# Design and Implementation of Robot Equipped with Balancing Biped Mechanism

Engr. Bony Francis Rozario, Engr. Safwat Mostafa Noor, Engr. Md. Mahabub Hossain Bhuiyan, Md. Mahfuj Shekh

***Abstract***— Robotics is a field that brings together science and engineering, resulting in systems that interact intelligently with their environment. With applications ranging from agriculture to factory automation, from health-care to education, robotics is a fascinating and fun way to develop creativity as well as the design, implementation, and integration skills that are essential for computer scientists and technologists. Robotics has proven to be more friendly and economical in terms of technological advancement. The practical application of the robotics is achieved through the structure called ROBOT. Robotics is the science and technology of robots, their design, manufacture, application, and practical use. Robots will soon be everywhere, in our home and at work. They will change the way we live. This will raise many philosophical, social, and political questions that will have to be answered. In science fiction, robots become so intelligent that they decide to take over the world because humans are deemed inferior. In real life, however, they might not choose to do that. Robots might follow rules such as Asimov's Three Laws of Robotics that will prevent them from doing so. When the Singularity happens, robots will be indistinguishable from human beings and some people may become Cyborgs: half man and half machine.

## 1 INTRODUCTION

This research study is The Interface of electronic devices and mechanical structure which is programmed through the computer software to provide some specific tasks is defined "ROBOT". Robots are built to conceive the ideas of human being and take the modernization to a advanced level. The main theme of robotics is to bring the work of human, nature, animals and other world elements into a mechanical structure. A robot is a virtual or mechanical artificial agent. In practice, it is usually an electro-mechanical system which, by its appearance or movements, conveys a sense that it has intent or agency of its own. The word robot can refer to both physical robots and virtual software agents, but the latter are usually referred to as robots. There is no consensus on which machines qualify as robots, but there is general agreement among experts and the public that robots tend to do some or all of the following: move around, operate a mechanical limb, sense and manipulate their environment, and exhibit intelligent behavior, especially behavior which mimics humans or other animals. To relate the terms more accurately it might be said design, manufacturing and application of a certain ROBOT implies the term ROBOTICS. In this sense the term application specification is achieved through programming and electrical and mechanical advancement is done through design and manufacturing term of Robot. So by interfacing both this terms a structure is built, known as Robot. Design, manufacturing and application of a certain ROBOT implies the term ROBOTICS.

Application Specification: Programming >> Electrical and Mechanical: Design and manufacturing >> Robot

In general, robots are classified based on their capabilities. Some standard classifications of robots include their domain of operation, degree of autonomy, and the goal they are designed to fulfill. The fulfillment of such applications is achieved through the Artificial intelligence. To create a specific AI for the application oriented robot is the most crucial part of building a robot.

## 2 OBJECTIVE

The purpose of this robotic structure is to create an adaptive balancing mechanism based on simple sensors, actuator and simple algorithms which can be readily modified to be used with structure of any size and weight. The collaboration of the locomotion and the balancing of the robot have been achieved through instantaneously calculation of the pressure sensor values.

I. To design the structure of a Biped robot.
II. To implement the control circuit for balancing biped mechanism.
III. To implement a biped robot equipped with artificial intelligence for adaptive balance.
IV. To generate the accurate steps through the calculated values of pressure sensors.

After all the above mentioned states are completed a balancing biped model can be presented that response intelligently while undertaking the balancing process for walking. This model will have the provision to be edited and adapted to different type of robot structure as per requirement.

## 3 STRUCTURE OF BIPED ROBOT

The structure was basically designed to provide the joints necessary for walking. as the purpose is to mimic the walking nature of human, so all the necessary joints with relevant degrees of freedom was provided. the locomotion was achieved through the actuators which consist of dc motor, gears and holders. as for balancing purpose the pressure sensors were used at the bottom. the structural designs are discussed first followed by the working principle of all the devices and at the end prototyping is discussed.

### 3.1 PRINCIPLE OF DESIGN

To achieve the balancing mechanism of biped robot, at first the walking behavior of human body should be examined. The adaptation of the walking nature of human is sufficient for an efficient balancing mechanism. The degrees of freedom of muscle activation are vastly more numerous. There are more than 50 different muscles in one limb only, and each muscle is characterized by multiple functional actions. For simplicity, the degree of freedom is considered only for the movements of a leg. A leg's movement certainly depends on the individual locomotion of ankle, knee and hip. So, the degree of freedom of human leg can be represented in the following tabular form.

| Joint Name | DOF (prototype) | DOF (human) |
|---|---|---|
| Ankle | 2 | 2 |
| Knee | 1 | 1 |
| Hip | 2 | 3 |

Table 2.1: Degree of freedom of different joints of human

In human bipedal walking, body segments act in harmony with each other. Both the human body and bipedal walking are unique among other primates and other terrestrial animals. For adaptation of human walking pattern individual parts degree of freedoms should be considered.

## 3.2 STRUCTURAL DESIGN AND PARAMETERS

The main goal in the designing of the structure was to mimic the human leg as much as possible while keeping the complexity minimum[20]. The structure must contain adequate degrees of freedom in the same directions as per the human leg. It is to be noted that not all the joints are targeted for implementation. Only the joints necessary for performing and viewing the balancing logic at work are to be implemented in the prototype. Table lists all the implemented joints and their degrees of freedom[19] from the prototype.

The hip joint in the prototype is lacking one DOF which will prevent it from moving in any other direction other than the XZ and YZ plane. This is adequate because the biped robot is intended to walk only on fully horizontal and horizontally sloped planes. The weight of the total structure also requires careful attention as it can severely affect the total balancing scenario of the biped system. Other parameter that must be considered while designing is the space required to implement the actuation mechanism, the available torque from the actuators to be used in the structure and space for placing the control circuitry, connections, sensors and feedback mechanisms. Figure 2.2 shows a 3D visualization of the proposed prototype.

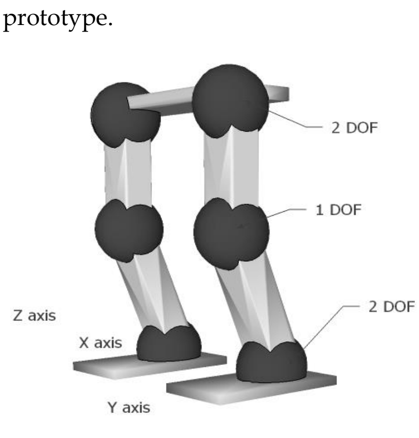


Figure2.2: 3D visualization of DOF of the robot.

Instead of designing a live size prototype a miniature model was targeted. This would prove greatly efficient for:

a) Weight of the structure.
b) Required actuators.
c) Required sensors.
d) Availability of build building materials.
e) Maneuvering the structure.
f) Selecting a power source.

Figure2.3 shows a more technical 3d visualization that proposes certain shaft placements for achieving the required DOF. The model also gives an idea on the possible dimensions targeted for building the robot.

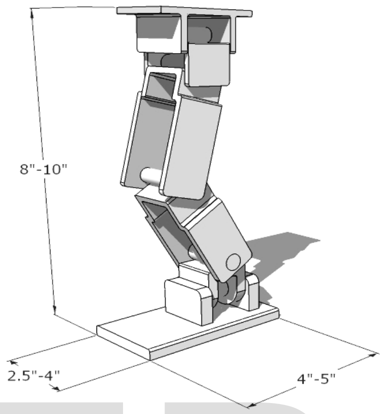


Figure2.3: Proposed shaft placements and targeted dimensions in 3D.

