Design and Implementation of BIPED Robot using dsPIC30F2010 controller

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Abstract- *The rapid advancement and development in the field of Electrical and Electronics Engineering has led to major innovation in the field of motion controls. So to implement the motion control of a DC servomotor is been taken and for the use and application of Dc servomotor Robotics is been chosen, so by combining the electrical and mechanical knowledge a moving Robot is being implemented. In the field of Robotics motor controlling has become most challenging task. This really needs sound knowledge over machines and speed/motion/movement control and also proper planning of the steps. By using the same idea a BIPED Robot will be implemented. This paper proposes PWM (Pulse Width Modulation) based control of servo motors which are being used to control and design a BIPED Robot. BIPED Robot stands for a Robot which can walk with two legs, the demonstration of BIPED Robot which will be nothing like PENGUIN. A servo motor controller is designed to control the motions of the BIPED robot, which has servo motors (Tower Pro MG90S) to accomplish the movement of Biped Robot legs and Torso. Microchip's dsPIC30F2010 is being used to design the controller for servo motors. The version of dsPIC which is been chosen here is of 30F2010 since it is having special features to control the electrical machines which feels better advantageous over other types. Biped robot walks like a human by balancing the Centre of Mass which resembles the peguin.*

Keywords — *Biped Robot, dsPIC30F2010, Tower Pro MG90S Micro Servomotor, PWM*

INTRODUCTION

With advances in science and technology, the interest to study the human walking has developed the demand for building the Biped robots. The development of Biped walking robot involves research in heterogeneous areas. This Paper describes the first attempt in building the Bipedal walking robot. DC Servo Motors become an important device in a wide range of industrial applications that require high dynamics on position control such as numerically controlled machinery, robotics, automation and other mechanism where the starting and stopping functions are quick and accurate. These applications require a high-speed control accuracy and good dynamic respond. In robotic applications, servo motors are used to move the robotic arm to a relevant position by means of controllers in the automated manufacturing lines of industries. The rotor construction of servo motors is made up of special material with less weight to decrease the inertia of armature but capable to produce the necessary magnetic flux. Low rotor inertia increases the capability of immediate starting and stopping during the on-off conditions. The torque holding capacity of normal DC motors becomes a major issue. Hence Tower Pro MG90S Micro Servomotors are used to make the Biped Robot which gives the stiffness in the movement. One more aspect of implementing Biped Robot with servomotor is reducing the time delay between the commands. By using data sheet of MG90S micro servomotor frequency and duty cycle required for the movement of the motor were calculated. According to the requirement PWM signals are generated for 50 Hz frequency with variable duty cycle and are given to the servomotors to achieve the movement of the Biped Robot. These PWM signals are controlled by dsPIC30F2010. DsPIC30F2010 has 6 channels of PWM available. Hence it makes 3 servo motor connections easier for the implementation.

THE PROPOSED METHOD

In this paper the Biped Robot is constructed by using 3 servomotors, MG90S, which are controlled by servo motor controller. The block diagram for implementing Biped Robot is shown in Fig.1 as below:

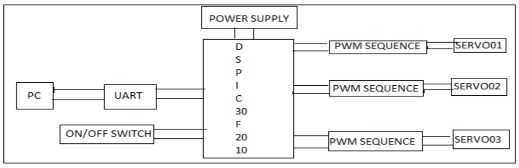

Figure1: Block diagram for Biped Robot

(a)Generation of PWM signal:

Pulse Width Modulation (PWM) or Pulse Duration Modulation (PDM) signals are a two state signal (square or digital) with a fixed frequency and whose duty cycle can vary. The simplicity of such coding is widely used in reduced model. Receiver transmits servo-motor position information through a PWM signal whose frequency is 50Hz (20ms period) and whose duty cycle takes values between 1ms and 2ms, 1.5ms being the servo motor central position. PWM transmission is one of the easiest ways to have two microcontrollers exchanging variables.

