz and the highest frequency is 1633 Hz. The DTMF keypad is arranged in such a way that each row will have its own unique tone frequency and also each column will have its own unique tone frequency.

Dial push button mobile method using DTMF decoder

During any call if a button is pressed, a tone corresponding to that button is generated and heard at the other end of the call. This tone is basically known as DTMF tone and these tones are standard one, fixed by IEEE, ISO, EIA, ITU etc., [9].

The tones produced when dialling on the keypad on the phone could be used to represent the digits, and a separate tone is used for each digit. Pressing any key generates unique tone which consists of two different frequencies, one of higher and one of lower frequency range as shown in Figure 9. The resultant tone is the convolution of two frequencies [10]. Simply, to describe the DTMF generation frequency through keypad mobile structure can be shown in Figure 8. For encoding, it has to use encoder chips or a DSP [11]. The generated signal can be expressed mathematically given in equation 1.

$$f(t) = AH \sin(\pi f_H t) + AL \sin(2\pi f_L t) \quad (1)$$

Where AH, AL are the amplitudes and fH, fL are the frequencies of high & low range. The results of keypad button of Figure 8 adding the low and high frequency, as stated in the equation (1) are seen in the Table 1.

Relay circuit

Relay is used in the circuit because it is an electrical operated switch, connected to output load. It opens and closes according to the program of microcontroller. The relay switch connections are usually labeled as Common (COM), Normally Closed (NC) and Normally Open (NO). The circuit is connected to COM and NO if it is switched to ON when relay coil is in ON state, while to switch OFF the circuit connects the COM and NC together. Therefore, the relay contacts when it detect

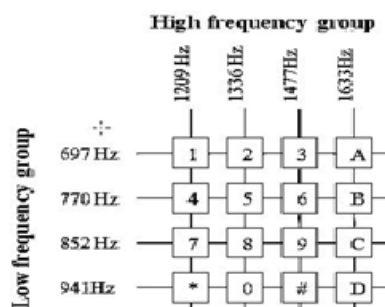


Figure 8: Keypad matrix.

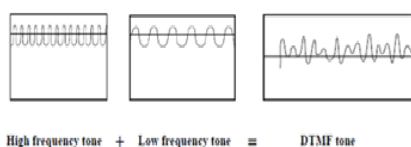


Figure 9: Combination of high and low tone produce DTMF tone.

Button	Low frequency	High frequency	Low + High frequency
1	697	1209	1906
2	697	1337	2034
3	697	1477	2174
4	770	1209	1979
5	770	1337	2107
6	770	1477	2247
7	852	1209	2061
8	852	1337	2189
9	852	1477	2329
0	941	1209	2150
*	941	1337	2278
#	941	1477	2418

Table 1: Table tone frequency associated with keypad buttons.

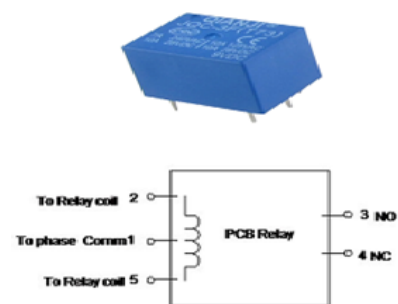


Figure 10: Relay and relay circuit.

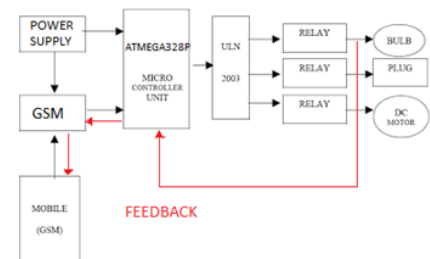


Figure 11: Block diagram of the system flow.

signal from the PIC circuit. Figure 10 shows the relay that has been used needs 12 V DC supply its coil.

Circuit Design

Block diagram of the wireless control system of home appliances

The block diagram in Figure 11 illustrates the process flow of how the system works and giving its feedback of the home appliance at current state. The mobile phone will integrate with the Arduino Uno microcontroller. The Arduino will receive message from the mobile phone by the user and trigger the control circuit to turn ON or OFF the lamp.

