Understanding Mechatronics Engineering Using a School Project

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---**Abstract**--
One of the approaches of teaching mechatronics engineering is discussed in this paper. Due to lack of proper awareness regarding mechatronics engineering in Nigeria, a means of creating awareness and interest in the subject using laboratory works and experimenting with the first set of students in Bells University of Technology, Nigeria, as a case study, was investigated and satisfactory results was obtained. Student's curiosity increased and the subject is easier to teach. Procurement of training equipment is fast-tracked by the school management as the programme enrolment increases on a yearly basis. Popularity of the subject increases as more institutions are seeking ways to start the programme too.

The laboratory project used for analysis in this paper is a branch of mechatronics engineering, that is, sensing and control systems, whose principles was adapted to control home appliances using GSM modem, a microcontroller, a mobile phone, and electronic switches.

Keywords: *Mechatronics, microcontroller, modem, GSM, automation*

Date of Submission: 08, December, 2012 <=====> Date of Publication: 05, January 2013

I.   Introduction

Mechatronics engineering is a new field of engineering that combines mechanical engineering, electronic engineering, software engineering, computer engineering, control engineering as well as system design engineering (Wikipedia, 2012). This new field of engineering seeks to produce an all-round engineer that would fit into virtually all engineering activities in industries such as; machine vision, automotive engineering, computer aided design, sensing and control systems, mobile applications, robotics and so on. However, mechatronics engineering is not popular in Nigeria as only two universities presently offer it as bachelor degree programme; Bells University of Technology, Ota, Ogun state, and Afe Babalola University in Ado-Ekiti, Ekiti state. This paper is therefore serving as a medium to introduce mechatronics engineering to Nigerian populace using a school project to drive relevant points home (Donald et al, 2010). The aspect of mechatronics engineering that deal with sensing and control system is greatly exploited in this work.
The rest of this paper is divided into; concept of automation, methodology, results and discussion, conclusion and recommendations.

II.   Concept Of Automation

Automation engineering involves the design, development and implementation of sensor and robotic systems for applications across a wide range of technological sectors(Rosslin & Tai-hoon, 2010). Modern engineering systems employ a broad spectrum of technologies, which when integrated provide for improved efficiency, quality and reliability (Efstathiou, 2011). The combination of mechanical, electrical and electronic engineering with computer technology, namely; mechatronics, is core to this endeavour. This integrated approach is becoming increasingly important in modern technological environments as seen in the work of Si Kandar, Khan, and Shehzadi (2009).

This automation concept is used in this work to provide remote monitoring of electric power availability in Nigerian homes and control of home appliances through mobile phone.

III. Methodology

3.1. Algorithm

The steps taken to accomplish this task are as follows:

    i.   A 12Volts power supply unit is designed with regulator.

    ii.   A microcontroller is chosen and programmed using C-language (Krishnan, 2011) to communicate between 2-SIMs(subscriber identity module). This serve as a controller between the mobile phone and the electromechanical actuator that is being constructed.

    iii.   Design the switching circuit using electromagnetically operated switches such as dc relays.

    iv.   Connect a GSM module to the microcontroller in the actuator circuit (Mishra, 2004).

    v.   Test the module and correct any error(s).

From this algorithm, the skills needed to accomplish this task cut across the following engineering fields; electronic engineering, computer engineering, control engineering, mechanical engineering, software engineering, and telecommunication engineering.

Any engineering task involving diverse engineering skills such as this is a mechatronics engineering task.

3.2. Hardware Supports

The units involved in this model of GSM based automation for monitoring and control of power systems are:

    i.   Power supply

    ii.   Regulator

    iii.   Microcontroller

    iv.   GSM Modem

    v.   Switches

3.3. Block Diagram

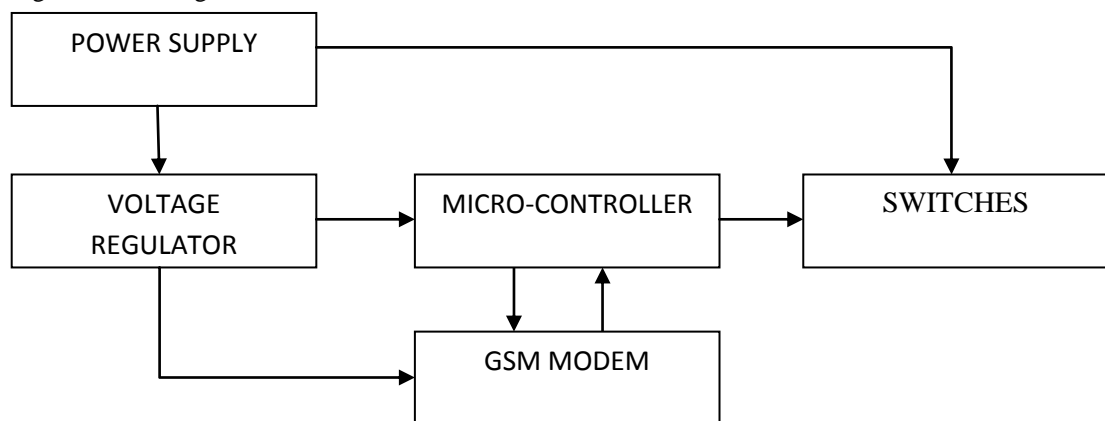The block diagram combining the five units involved is shown below:

Figure 1: Block diagram of GSM based automation for monitoring and control of power systems
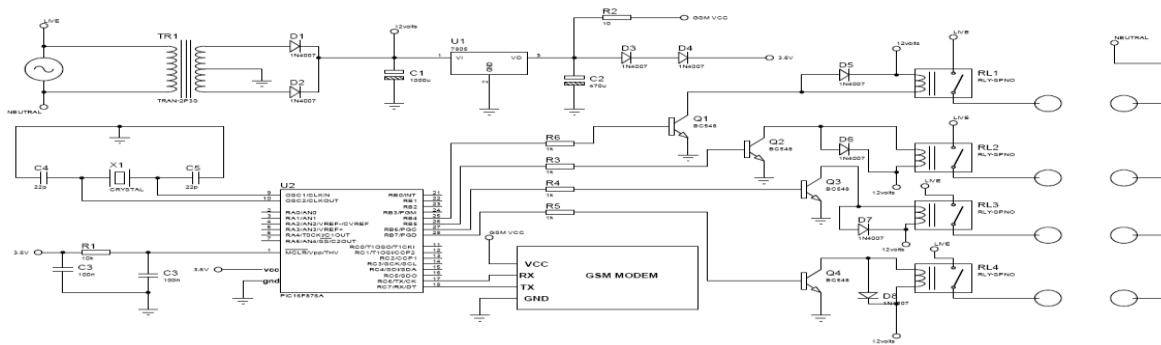
3.4. Circuit Diagram

Figure 2: Schematic for GSM based automation for monitoring and control of power systems

3.5. Design Calculations of Power Supply and Regulator

The microcontroller, PIC16F876A, requires a 5-volt supply. For this novel design, a voltage regulator IC78L05 was used to regulate the rectified output dc voltage of 12V to 5V that is, a 220V AC to 12V AC transformer is used to step down the 220V to 12V that is rectified into 12V DC supply which is further regulated and filtered into 5V DC.
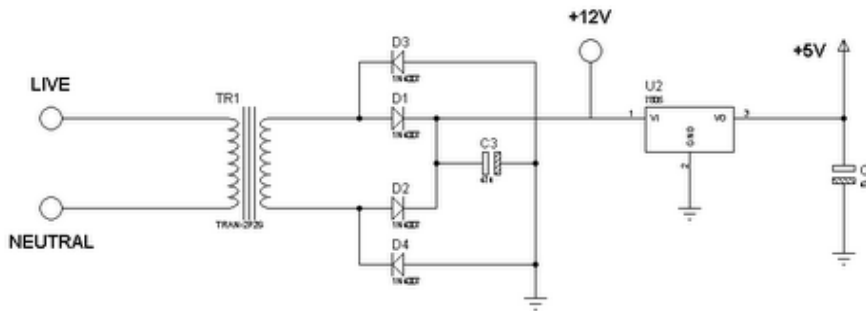

Figure 3: Power Supply Unit

By using a 240V transformer on a 50Hz supply and transformer secondary root mean square (r.m.s.) voltage output is 12V.

$$Peak\ Voltage, Vp = Vrms * \sqrt{2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

$V_p = 12\sqrt{2} = 16.97V$

$$Supply\ frequency, f = \frac{1}{period\ (T)} = 50Hz \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

$$Period, T = \frac{1}{f} = \frac{1}{50} = 0.02s = 20ms \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(3)$$

The total voltage drop, V_d , for the two diodes involved in the rectification process in either of positive or negative cycles,

$$Vd = 2 * Vbe \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(4)$$

$$Vd = 2 * 0.7 = 1.4V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(5)$$

Actual peak voltage values, $Vlm = (Vm - 2 * Vbe)$V $\dots\dots\dots\dots\dots\dots\dots$(6)

$$Vlm = (16.97 - 1.4)V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(7)$$

$$Vlm = 15.57V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots(8)$$

Change in peak voltage value over the discharge period,

$$\delta V = V_{LM} - V_{dc} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(9)$$

$$V_{dc} = 10V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(10)$$

The filter capacitor should not discharge down to 6V in accordance with the input voltage specification of the voltage regulator.

$$\delta V = (15.57 - 10.0) = 5.57\ V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(11)$$

Change in time over the discharge period, $\delta t = 10ms$

Total current consumption for this design is not expected to exceed 600mA.