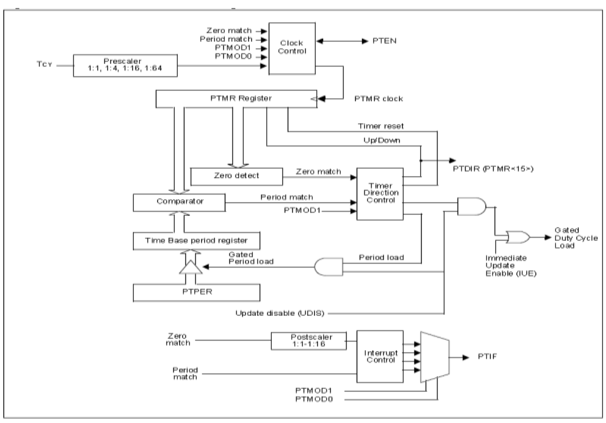

Figure.2. dsPIC30F2010 PWM Time Base Block Diagram

The PWM time base is provided by a 15-bit timer with a prescaler and postscaler (see Figure.2). The 15 bits of the time base are accessible via the PTMR register. PTMR<15> is a read-only status bit, PTDIR, that indicates the present count direction of the PWM time base. If the PTDIR status bit is cleared, PTMR is counting upwards. If PTDIR is set, PTMR is counting downwards. The time base is enabled/disabled by setting/clearing the PTEN bit (PTCON<15>). PTMR is not cleared when the PTEN bit is cleared in software. The PWM time base can be configured for four different modes of operation, such as:

- Free Running mode
- Single Event mode
- Continuous Up/Down Count mode
- Continuous Up/Down Count mode with interrupts for double-updates.

These four modes are selected by the PTMOD<1:0> control bits (PTCON<1:0>)

The generated PWM signal for following specification is shown in figure.3

Pulse cycle 20ms,

Pulse width 450-2450 µs /0.5ms-2.5ms

Frequency 50Hz

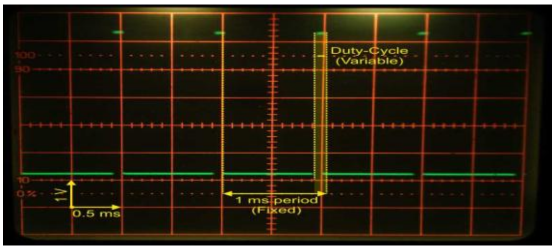

Figure3: PWM Output for 50Hz Frequency

The following formulas were used to calculate frequency for generating PWM signals:

PTPER-PWM Time based Period

PTMR- PWM Time based register

$$PTPER = \frac{Fcy}{Fpwm * (PTMR\ prescalar)} - 1$$

$$\text{Duty cycle} = \frac{\left(\frac{PDCx}{2}\right) - DT}{PTPER + 1}$$

(b)Principle of operation of servomotor:

Servos are controlled by a pulse of variable width. The sent signal of this input pulse is characterized by a minimum pulse, maximum, and a repetition rate as seen in Figure 3. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in a clockwise direction as it is in a counter clockwise direction. The angle is determined by the duration of applied pulse to the signal wire which is called PWM or Pulse Coded Modulation. The servo should detect a pulse every 20ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to a 90 degree position (neutral position). The position pulse must be repeated to instruct the servo to stay in position.

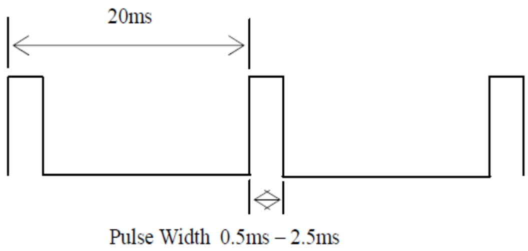

Figure4: input pulse to servo-motor

When a pulse is sent to a servo that is less than 1.5 ms, the servo rotates to a position and holds its output shaft some number of degrees counter-clockwise from the neutral point. When the pulse is wider than 1.5 ms, the opposite operation is occurred. The minimal width and the maximum width of pulse that will command the servo to turn to a valid position are functions of each servo. Generally the minimum pulse will be about 1ms wide (some servo is 0.5 ms) and the maximum pulse will be 2 ms wide (some servo is 2.5 ms). The servo motor operates in the range of 3 % to 12 % of duty cycles. Figure5 shows relationship between pulse and direction of servo motor.