Design the circuit using proteus software

The circuit for mobile control of the light system is designed in Proteus software. Two parts are designed, the controller circuit and the

relay circuit. These two circuits are combined as shown in Figure 12.

Block diagram of DC motor speed control

Figure 13 shows the block diagram of the motor speed controller. DC motor, GSM module, H-bridge, Arduino microcontroller and LCD (Liquid Crystal Display) are included in the circuit using Proteus software.

Circuit design of DC motor speed control

Figure 14 shows the circuit design using the Proteus software. Arduino microcontroller is used to interpret the signal received to control the speed of the DC motor. H-bridge is also included to control the direction and regulates the speed. LCD is used for displaying the

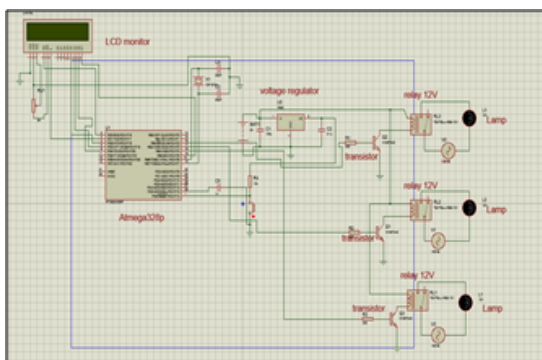


Figure 12: Circuit designed in Proteus.

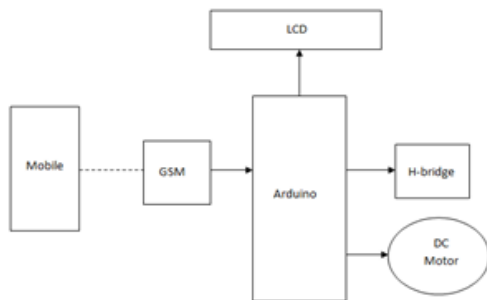


Figure 13: Block diagram for controlling DC motor speed by SMS.

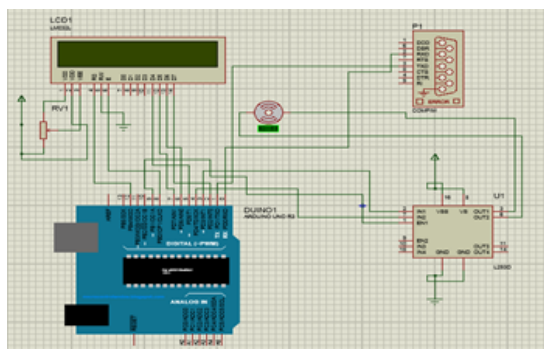


Figure 14: Circuit design for the DC motor speed controller.

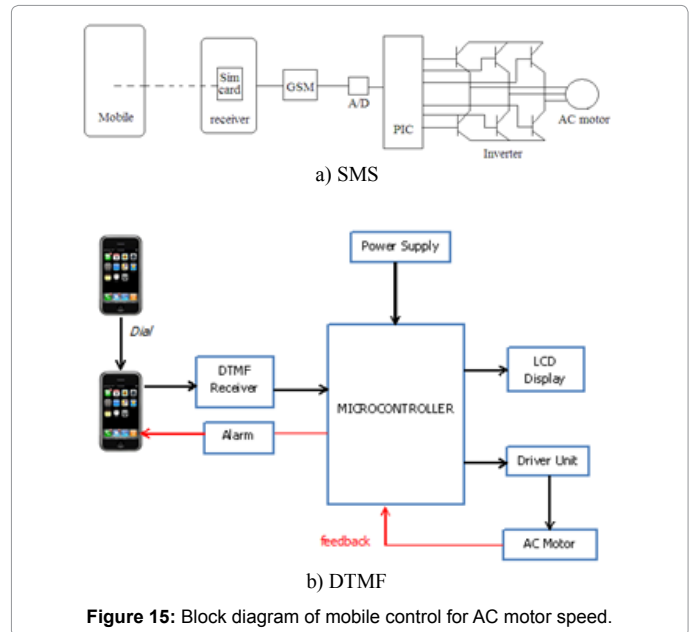


Figure 15: Block diagram of mobile control for AC motor speed.