The drawing for the final design is found at figure 2.6. this structure involves using a gearbox which is commercially available and uses only plastic spur gears. A smaller DC motor (RF 310TA) was used. The materials used for housing the motor and gears and output shafts where also made out of materials which are light in weight. This resulted in a structure which was light in weight and had very little amount of slack at the output shaft. Due to the readymade gearbox, the precision of this system was very high. The structure also has the provision to attach a POT to the output shaft which would take the feedback and indicate the current location of each joint.

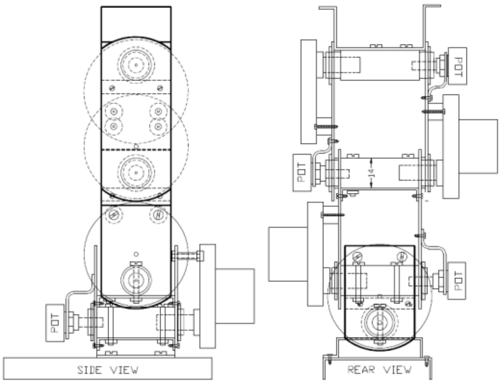


Figure 2.6: Front view and rear view of final structure

The structural design meets all the requirements for mimicking the human leg and biped walking. It has all the degrees of freedom mentioned earlier.

Figure 2.9: Actual gear arrangements in each module

## PROTOTYPING PROCEDURE AND MATERIALS

- Plastic Gear
- DC motor RF-310TA-11400
- DC motor RF-300EA-1D390
- Pressure censor
- Aluminum shaft
- Thin iron sheets

## THE TOTAL STRUCTURE

Figure 2.16 shows the total structure after completion. With the help of the devices described above the structure was completed. The structure is well within the dimensions of the firstly propose structure and has a weight under 1kg (without circuitry and power source).

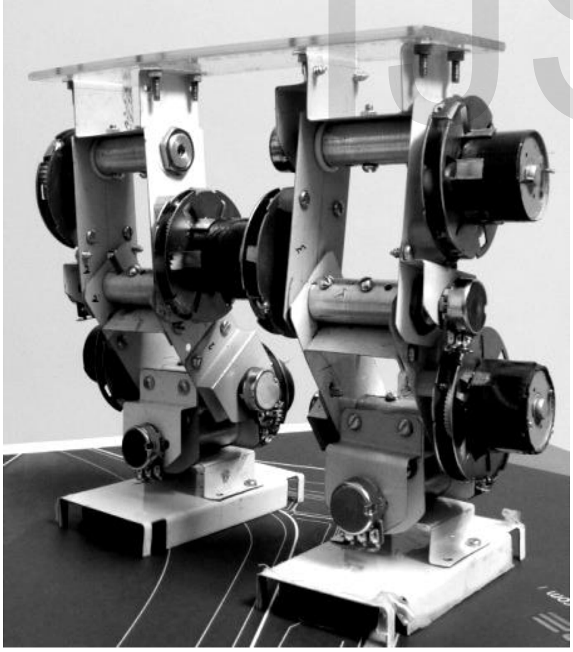


Figure: 2.16: The total structure of the robot.

## *DESCRIPTION OF IMPLEMENTED CIRCUIT*

To operate the robot a special board was developed for the locomotion. For this purpose a basic development board was designed to operate the whole structure through a microcontroller. The design of the development board should be such that it provides the basic artificial Intelligence accustomed with the circuitry to provide the relevant locomotion of the total structure. For controlling the DC motors used for the joint movements the concept of "H-Bridge" circuit [] has been used. This setup of motor control circuit requires 4 pins. Robot has in-total 12 motors, which will require 48 pins to achieve the rotation of each motor but our microcontroller has only 32 input output pins. To reduce the consumption of pins, the circuit must be modified as shown in figure 3.2.

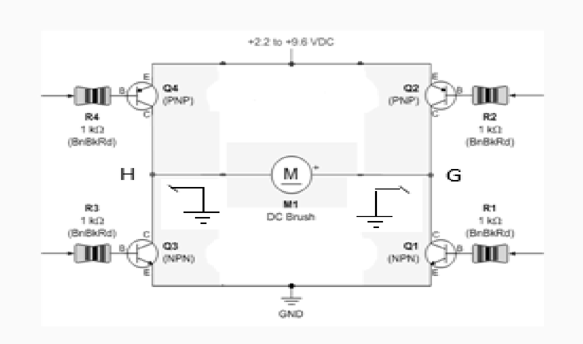


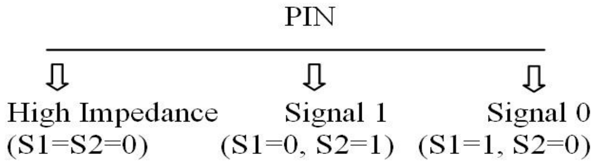
Figure 3.2: Modified H-Bridge Circuit

Firstly, two control signals will be considered S1 and S2. To turn the motor in the clockwise direction signal S1 is provided to transistor Q1 and the transistor Q4 is connected to point G in between transistor Q1 and Q2[29]. As a result when transistor Q1 is turned ON by signal S1, point G will virtually convert to ground making transistor Q4 also turn ON. Again for transistor Q2 providing the signal S2 and connecting the base of transistor Q3 to point H between transistor Q2 and Q4 will rotate the motor in anti-clockwise direction.

Table 3.2: Motor Rotation Controlling through modified H-Bridge Circuit

| Signal | Turn ON | Turn OFF | Rotation |
|---|---|---|---|
| S1 | Q1,Q4 | Q2,Q3 | Clockwise |
| S2 | Q2,Q3 | Q1,Q4 | Anti-Clockwise |

By modifying this circuitry it is also possible to provide two signals by only one pin. The basic concern will be to use a single pin and provide two signals represented by 1 and 0. This condition will give rise to a third signal which is "High impedance" state. Single pin outputs are shown in the following chart:



The high impedance state is achieved by assigning the control pin of the microcontroller as an input. The high and low state is achieved by assigning the control pin of the microcontroller as an output and provide required control signal. For generating the above mentioned states for S1 and S2, by only a single pin requires a two stage transistor based conversion circuit. This circuits it shown in figure 3.3.

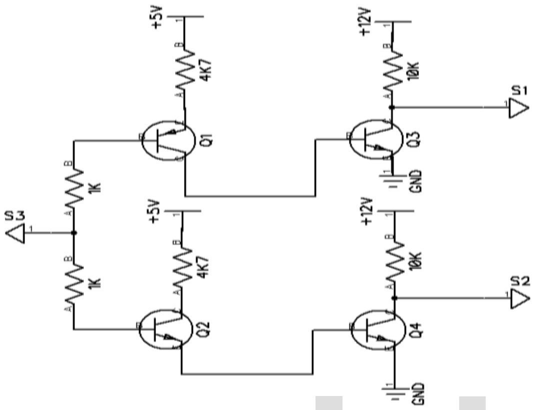


Figure 3.3: Modified control circuit (single pin) for H-bridge.