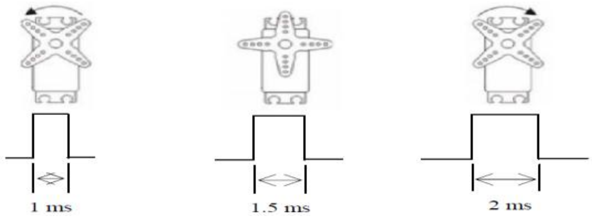

Figure5: Relationship between pulse and direction of servo-motor

The PWM is a commonly used technique for controlling power into electrical device. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load, ON and OFF at a fast pace. The longer the switch is ON compared to the OFF periods, the higher the power supplied to the load is. AC drives required the sinusoidal signal and modulation generator. The triangular signal is the carrier or switching frequency of the inverter. The modulation generator produces a sine wave signal that determines the width of the pulses, and therefore the RMS voltage output of the inverter. For DC drives, the PWM signal is generated by comparing a triangular wave signal with a DC signal as shown in Figure6. The DC signal can be ranged between the minimum and maximum voltages of the triangle wave. The PWM signal is measured using the percentage of duty cycle where the pulse duration over the pulse period.

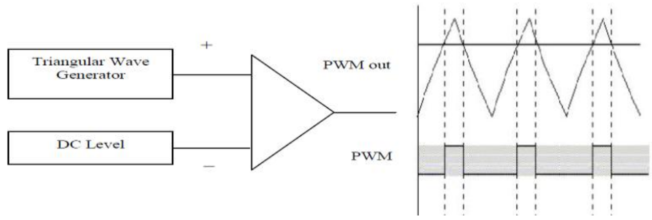

Figure6: Generation PWM for DC Drives

The mathematical model of DC servo motor can be simplified by mean of the circuit as shown in Figure 7. The electrical part represented by armature and the mechanical part by T and J. As the field excitation is constant, the armature controller only depends on armature voltage. The mechanical equations describing this system can be written with the assumptions that the loss is included in load torque and neglecting viscous friction constant as given below:

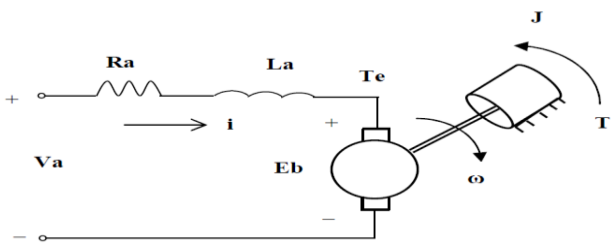

Figure7: DC servomotor equivalent circuit

$V_a = R_a i + L_a di/dt + E_b$

$J d\omega/dt = T_e - T$

With

$E_b = K\omega$; $T_e = Ki$

Where;

V_a = Armature voltage, R_a = Armature resistance

I = Armature current, L_a = armature inductance

K = Torque and back electromagnetic constant ($Nm.A^{-1}$)

ω = Rotor angular speed, T_e = Electromagnetic Torque

T = Total load torque, J = Rotor inertia

simulation of servomotor parameters Simulation circuit:

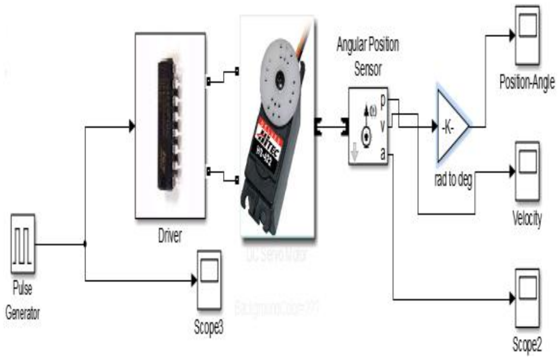

Figure8: simulation circuit for servomotor

The simulation circuit consists of four major blocks

1. Pulse generator
2. Driver circuit
3. DC servomotor
4. Angular position sensor

According to motor specification PWM signals are generated with the frequency of 50Hz and duty cycle of

2% to 13%. Driver circuit consists of H-Bridge configuration which provides motor to rotate in forward and reverse direction. Then next block will be consisting of servomotor, here motor itself is controlled in closed loop control system. To sense the motor shaft position, angular position sensor is being used. Angular position sensor will give three outputs they are: step angle, velocity and acceleration. The step angle will be in radians and to convert it into degree, radians to degree converter block is being used. The output for the simulation is as shown in Figure.9, Figure.10 and Figure.11.