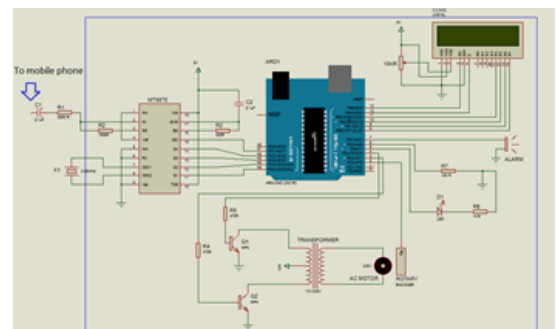


Figure 16: Circuit design for the AC motor speed controller.

state and speed. The COMPIM component in the circuit represents the GSM where RX pin is used for receiving signal from the Arduino while the TX pin is used for transmitting.

Block diagram of AC motor speed control

A text message (SMS) indicates the rpm value will be sent using any type of mobile phone to GSM Module. Figure 15a describes the block diagram. SIM900 GSM Module is used as the receiver and transmitter. The desired speed for the motor sent by the user was directly forward to the SIM card which acts as the receiver before send it to GSM Module. SIM900a GSM Module which is connected to the Arduino Uno microcontroller will receive the signal. The microcontroller unit will convert the signal to Pulse Width Modulation (PWM). Inverter used in this system to create a frequency since AC Motor selected to be the driver compare to DC that use chopped to produce duty cycle. The speed of AC Motor depends on the frequency in term of revolution per minute.

Circuit design of AC motor speed control

Figure 16 shows the full diagram of circuit connection in Proteus software. 5 V supply is used for the ATMEGA IC in the Arduino. The supply is also connected to the LCD display, MT8870 decoder

IC, Rotary Encoder, and alarm. The motor is supplied by 240 V from transformer which is run by 12 V adapter.

The IC MT8870 is used; however, it is not available in any simulation software such as Proteus, it needs to be constructed directly to test it. Female connector is defined as an input to link a mobile phone into the receiver. The connector will receive a frequency from mobile phone generated in dialling mode by pushing the keypad button of mobile phone. The output in the figure is in the pin Q1, Q2, Q3, and Q4 and StD that represented the LED (light-emitting diode).

Inverter is used to drive the AC Motor and NPN transistor TIP122 is used as switching device. Pin 3 and Pin 4 is connected to the microcontroller using delay function so transistor will have a certain period to switch voltage into the transformer. The variation voltage at transformer also varies the frequency received by motor so the speed can be controlled as desired. The motor is attached with rotary encoder to detect the motion.

If sudden fault occurs and the motor is stopped, users must be informed about the current situation. The feedback system is applied by using Rotary Encoder, attach to the motor so it can detects the motion of the motor. Rotary encoder connect to pin2, LED to pin5, R7 connect to 5 V and Pin 6 while buzzer to pin 7. As long as the motor is stopping, buzzer with the LED will be on for indicator. Rotary Encoder is used to calculate the motor velocity and display the value in serial monitor.

Hardware Implementation

This section presents the hardware of receiver circuits in association with the transmitted signal from smart phone When user touch ON or OFF, Figure 17, and sends the command according to program that is already embedded in Atmega328p microcontroller, “a” represents bulb 1, “b” is bulb 2 and “c” is bulb 3. Number “1” represents ON and “0” represents OFF condition. In Figure 18, it shows the command that user sent through SMS whether to switch OFF or ON will display at LCD and user will get the feedback status. The light also can switch OFF or ON together or separately according to the command. Different command that user send through SMS will show different status and feedback in LCD.

For the testing of the DC motor speed controller, several different values of rpm is tested. Figure 19 shows the motor is controlled at speed of 1500 rpm while Figure 20 shows the motor is turn off by SMS of 0 messages. In this condition, the Enable pin in the H-bridge is in low state. Reverse direction is also tested when the SMS message has negative sign, such as -1000 rpm.

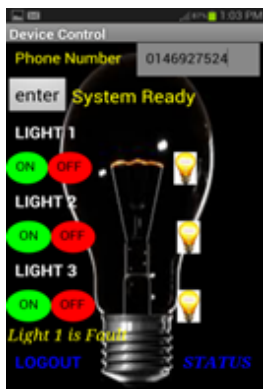


Figure 17: Switch all lights ON in mobile program.