Here the first stage circuit is comprised of Q1 (2SC1815) and Q2 (BC557)[17]. The base of these two transistors is connected to each other through two resistances. In this special configuration both of the transistors are turned on. This is because the base of a PNP transistor usually stays at potential which is 0.7v less than its emitter voltage and for a NPN the base will stay at a potential which is 0.7v more than its emitter voltage. So it is clear that the base of Q1 will be at a higher potential than the base of Q2 causing a small base current to flow from Q1-base to Q2-base, keeping both of the transistors in ON state. This is particularly helpful for our goal as the transistors stay in a definite ON state when no signal is provided to S3. The second stage of the circuit is comprised of Q3 (2SC1815) and Q4 (2SC1815). These two transistors are shifting the level of voltage from 5v to 12v. This is necessary because the control signal from the microcontroller will only be at 5v where as the transistors used in the H-bridge circuit will operate at 12v. Q3 and Q4 are both in common emitter configuration and their output is inverted as to their input.

When a control signal of positive 5v is present at S3, the transistor Q1 will be turned off and Q2 will be turned on. Due to this change in the first stage, Q4 of stage two will be on and Q3 will be off. Thus we will be getting high (+12v) at S1 and low (0v) at S2. For a control signal of zero volts (0v) at S3, Q1 will be on and Q2 will be off. This will cause Q3 to be in on state and Q4 to be in off state. Thus S2 and S1 will be high (+12v) and low (0v) respectively. When no control signal is present at S3, both Q1 and Q2 will be on in the first stage and accordingly Q3 and Q4 on in the second stage. For this condition S1 and S2 will both be zero. The total operation of the circuit can now be described in a table.

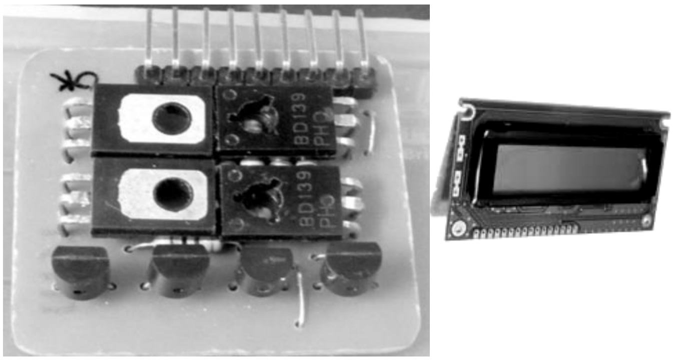


Figure 3.4: Actual implementation of Motor Control Circuit and 16 * 2 Alphanumeric LCD.

To control all the motors and to work with all the sensor data a main control board is required. This control board should have an environment for the microcontroller to interface with other circuits and equipments. The control circuit board should have proper power input for the microcontroller and additional onboard components. Also for independent movements control board should be fitted with power supply system. It also requires that power supply system of the total structure sync with microcontroller's required power additional circuitry.

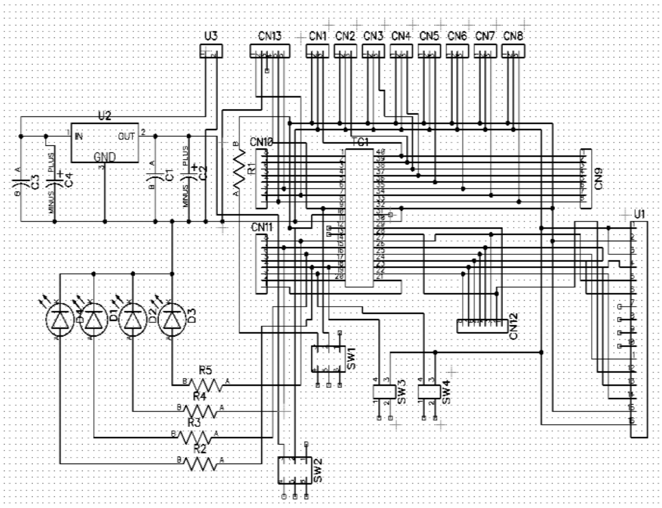


Figure 3.5: Schematic of Control Circuit Board

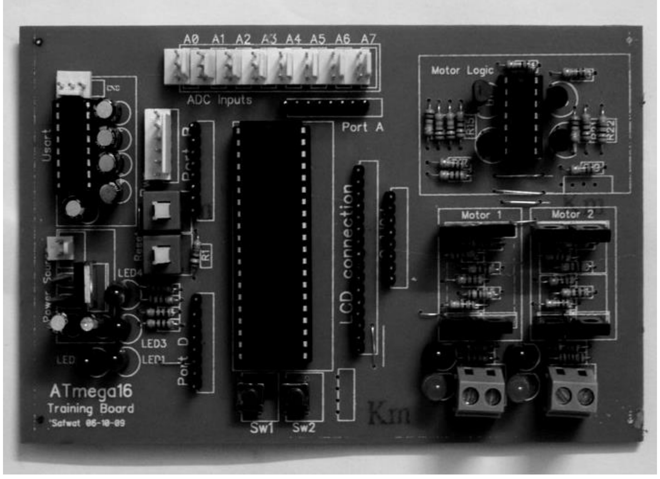


Figure 3.6: Control Circuit Board

List of feature
a. LCD connection.
b. Motor control logic circuit.
c. Motor driving circuit.
d. ADC sensor interfacing connection.
e. Serial communication connection.
f. Test switches.
g. Test LEDs.
h. In Circuit Programmable circuit.

A 16 Pin header is provided to interface one 16 * 2 Alphanumeric LCD. ADC input connections is used to take the values of the pressure sensors connections should be provided such that the analog values of the sensors are converted to digital value . A regulated Power supply [25] is the first and most essential step in projects involving digital ICs. **LM7805**

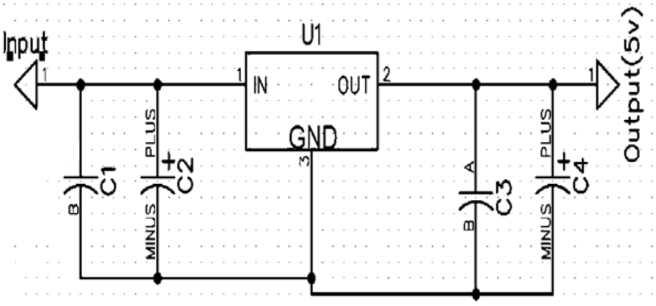


Figure 3.9: Circuit diagram of power supply

The board also has two switches for power on and reset. The circuit board also has a portion for motor control and driving. This is a two part circuit with one part dedicated to implementing motor control logic of PWM signal and the other part dedicated to supplying the motor with adequate power. The ATmega16 offers multiple protocols of serial communication including I2C, SPI, TWI and USART. The USART communication protocol is the most popular and can be easily implemented. This protocol is popular because it can be used to communicate with a computer as well as with other USART compatible devices such as another microcontroller.

RS232 communication through **MAX232 IC**

The robotic structure needs some specific instructions to execute the tasks provided to it. The movement mechanism of the robot is achieved by certain instructions. Before encoding the instructions the balancing mechanism should be sensed through specific sensors. After proper detection of the data gained through the sensors the robot is eligible to take the preferable steps. In other word the robot should senses the environmental change and then take a proper decision to execute the task. So an artificial intelligence should be created for the robot for the execution of the desired operation. This artificial is created through the programming of the microcontrollers. With specific code burning in the microcontroller and proper circuitry the desired tasks are done.

Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines. Artificial intelligence is the end result of computer and electrical engineering trying to simulate intelligence found in nature or intelligence required to achieve the goal of the a machine or a robot.

Artificial intelligence can be broken down to smaller independent desicional logic which can be then combined with one another for setting the course of action. So, The requirements are:

a. Digital Logic Device/IC.(For taking desicions)
b. Sensors (For taking environment data)
c. Some output device (For excecuting required action)

In other words, through sensors the environmental changes and other relevant changes are sensed. These sensed effects are processed through some digital circuitry or analog circuitry to provide some required output. To sense and then to provide the required output through some process of circuitry is achieved through Basic Artificial Intelligence. To achieve the balancing mechanism in this particular robot the pressure sensors are used to detect the surface alignment upon which the robot will move. This sensing data are used further to incorporate the programming part on microcontroller, which in this case is Atmel AVR Atmega16.

### Atmel AVR Atmega16

The ATmega16 has external connections for power supplies(VCC, GND, AVCC, and AREF), an external time base (XTAL1 and XTAL2) input pins to drive its clocks, processor reset (active low RESET), and four 8-bit ports (PA0-PA7, PC0-PC7,PB0-PB7, and PD0-PD7), which are used to interact with the external world. The ports are interconnected with the ATmega16's CPU and internal subsystems via an internal bus. The ATmega16 also contains a timer subsystem, an analog-to-digital converter (ADC), an interrupt subsystem, memory components, and a communication subsystem. The ATmega16 is equipped with three main memory sections: flash electrically erasable programmable read-only memory (EEPROM), static random access memory (SRAM), and by the addressable EEPROM for data storage.

The programming for the ATMEL ATMEGA16 mainly involves configuring internal registers as they are the main controlling elements of the microcontroller. Access to the internal registers of the microcontroller is done using the following tools:

a. CodeVision AVR C compiler. [10]
b. USB ASP MCU burner. [11]
c. Extreme burner. [12]

### Sensor interfacing

The two types of sensors that are to be interfaced with the ADC subsystem both has a common property. That is there resistance changes with respect to outside change. The potentiometer connected to each joint has a range of 0 to 22K of resistance change and the pressure sensors used has a range of 1M to 15K. To collect these reading by using the ADC, it is first required to convert these resistance changes into voltage changes. This is established using a voltage divider configuration.

The voltage drop across the POT or pressure sensor is taken as an analog input by the ADC. This voltage drop can be varied by changing the value of R1. The equation to calculate voltage across the sensor and its corresponding digital value is given by:

$$V_1 = \frac{V\ X\ (Sensor\ Res.)}{R1 + Sensor\ Res.}$$ [14]

ADC value =$V_1$ x 255/$V_{ref}$ (for 8 bit) [15]

ADC value =$V_1$ x 1023/$V_{ref}$ (for 10 bit) [15]

### Communication with ATtiny26

The ATmega16 SPI also provides for two-way serial communication between a transmitter and a receiver. In the SPI system, the transmitter and receiver share a common clock source. This requires an additional clock line between the transmitter and receiver but allows for higher data transmission rates as compared with the USART. The SPI system allows for fast and efficient data exchange between microcontrollers or peripheral devices. There are many SPI-compatible external systems available to extend the features of the microcontroller. For example, a liquid crystal display (LCD) or a digital-to-analog converter (DAC) could be added to the microcontroller using the SPI system.

### Motor interfacing

The actuation of the biped robot is based on DC motors with gear boxes attached. They provide low speed and high torque at the output shaft while consuming very little current. Though little, the microcontroller isn’t capable of directly driving the motors as they will consume current 5 to 6 times higher than that of a microcontroller can supply when they have to work under load. Due to this, an intermediate circuit is necessary which can operate the motors with respect to the control signals from the microcontroller while meeting their current demand. This circuit is based around high current capacity NPN and PNP BJTs and was described earlier in chapter three. The final characteristics table for that circuit was:

Table 4.1: Motor rotation at different state

| **State of S3** | **Motor Rotation** |
|---|---|
| No input (high impedance) | None |
| High (+5v) | Clockwise |
| Low (0v) | Anticlockwise |

So the code for controlling the motor should be able to change the states of the control pin to these three mentioned states: High, Low and high impedance. To do these one needs to access the I/O subsystem registers. The I/O subsystem assigns three register for each port. These three registers are:

a. DDRX register or the Dual Direction Data Register.
b. PORTX register.
c. PINX register.

Here X represents either A, B, C or D.

A brief description of the work of these register should be provided in order to understand their role in changing the state on the motor control pins.

The PORTX register is also known as the PORTX Data register. Any data that is to be outputted through a port must be first written in this register. The DDRx register or the Dual Direction Data register is used to set the I/O condition of the port to either input or output. It is to be noted that the input state will actually work as the high impedance state required for operation. The PINX register is where the data from the outside is stored when the port is set as input. Figure 4.8 summarizes the functions of these registers:

### Algorithms and Experimental Results

The robotic structure and the related programming and algorithms [23] are intended to work together to achieve the balancing mechanism of the total system. The response of the total robot therefore must be properly tuned and examined to detect any unwanted response. Each point of actuation and the value of each sensor must be calibrated for proper control. For this, simulation models and data tables are to be prepared that lists all the characteristics and operating behavior, including amount of errors. Every control element therefore must be individually tested and the codes regarding that part must be tweaked if necessary. After this processes a simulation or mathematical model of these parts/sensors and feedbacks may be prepared to pre estimate their condition in real life working scenario.

### Feedback characteristics:

The actuation in the robot structure was established based on DC geared motors. These geared motors were not run by applying direct DC voltage due to lack of control and inertia problem. A pulsed controlling mechanism was designed to control these motor gear arrangements. The first goal in programming a pulsed control signal for the actuation system was to create a pulse length that will enable the movement of the output shaft for a single unit movement. This unit movement is determined by the feedback system of each joint described earlier. The range of movement is detailed in the table below.

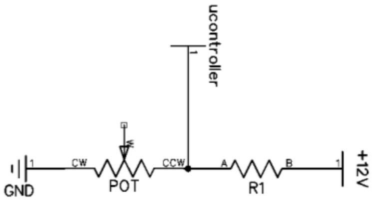


Figure5.1: Sensor configuration

Table: 5.1 ADC value from potentiometer for different position of each joint.

To achieve the optimum feedback resolution of each actuation, the range based on the 10K value in the voltage divider was selected. This range provides a total of 40 units of feedback change in the total range of movement, which ultimately results in 40 very minute movements in total. The next step in programming would be to program the motor pulse length in such a way so that each pulse moves the main output shaft "one unit" with respect to the feedback value.

**Actuation characteristics**

The actuation systems based on the geared motors are all connected to the feedback system described in the previous article. For controlling the movements monitoring the feedback values firstly require a proper control scheme for the motor itself. For driving the DC motors a pulsed signal control method was chosen due to the following reasons:

a. Enables the output shaft to be driven for unit rotations.
b. Removes the problem of movement due to inertia as with continuous drive.
c. Allows the control of the speed of the movement of the joints (at the cost of the inertia problem).