(i)Step angle

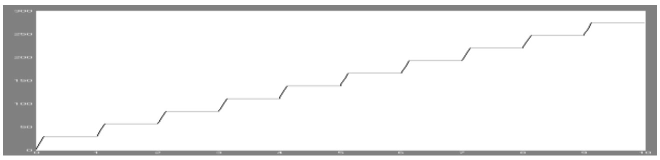

Figure9: Step Angle

(ii)Velocity

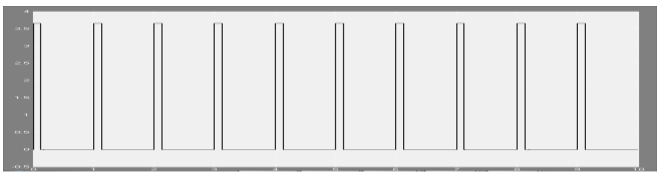

Figure10: Velocity

(iii) Acceleration:

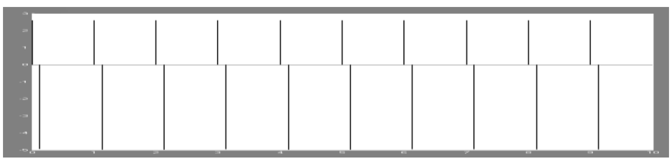

Figure11: Acceleration

CONTROL OF BIPED ROBOT

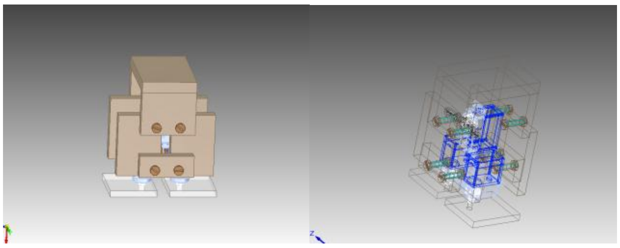

Figure12: 3D Model of the designed Biped robot

Generally any robot has a combination of motors and sensors, which are controlled by microcontrollers. Figure.12 shows a 3D model of the Biped robot designed using the solid works design software. There are wide varieties of motors, sensors and microcontrollers available. In this project low cost dsPIC30F2010 and actuators are used. There are three D.O.F (Degree of freedom), each D.O.F has one servomotor and it is controlled by DSPIC30F2010. The robot controller board has been specifically designed for this project and it measures 90X70mm. The controller board has the capability to control upto six actuators and it has a provision for providing sensory inputs to the controller. The robot has the capability to work in closed loop with the help of sensory inputs. The robot is controlled and actuated using a pre-defined sequences and it implements an open loop control and thus does not use sensors.

Algorithm:

All the three motors are controlled and actuated simultaneously while maintaining the previous positional values. Initially, the first motor will be serviced with on-time pulse period and during the off-time pulse period of the motor, second motor will be serviced with on-time pulse period. This type of actuation is continued till all the three motors are serviced. Positional values loaded in the Look-up table and are retrieved and pulses are sent to the motors accordingly. It is shown in the figure,13 with various ON and OFF time periods. No special algorithms are used for balancing the bipedal robot. Currently, the walking gait was developed by studying possible walking movements using the prototype and by simulating various walking gaits using the simulink. In the future we hope to add sensor-based active balancing.

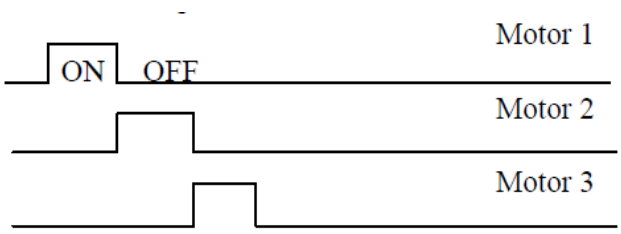

Figure13: PWM pulses for Servomotors

Arrangement of Servomotors for Biped Robot:

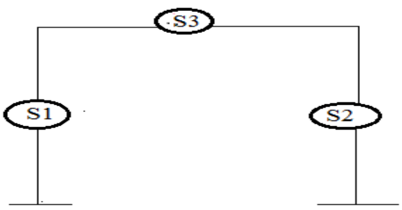

Figure14: Arrangement of servomotors

Figure.14 shows the arrangement of the servomotor in th biped. To make Biped Robot, three servo motors are being used. Two servomotors are used for knee of the legs of Biped Robot. S1 for right leg and S2 for left leg knees respectively. S3 is used as mass at the center of the Robot.

The schematic of the circuitry employed in the project is shown in Figure.15. During the initial working of the robot the position of the motors were sent manually from the PC. Hence the circuitry is provided with MAX232 circuitry for RS232 to TTL conversions. The same is being used to get the debug messages on PC knowing the current status of the code running inside microcontroller. Further all the Servo motors being used are connected on the PWM channels of the microcontroller. A 5 MHz crystal oscillator is used in the project to generated PWM frequency as lowest as 50 Hz.