Hence, the value of the filter capacitor is obtained this:

$$C = \frac{600mA \cdot 10ms}{5.57V} = 1077.20\mu F \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(12)$$

To provide a safety margin, the capacitor value chosen is twice the calculated value which implies a value 2154.4 μF. The nearest available capacitor value of 2,200μF is used as the filter capacitor.

$$T = R * C = 10k\Omega * 100pF \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(13)$$

$$T = 1\mu s \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(14)$$

3.6. Basics of Microcontroller - PIC16F876A
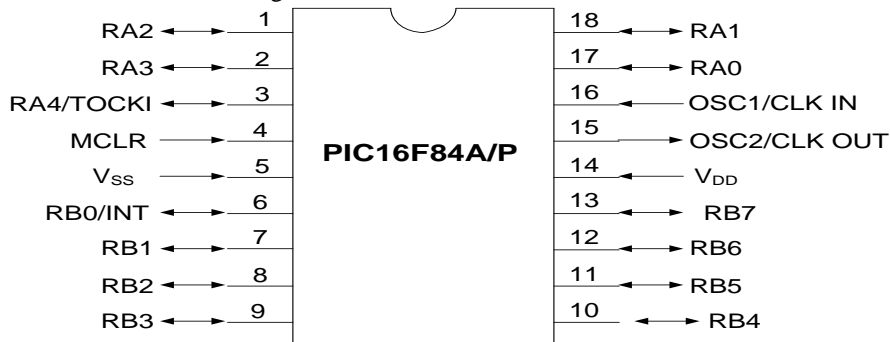
PIC16F876A architecture is shown in figure 4.

Figure 4: PIC16F876 Pin out

The microcontroller input voltage is made low at start up and hold a value of zero such that program execution begins at the top of the program memory (at address 0×0000). This is achieved by arranging a RC integrator at the microcontroller input. The capacitor is unchanged at start up and therefore short circuits microcontroller to ground causing a reset. But with time, the capacitor charge up, releasing the controller from reset as the microcontroller voltage rises. The basic RC network used to achieve this allows for a 1µs reset at start at for the microcontroller (Lucio, 2012).

3.7. Algorithm for Programming the Microcontroller
* The microcontroller sends "AT + CMGR = 1" to the GSM modem. This command means reading a message from memory location 1.

* If the location 1 is empty, the modem will reply with a message that contains the string "ERROR". Then the microcontroller keeps sending the message (content of memory location) back to the microcontroller.
* The received message is then checked and if it matches any of the predefined commands, then the instruction attached to the mach is carried out.
* The microcontroller will then send "AT + CMGR = 1" to the modem. This means delete the message in location 1. This is to make location 1 free to receive any incoming message.
* The microcontroller goes back to step 1.

3.8. The Switches
The output of the microcontroller controls the switching of the relays via the transistor switching stages, which switches to the different command signal's instructions. The power of the load to be activated depends on the relay contact rating; hence the choice of relay is critical.

Figure 6: Relay as a switch
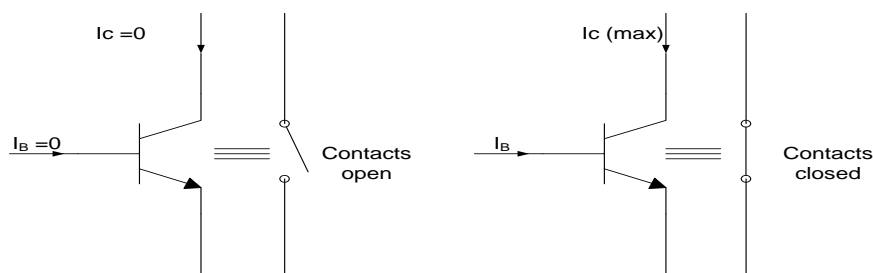
Figure 7: Transistor as a switch

The transistor as a switch operates in class A mode. The relay is switched on when the microcontroller gives a HIGH output. A base resistor is connected to ensure perfect switching of the transistor in saturation. The diode protects the transistor from back emf that might be generated since the relay coil presents an inductive load.

In this case R, which is the collector resistance, is the resistance of the relay coil, which is 400Ω for the relay type in this project.