The pulse length now needs to be tested in a practical model to determine the optimum value. For this test, the ankle joint form the robotic structure was disassembled and tested individually. The POT value was taken using a single channel of the ADC and the motor was controlled using the motor driven circuit mentioned and described in the chapter thee.

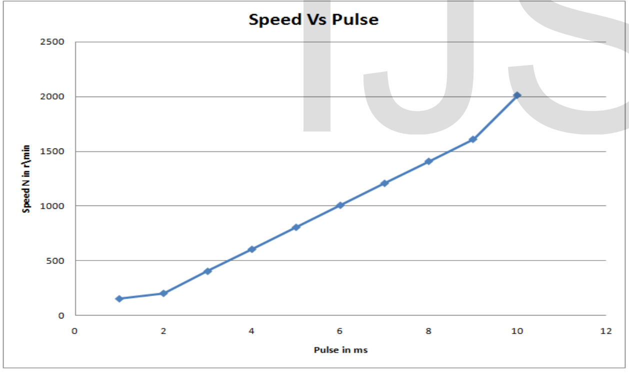


Figure5.2: Configuration for actuation characteristics testing

The following data was collected from the series of tests conducted on the testing configuration. From this table a controlling scheme is to be decided.

| Joint position | R1(1K) | R1(10K) | R1(22K) |
|---|---|---|---|
| Max Cw | 34 | 90 | 230 |
| Min Acw | 14 | 150 | 120 |

Table 5.2: Motor actuation characteristics.

In this type of controlling of the motor, the starting current and torque characteristics of the motor must be considered, because the tiny time period for which the pulses are given should generally be considered as a the starting condition of the motor. The starting torque of the motor isn't high enough compared to its running torque. Thus the torque available here isn't as high as the torque available while running in the normal dc voltage operation. From this table it can be seen that two of the pulse types provide greater torque than the other two schemes. Among these two the most appropriate will be the one which has the movement closer to the unit movement. Thus the pulse width of the motor control signal, sent to the motor driving circuit will be 3ms. A program that configures the output pulse was written and was used throughout the project programming.

**Balancing Mechanism**

The main goal of this project is to develop a mechanism that will balance the biped robot structure while it tries to walk. A simple and flexible implementation of this mechanism is also one of the prime objectives. Due to keep the complexity level low, very commonly found components where firstly chosen for this operation. To match with this trend, a simple and easily understandable process of walking should now be developed. Design of this will include three important parts:

a. A definite walking or moving pattern that the robot will try to follow.
b. Preprogrammed responses based on pressure sensor readings.
c. An algorithm that combines the above mentioned steps while walking.

All of the three steps mentioned are implemented are going to be performed by the microcontroller, where all the walking patterns, responses from pressure sensors and algorithms are programmed and stored.

**Moving pattern**

To make the robot take human like steps it is firstly required to design some movement pattern of each joint[18] that will enable the robot to walk in biped motion[24]. The movements should be carefully monitored and calculated so that the robot does not loose balance while walking. These movements will be done in series after one another, so that the robot takes successive steps when given the command. Each actuation will be governed by the motors and precisely placed using the feedback system. To illustrate the moving pattern, a series of 3D views of the robot is provided that exhibits how the joints will be moving on the process of taking a single step. Each joint is this view is marked with individual notations and the joint that is to be moved is marked in bold.

| Drive Pulse type | Pulse gap | Unit move ment | Movement accuracy test 100 | Movement accuracy test 120 | Speed/torque of movement |
|---|---|---|---|---|---|
| 2ms | 8ms | Less than 1 | 100% | 100% | High/Modera te |
| 3ms | 8ms | ~1 | 90% | 90% | High/Modera te |
| 2ms with stop pulse | 8ms | 0.5 | 100% | 100% | Slow/Low |
| 3ms with stop pulse | 8ms | 1 | 100% | 100% | Slow/Low |

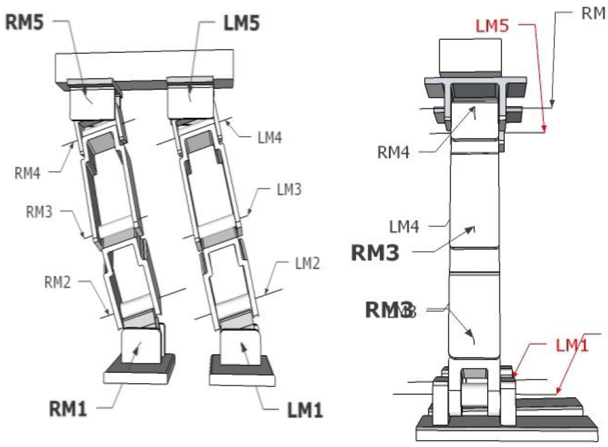


Figure5.3: First sequence of a step Joint LM1 RM1 and LM5 RM5 are actuating.

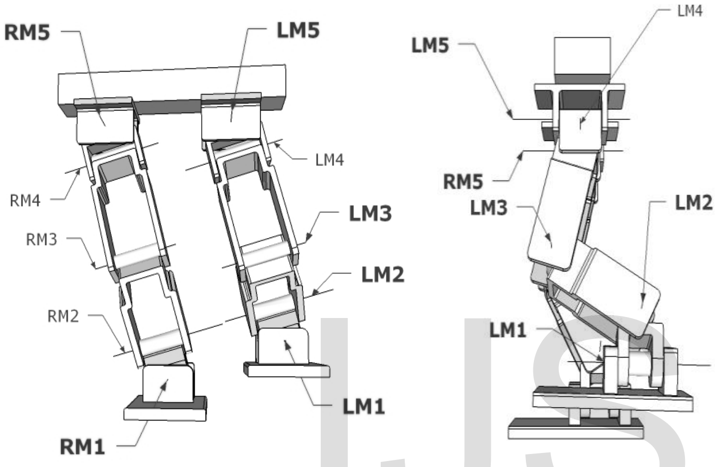


Figure5.4: Second sequence of a step. Joint LM3 and LM2 are actuating.

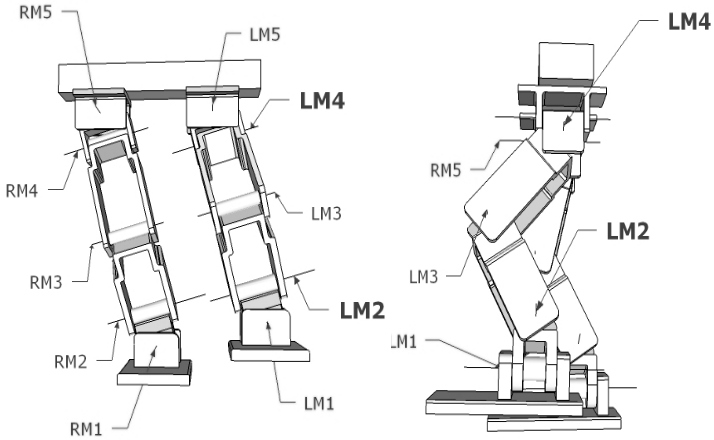


Figure5.5: Third Sequence of a step. Joint LM4 and LM2 are actuating.