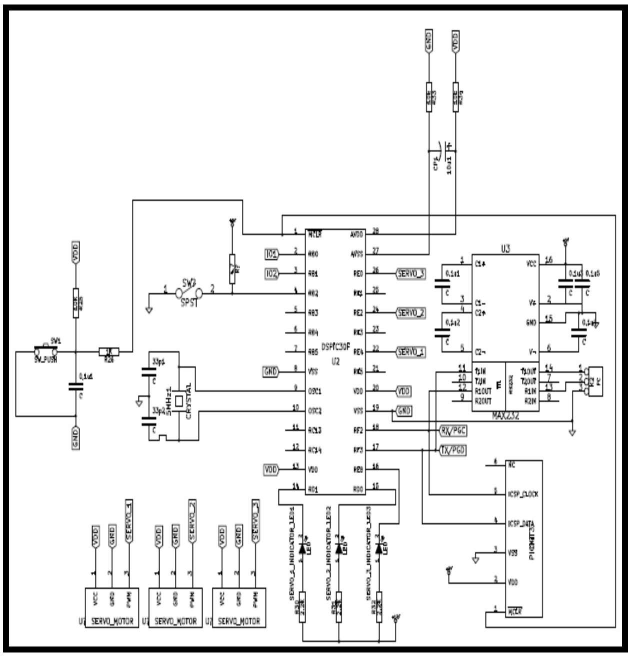

Figure15: Schematic diagram of Biped Robot

Microcontroller features

1. High Performance Modified RISC CPU:

Modified Harvard architecture, C compiler optimized instruction set architecture, 84 base instructions with flexible addressing modes, 24-bit wide instructions, 16-bit wide data path, 12 Kbytes on-chip Flash program space, 512 bytes on-chip data RAM, 1 Kbyte non-volatile data EEPROM, 16 x 16-bit working register array, Up to 30 MIPs operation:

- DC to 40 MHz external clock input

- 4 MHz-10 MHz oscillators input with PLL active (4x, 8x, 16 xs)

Up to 42 interrupt sources, three external interrupt sources

- 8 user selectable priority levels

- 54 interrupt vectors

- 8 processor exceptions and software traps

2. DSP Engine Features:

Modulo and Bit-Reversed modes, Two, 40-bit wide accumulators with optional saturation logic, 17-bit x 17-bit single cycle hardware fractional/integer multiplier, Single cycle Multiply-Accumulate (MAC) operation,40-stage Barrel Shifter, Dual data fetch.

3. Peripheral Features:

High current sink/source I/O pins: 25 mA/25 mA, Three 16-bit timers/counters; optionally pair up 16-bit timers into 32-bit timer modules, Four 16-bit Capture input functions, Two 16-bit Compare/PWM output functions- Dual Compare mode available, 3-wire SPITM modules (supports 4 Frame modes), I²C™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing, Addressable UART modules with FIFO buffers.

4. CMOS Technology:

Low power, high speed Flash technology, Wide operating voltage range (2.5V to 5.5V), Industrial and Extended temperature ranges, Low power consumption.

5. Special Microcontroller Features:

Enhanced Flash program memory:- 10,000 erase/write cycle (min.) for industrial temperature range, 100K (typical) Data EEPROM memory:- 100,000 erase/write cycle (min.) for industrial temperature range, 1M (typical), Self-reprogrammable under software control, Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST), Flexible Watchdog Timer (WDT) with on-chip low power RC oscillator for reliable operation, Fail-Safe clock monitor operation, Detects clock failure and switches to on-chip low power RC oscillator, Programmable code protection, In-Circuit Serial Programming™ (ICSP™), Selectable Power Management modes-Sleep, Idle and Alternate Clock modes.

6. Motor Control PWM Module Features:

Six PWM output channels- Complementary or Independent Output modes- Edge and Center Aligned modes, 4 duty cycle generators, Dedicated time base with 4 modes, Programmable output polarity, Dead-time control for Complementary mode, Manual output control, Trigger for synchronized A/D conversions.

CONCLUSION

A Biped Robot being designed and which is controlled by servo motor controller using dsPIC30F2010 is proposed in this paper. An extensive Literature Survey conducted for the project gave profound insight on the requirements for building the Biped robot. Based on the Literature survey, the inputs for designing the robot have been decided and the hardware has been implemented so that the robot moves inculcating the gaits of a penguin.

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