Figure 18: Receiver circuit of the lights.



Figure 19: DC motor is controlled at speed of 1500 rpm.

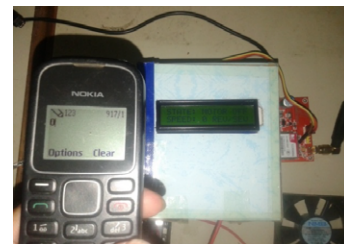


Figure 20: DC motor is stop at a speed of 0 values.

Button	Speed (rpm)/ Task	Duty cycle (%)
1	1500	11
2	3000	22
3	4500	33
4	6000	44
5	7500	55
6	9000	66
7	10500	77
8	12000	88
9	13500	100
0	Motor Stop	0
*	Motor ON	100
#	System Reset	0

Table 2: Speed and task assign to mobile button.

For testing the brushless DC motor speed control by using 2 mobile phones, the system initiated by calling the other mobile phone, this phone was set to auto answer so that the user does not have to pressed answer button on second phone. Upon successful calling, the user can start the selection from the calling mobile phone button keypad. The user need to on the dial pad tones so that the DTMF module can detect the tones signal coming from the mobile phone. This dial tone is by pressing the button of required speed based on Table 2. Figures 21 and



Figure 21: User select button number 1 for speed 1500 rpm.

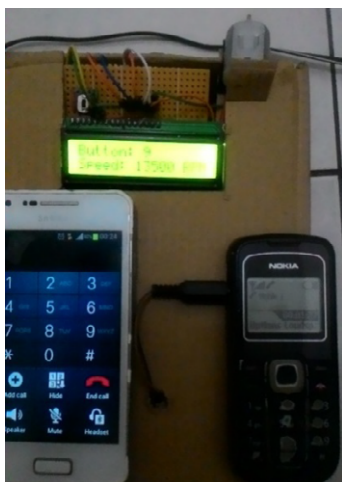


Figure 22: User select button number 9 for Speed 13500 rpm.

22 showing 2 examples of DC motor speed display according to the user selection.

Interface GSM (Mobile Phone) with Hyper Terminal, Interfacing GSM Module with Arduino Microcontroller and Interfacing Arduino with motor are important for both DC and AC control. For speed control of a shaded pole AC motor by SMS the following program codes are generated by the microcontroller:

- Line 1: AT is send to GSM Module to test connection. GSM will reply OK (Line 2) if connection is successful.
- Line 3: AT+CMGF=1 is send to set the GSM in SMS text mode. GSM will reply OK (Line 4) if it support SMS text mode.
- Line 5: AT+CSCS= is command to set the network provider service centre number. GSM will reply OK (Line 6) to indicate that the service centre number is stored.
- Line 7: AT+CMGS+=xxxxxxxxxxx is command to set the recipient number. GSM will reply > and we can start typing message with ending by pressing CTRL + Z (→) from keyboard. GSM will reply OK (Line 8) to indicate message is sent.

In order to generate the speed of AC motor, two pins of Arduino board which is digital PWM need to be declared as output. The pins that declared in this part are Pin9 and Pin10 of Arduino board. The output pins will be set or written "HIGH" and "LOW" simultaneously in codes to generate pulse. To obtained variable frequency which needs to be triggered by the controller codes, the formula of calculation shown in equation (2) is used:

$$f = \phi / (360 \Delta t) \quad (2)$$

Where f = frequency, ϕ = Phased Angle and Δt = time delay.

When valid message sent to the system, SIM900a GSM modem acts as receiver trigger the message and processed by the microcontroller as shown in Figure 23. Motor operates according to the valid message receive and gives feedback to user which informs that motor has run according to the desired value. Step up transformer with inverter is used in this hardware circuit.

Based on Table 1 and the corresponding Table 3 as well as the block diagram Figure 15b, AC shaded pole motor is tested by DTMF. Figure 24 is the hardware implemented in complete circuit. The rotary encoder is tested and shows that it detects motion in a form of pulses. The data of velocity and motion can be displayed in the serial monitor. Rotary encoder kit cannot be defined to measure the speed or rpm of the motor because it detects the motion in the form of pulses. Figure 25 shows the serial monitor in Arduino software displaying the movement of motion whenever the motor is running. When the motor is stopped it shows that velocity is 0 and this is functioning to trigger the alarm to ON.