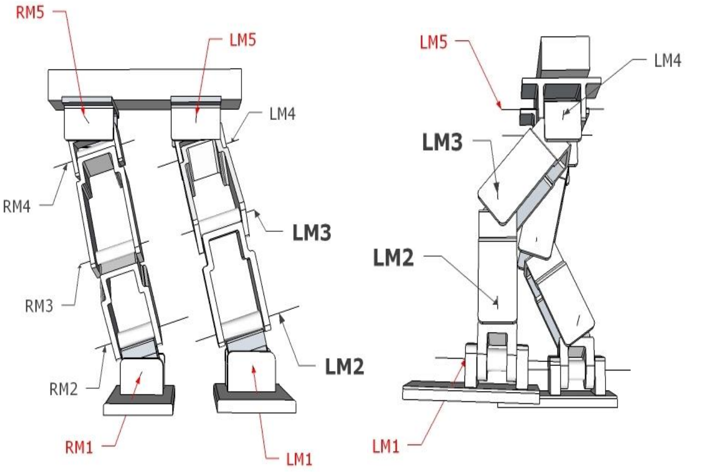


Figure5.6: Fourth sequence of a step. Joint LM3 and LM2 are actuating.

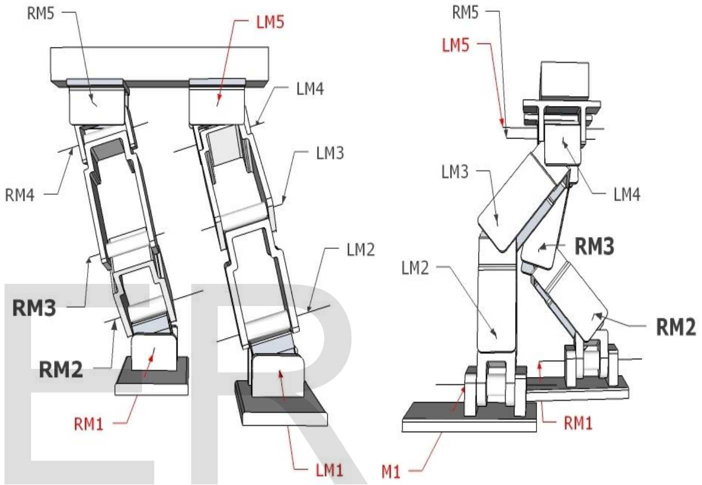


Figure5.7: Fifth sequence of a step. Joint RM3 and RM2 are actuating.

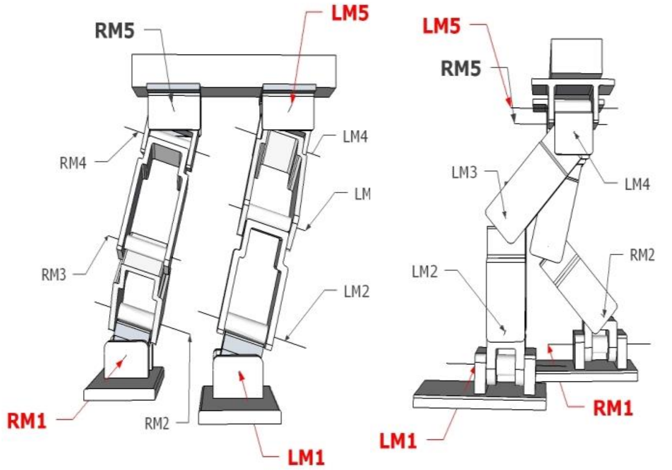


Figure5.8: Sixth sequence of a step. Joint RM1, LM1 and RM5, LM5 are actuating.

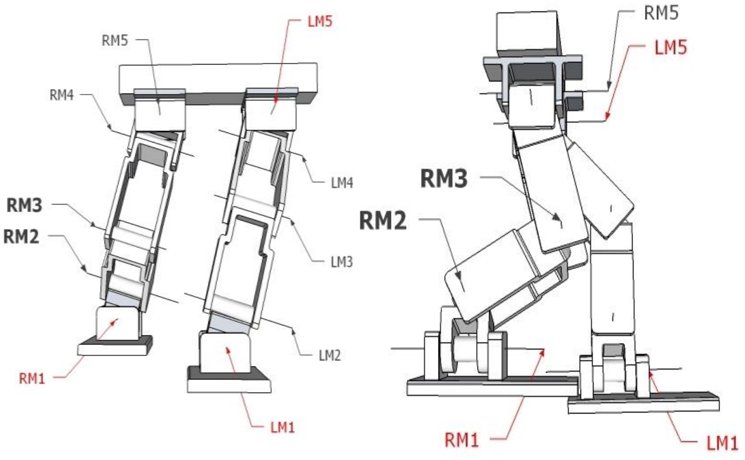


Figure5.9: Seventh sequence of a step. RM3 and RM2 are actuating.

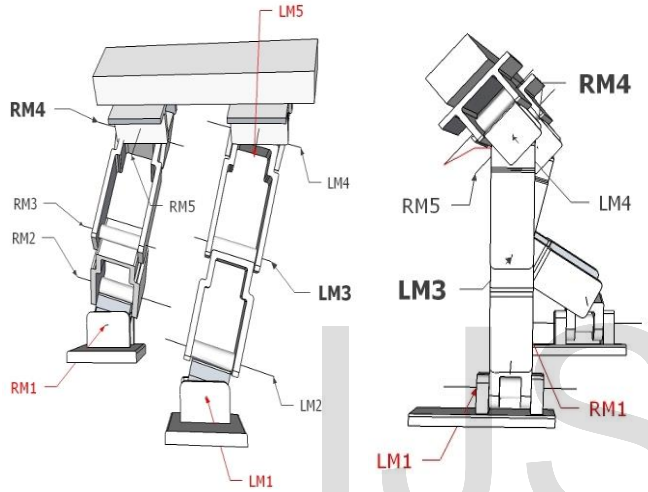


Figure5.10: Sequence eight of a step. RM4 and LM3 are actuating.

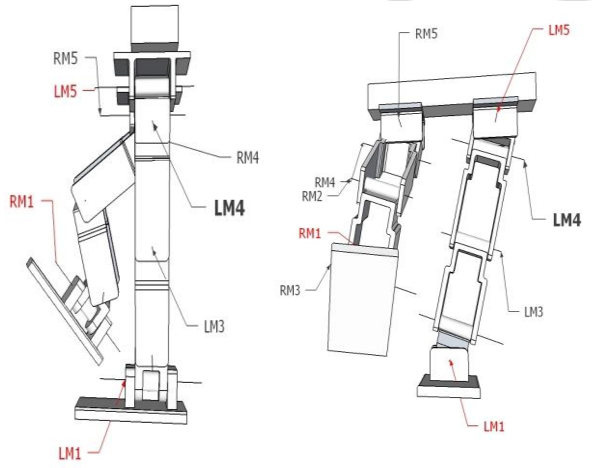


Figure5.11: Sequence nine of step. Only LM4 is actuating.