Hence, given that R_c = 400Ω (Relay coil resistance)

$V+= 5V$ (regulated voltage from the power supply stage), $Vbe = 0.6V (for\ silicon\ transistor)$, $Vce = 0V$ (when transistor is switched on),

$Vin = 4V (supplied\ from\ microcontroller)$, $hfe = 300\ (obtained\ from\ data\ sheet\ for\ BC337)$

Therefore,

$$V+= IcRc + Vce \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(15)$$

$$Vin = (Ib * Rb) + Vbe \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(16)$$

$$\frac{Ic}{Ib} = h_{fe} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(17)$$

$$R_b = \frac{Vin - Vbe}{Ib} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(18)$$

where, I_c = collector current, I_b = base current, V_{in} = input voltage, V_s = supply voltage, V_{ce} = collector – emitter voltage, h_{fe} = current gain

From equation (15),

$$Ic = 12.5mA$$

From equation (17),

$$Ib = \frac{12.5mA}{300} = 0.417\mu A$$

From equation (16)

$$5 = 0.417\mu A \times R_b + 0.6$$

$$Rb = \frac{4.4V}{0.417\mu A} = 10,000\Omega.$$

IV.   Results And Discussion

4.1. GSM MODEM

The GSM modem is a bridge responsible for enabling/disabling of SMS capacity. The cell phone communicates with the GSM modem through radio waves. The mode of communication is wireless and mechanism works on the GSM technology. Cell phone number is configured on the system. User transmits instructions through SMS and the system takes action against those instructions. Sony Ericcson's K750i mobile phone handset acts as the modem, a necessary link between the user and the model.

Figure 5: Sony Ericcson K750i Model used as Modem

4.2. Model Construction and Testing

Having arranged the components on the breadboard, and satisfied with the performance of various key parts, that is, components, real construction on permanent platform is done.

Figure 8: Breadboard View

4.3.   Vero-Board and Soldering

Actual components were slotted into appropriate holes on the Vero-board to make the complete circuit. Soldering was carried out using a 40W soldering iron and flux for contact surface cleansing. Dry joints were prevented using appropriate testing skills in soldering.
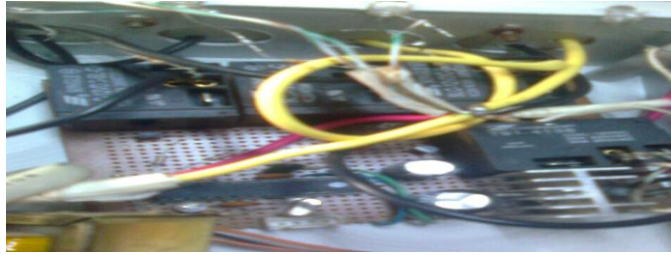
Figure 9: Soldered components display on Veroboard

4.4. Casing
A plastic case was used to house the circuit board. Attached to the plastic case is an extension box representing various load terminals for testing purposes.

Figure 10: Model Housing

4.5. Testing
In order to test the overall performance of the project, the following commands were sent from a configured/ designated GSM mobile phone to the mechatronics system's GSM mobile number as highlighted in table 1:

Table 1: Command and Interpretation of the signal

Command	Interpretations
ON UNIT 1	This command turns switch labeled '1' on. Once it turns on, an indicator (LED) is ON.
OFF UNIT 1	This command turns switch labeled '1' off. Once it turns off, an indicator (LED) is off.
ON UNIT 2	This command turns switch labeled '2' on. Once it turns on, an indicator (LED) is off
OFF UNIT 2	This command turns switch labeled '2' off. Once it turns off, an indicator (LED) is off.
ON UNIT 3	This command turns switch labeled '3' on. Once it turns on, an indicator (LED) is on
OFF UNIT 3	This command turns switch labeled '3' off. Once it turns off, an indicator (LED) is off.
ON UNIT 4	This command turns switch labeled '4' off. Once it turns off, an indicator (LED) is off
ON ALL UNITS	This command switches on all the units and their indicators glow
OFF ALL UNITS	This command switches off all the units and their indicators put off
STATUS	This command inquires whether a unit is ON or OFF. It displays results in decimal of all the units. For example, when a decimal number 9 is received, convert 9 to binary and you will have 1001. The most significant bit represents switch 1, while the least significant bit represents switch 4. The above result means switches 1 and 4 are on but switches 2 and 3 are off

V.   Conclusion And Recommendations

Mechatronics engineering could be taught effectively using laboratory exercises, handled by experienced tutors. A clear distinction was made in the course of teaching between mechatronics engineering and other traditional engineering branches such as mechanical engineering, electrical engineering, computer engineering, control engineering, and so on. Adopting the method of using practical illustrations in passing mechatronics engineering knowledge across to students quickened their assimilation rate and stirred up interest in the subject as experienced with the students of Bells University of Technology, Nigeria.

More institutions in Nigeria should be encouraged to start mechatronics engineering as a course of study. Sensitization should be carried out to encourage young individuals to take up careers along this line. Technologically, Nigeria cannot afford to be left behind in the scheme of things. All hands must therefore be on deck.

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