Conclusion

It has discussed and successfully demonstrated the purpose, use and implementation of mobile communication system to control the appliances and motor speed of DC and AC devices from far distance

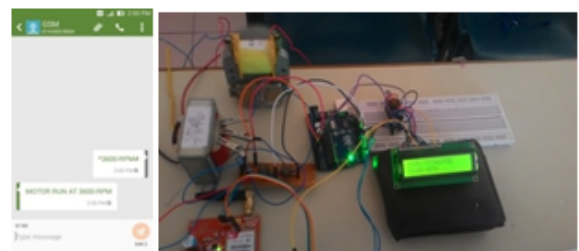


Figure 23: Speed of AC motor with GSM and Arduino.

Button	Delay (ms)/command	rpm
1	500	60
2	75.0	400
3	37.5	800
4	25.0	1200
5	18.8	1600
6	15.5	1940
7	12.5	2400
8	10.7	2800
9	9.4	3200
0	OFF	0
*	Decrease speed	vary
#	Increase speed	vary

Table 3: Configuration of keypad button with desired speed.

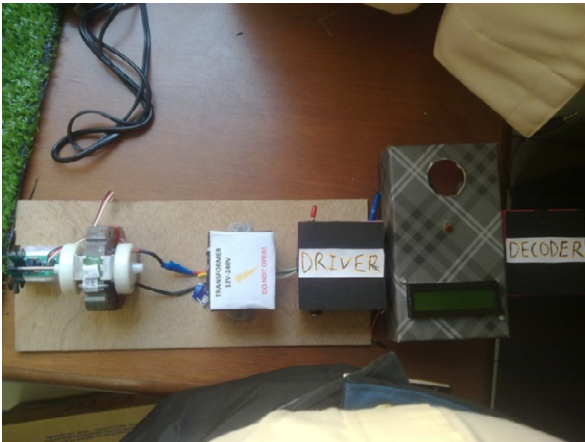


Figure 24: Circuit implementation of AC shaded pole speed control by DTMF method.

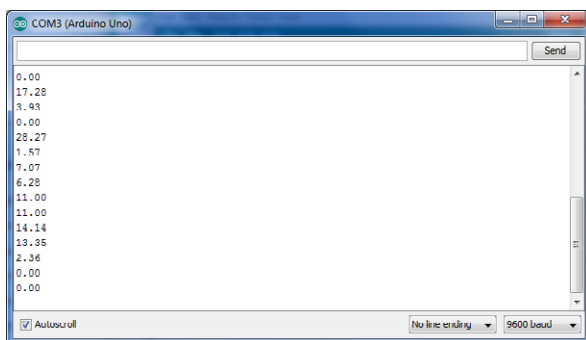


Figure 25: Motion results displayed in serial monitor of Arduino.

using smart phone. Descriptions of components are stated and all equipment is investigated. This technology will save cost for wiring.

The light system can switch ON and OFF the bulb by using mobile phone through text message. The device with low cost and scalable to less modification to the core is much important. It presents the design and implementation of automation system that can control home appliances via phone, iPad or tablet. The integration of software and hardware has performed a good task in producing the SMS system.

The speed of the DC motor can be controlled by SMS. The GSM will receive the SMS signal which then will be interpreted by the Arduino microcontroller. This application will reduce the manual work and save the cost for wiring. When using 2 mobile phones, the system can decode the tones from the mobile phone and the decode tones can be programmed into the Arduino for DC speed controlling via PWM.

AC Motor Speed Control Using SMS-Based Application has also been implemented. Controlling the speed of AC motor by giving instruction to the microcontroller will reduce the manual work. Implementation of the system is easy as long as AC motor is controlled by frequency inverter. The hardware have been built in three main parts which are the inverter for of AC motor operation, the DTMF receiver and interfacing both system with alarm. Once can control the AC motor by just using dialling method and key button which gives a lot of benefits to community.

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