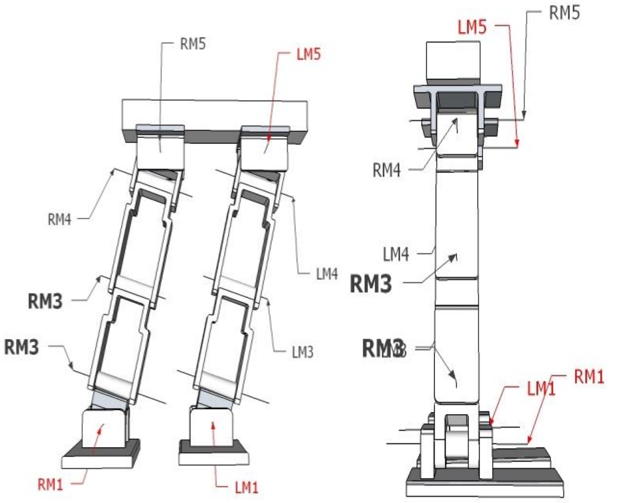


Figure5.12: Tenth sequence of a step. RM3 and RM2 are actuating.

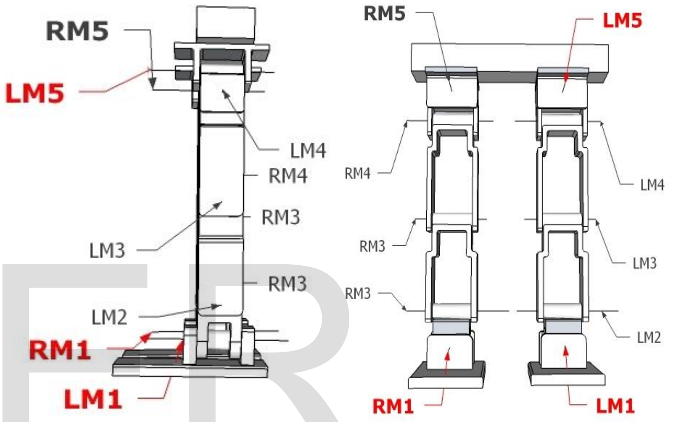


Figure5.13: Eleventh sequence of a step. RM5, LM5 and RM1, LM1 are actuating.

**Measuring Pressure**

After generating a successful walking pattern, the next step is to introduce the balancing mechanism that the robot will use to maintain stability in real time while walking. This balancing mechanism is mainly based on the pressure sensors values taken bye the microcontroller. The values of different pressures at four points under each foot is measured and used for deciding the proper response. The algorithm used behind this response will be described shortly, but for now the mounting and placement of the sensors must be decided. For the biped robot, each foot will have four sensors placed in the configuration shown in Figure 5.14. the sensors will be placed in between two rubber pads in order to make them stably fit during operation. The rubber pads will also protect the sensors from directly touching the ground surface and will reduce the error of the readings.

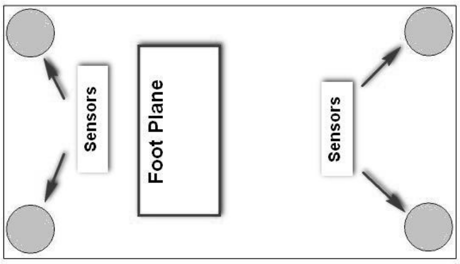


Figure5.14: Sensor placement under each foot.

The principle of making response to the values from the pressure sensors can be described pretty straightforwardly. By reading the value of these sensors, the microcontroller will virtually calculate an area under the foot, in which the center of mass of the total structure must stay in order to maintain balance. This area or stable zone under each foot can be calculated using the dimensions of the structure or can also be found by experimental testing. In the case of this project, it was found to be easier to determine the area using experimental testing as the dimension of the robot structure is not perfectly symmetrical. A small program was firstly written to test the approximate pressure on different sensors and the maximum value was noted for which the structure becomes unstable. The maximum value was tested for movements towards all the available direction of movement from the structure's point of view.

**Algorithm**

The algorithm used behind generating the response of the robot structure with respect to the values form the pressure sensors can be properly described using Figure 5.15. which shows a possible situation that the robot might face while walking.

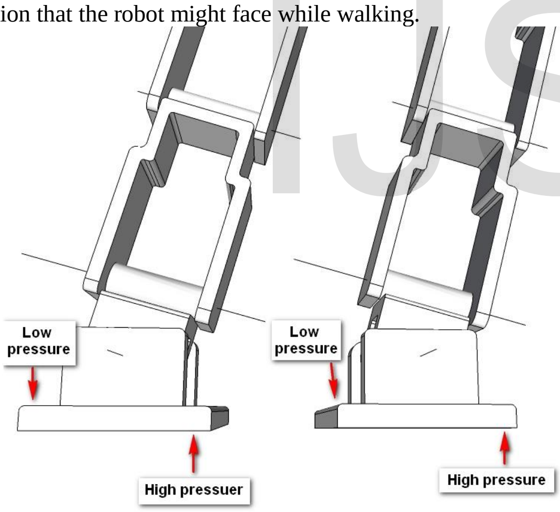


Figure5.15: Different foot conditions while walking.

In this figure 5.15 it can be seen that the robot is tilting to the right while its ankle joint keep both foot parallel on the ground. It can be understood from the figure 5.15 that the right side of each foot has more pressure than the left side dude to the tendency of the robot falling over on the right side. The amount of weight on each foot has moved from the center to the right side. This will be detected by the sensors on the right side and the microcontroller will detect that value by using its ADC. The algorithm must be such that, the detection of higher pressure on one side of the foot will trigger movements in the joint, such that the total weight of the structure moves to the central balancing zone of under one foot. This principle will be applies to the frontal sensors also. A separate algorithm for this operation is developed and will work in combination of the codes that generate walking the walking pattern.

**Results**

The response of the structure to the walking commands from the microcontroller was found to be satisfactory and the joints moved as per instruction to the control signals. The location of each joint was given to the secondary microcontroller through SPI and the secondary microcontroller takes proper feedback readings and generates control signals from the motors to place them in the location mentioned. As the result of this the walking pattern the robot takes successive steps forward. During these steps, the sensors value are taken regularly to ensure that the walking pattern does not cross the limit of the balance zone which maintains stability.

## LIMITATIONS

The main limitation of this project is the motors used. They provide just enough torque for moving the total structure but it is recommended to have torque higher than what is required. Due to no availability of servo motors, or better DC geared motors, this type of motors had to be used. Another drawback of this project is the potentiometers used. They do not provide accurate value in very minute changes of their shaft. Another limitng factor would be the time as it takes numerous design and correction steps to get to a final design capable of the objectives stated for this project.

## FUTURE PLAN

This project was built from the ground up to leave room for future work and easy adaptability. Thus suggestion for future work can include improvement of almost all of the aspects of the robot. The control circuit can be further enhanced to accommodate features for all the features of the ATmega 16 such as dedicated SPI pins, a motor driving circuits for all of the PWM channels, JTAG features etc. The motor control circuit can be made more compact and transistors of higher current can be used for higher load applications. Other than the circuits, the structure has room for huge improvements, better and more efficient gear mechanisms can be used to enhance the movement predictability of the structure. The use of servo motors would dramatically decrease the complexity of the structure and the number of individual parts used. Servo motors are very well suited for operations where continues rotation is not required. Thus in a robotic project servo motors would have proven very helpful, not only due to their single wire communication method, but also due to the high torque and accurate precision of its output shaft. The total structure design can be made more symmetrical to and the balance zone under each foot can be properly calculated for accurately maintaining balance. The weight of the total structure can be further reduced and the torque of the motors can be increased by using different type of motors with higher speed and gear box with higher reduction ratios. For taking feedback, the potentiometers can be replaced with optical encoders or high granularity potentiometers. The algorithms that where programmed in the microcontroller provide the maximum flexibility in this project for future work. The codes for motor driving and sensor data acquisition that were created can be used for different type of movement sequences. One can try out different walking patterns or any other movement patterns, without changing the codes for pressure sensor data acquisition. Even though that is possible, one can also change the codes for sensor data acquisition for further calibration of the walking process. Suggestions for future walk should primarily include a better control circuit board, a better and symmetric structure, better motors with higher torque and greater power efficiency and finally better algorithms and walking patterns by changing or rewriting the code. The current structure provides an insight on how these improvements can be achieved.

## CONCLUSION

The emergence of biped walking robots and balancing robots are increasing rapidly as advanced research goes into finding more efficient ways to make a man made robot structure move like man himself. Most of these researches include use of complex sensors such as accelerometers, gyroscopes, force meters etc. As a more natural flow of walking a running is researched, the complexity of the structures and designs increase. This project tries to move a little bit away from that flow and tries to implement that same balancing mechanism in a simpler manner with components that are very common. The complexity level is very low in this project and is suitable for any application where the high end accuracy and stability os not required. Along with being simple, this process of balancing also has high potential of being redesigned with other parametric enhancements for a very balancing very efficiently. Moreover, it is very easy to implement this logic in practical practice and one can add to this project with similar enhancements or can diversify this project through adding extra features such as an upper body structure. Since the main concept is simple, it takes less time to understand the concept and on can devote more time on future developments or adding extra features.

## REFERENCES

1] Wikipedia.org for information on robotics history. http://www.wikipedia.org
[2] Gear information from How Stuff Works http://science.howstuffworks.com/gear2.htm
[3] Datasheet of Mabuchi motor RF310TA http://www.mabuchi.com
[4] Datasheet of Mabuchi motor RF300EA http://www.mabuchi.com
[5] Datasheet of pressure sensor from interlink electronics.
[6] Datasheet of BD136 PNP and BD139 NPN BJT.
[7] Datasheet of LM7805 DC voltage regulator.
[8] MAX 232 level shifter IC datasheet. http://www.maxim.com
[9] Data sheet of Atmel AVR Atmega16.
[10] Application note of Atmel AVR ATmega16.
[11] CodeVision AVR manual from *www.hpinfotech.ro/html/cv**avr**.htm*
[12] USBasp - USB programmer for Atmel AVR controllers http://www.fischl.de/usbasp/
[13] Extreme burner for USB ASP www.extremeelectronics.co.in
[14] Steven F. Barrett and Daniel J. Pack, "Atmel AVR Microcontroller Primer: Programming and Interfacing", January 2008.
[15] Sourabh Sankule, "Beginners Guide To Embedded Systems & Robotics 2009", January 2008.
[16] Andrew L. Kun, W. Thomas Miller, "Adaptive dynamic balance of a biped robot using neural network" Robotics Laboratory, ECE Dept., University of New Hampshire, Durham.

[17] Pavan K. Vempaty, Ka C. Cheok, and Robert N. K. Loh "Model Reference Adaptive Control for Actuators of a Biped Robot Locomotion" Proceedings of the World Congress on Engineering and Computer Science 2009 Vol II WCECS 2009, October 20-22, 2009, San Francisco, USA

[18] Qiang Huang, Member, IEEE, Kazuhito Yokoi, Member, IEEE, Shuuji Kajita, Member, IEEE, Kenji Kaneko, "Planning Walking Patterns for a Biped Robot" IEEE Transaction on robotics and autonomous, VOL. 17, NO. 3, JUNE 2001
[20] Fred R. Sias, Jr. and Yuan F. Zheng "How many degrees of freedom does a biped need?" IEEE International Workshop on Intelligent Robots and Systems IROS '90
[21] Andre Senior, and Sabri Tosunoglu, "Design of a Biped Robot" Florida International University, Department of Mechanical Engineering, Miami, Florida 33174
[22] Ming-Yuan Shiehl, Ke-Hao Chang Chen-Yang Chuang, Juing-Shian Chiou, "ANFIS based Controller Design for Biped Robots" Kumamoto Japan, 8-10 May 2007
[23] Joao Paula Ferriera, Mauel Crisostomo, Paula Coimba," Neuro-Fuzzy ZMP Control of a Biped Robot" Modelling and Optimization, Lisbon, Portugal, September 22-24, 2006
24] Joe Cronin, Richard Willgoss, Robin Ford "Control of a Heavy Weight Biped Robot in the Frontal Plane" The University of New South Wales Sydney, Australia
[25] Robert L. Boylestad, "Introductory Circuit Analysis", Tenth Edition Prentice-Hall of India, April 2004 pp. 34-35 and 75-78
[26] Robert L. Boylestad, "Electronic Devices and Circuit Theory", Ninth Edition Prentice-Hall of India.
[27] Robert F. Coughlin, "Operational Amplifiers and Linear Integrated Circuits", Sixth Edition

Novemberl 2002 pp. 38-44 and 79-88.
[28] Charles A. Schuler and William L. McNamee, “Industrial Electronics and Robotics”, Sixth Edition January 2001 pp. 34-35 and 75-78
[29] Jacob Millman and Christos C. Halkias, “Electronic Devices and Circuit”, Fifth Edition Prentice-Hall of India, April 2002 pp. 54-65 and 75-78
[30] B.L.Thereja, “Electrical Machines” 10th Edition, Prentice Hall of India, pp. Synchronous motors September 2000

## AUTHORS BIOGRAPHY

Engr. Bony Francis Rozario: Engr. Bony Francis Rozario is on the verge of completing his Master’s degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB) having Power Engineering as Major. He has been serving as Assistant General Manager (Power Projects) from 2010 for a private organization named ‘MAISHA GROUP’. He has completed his bachelor degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB). Afterwards, he perused his Internship at Siddirgonj Power Station, Bangladesh having a 210MW steam power plant and 2×120MW gas power plant)
Email: bfrboss@gmail.com

Engr. Safwat Mostafa Noor: Engr. Safwat Mostafa Noor is perusing his PhD. Program at The University of Texas at San Antonio as Associate Research Scientist. He completed his Masters in Embedded System from Nanyang Technological University, Singapore. He was also severing as Embedded Engineer at TCAM Technology Pte Ltd. from 2012- 2013. He has completed his Bachelor Degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB).
Email: 4himel@gmail.com

Engr. Md. Mahabub Hossain Bhuiyan: Md. Mahabub Hossain Bhuiyan Noor is perusing his Master’s degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB). He has been serving as Coordinator (Power Projects) from 2011 for a private organization named ‘MAISHA GROUP’. He has completed his Bachelor Degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB).
Email: satubmh@gmail.com

Md. Mahfuj Shekh: Md. Mahfuj Shekh Noor is perusing his Master’s degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB). He is currently serving as RF Engineer at CFVL, Dhaka, Bangladesh appointed from 2012. Previously he served from Robson Engineering Ltd., Bangladesh as RF Engineer. He has completed his Bachelor Degree in Electrical & Electronic Engineering from American International University Bangladesh (AIUB).
Email: shekh_mahfuj@gmail.com