Singular Axis Self Balancing System

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***Abstract*— In this paper, we presented the Balance model as a singular axis self balancing system that is capable of adjusting itself with respect to changes in weight and position. We developed the Balance System from a single servo and a single accelerometer. The stability of the system is to show the capabilities of the ATMega8 in doing PID loops even with limited accuracy in position readings. PID control system is designed to monitor the motors so as to keep the system in equilibrium. It should be easily reproducible given the right parts and code.**

***Keywords*— Self balancing system, Accelerometer, PID controller, Single axis, feedback control**

I. INTRODUCTION

In Next Generation, much of these models capture our imagination, such models still only inhabit Science Fiction. People still haven't been able to give a robot enough 'common sense' to reliably interact with a dynamic world. The type of robots that you will encounter most frequently are robots that do work that is too dangerous, boring, onerous, or just plain nasty. Most of the robots in the world are of this type. They can be found in auto, medical, manufacturing and space industries.

Well it is a system that contains accelerometer, control systems, manipulators, power supplies and software all working together to perform a task. Designing, building, programming and testing a system is a combination of physics, mechanical engineering, electrical engineering, structural engineering, mathematics and computing. Designing a robot means all of these disciplines in a deeply problem-posing problem-solving environment.

This project is to design and fabricate a self balancing system model that has the ability to balance itself on flat terrain and investigate the suitability and performance of PID controller in balancing system. Here Accelerometer is used for sensing the tilting angle of the system. Microcontroller is used to be the brain of the system. The entire PID controller algorithm will compute into C programming and store inside the microcontroller. The PID controller is very much needed in error controlling technique.

As the physical characteristics of the system change with each loading and unloading of a product the control system either needs to adapt to the changes in the system or it needs to be able to balance the system effectively regardless of changes in system characteristics.

II. MECHANISM AND DESIGN

Mechanism, materials and peripheral circuits determine the system performance. A good mechanism affects control difficult. The materials that we choose plays an important role for designing a model because the frame of the model must be robust, symmetrical and the centre of gravity of the system should be high. Aluminium rod is used due to the light weight, rigid and robustness quality of the material which is much suitable for the balancing system. The design of the model determines the stability and centre of gravity in static position or when the system is in motion.

A. The design of the System

The configuration of the self-balancing model is shown in the Figure.1.

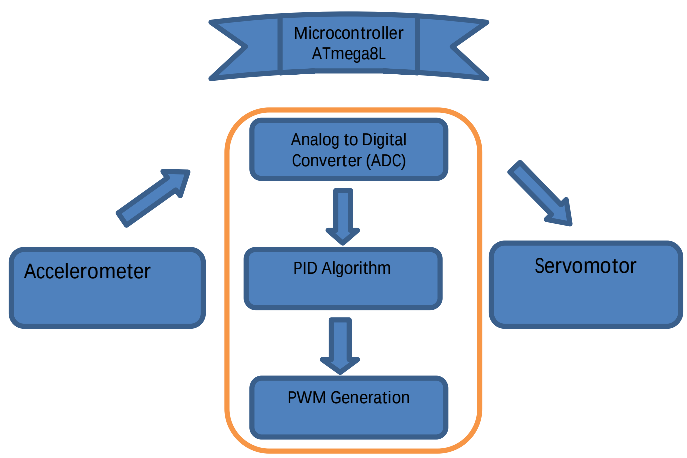

Figure.1 Design Layout

Here in this section, the components and techniques used for building the model which is composed of power manangement circuit, accelerometer interface, PIC Microcontroller, servo motor and control system.

III. ACCELEROMETER AND ELECTRONICS

The accelerometer ADXL335 is used on the balancing system in order to detect the current state of the model. The accelerometer ADXL335 is mounted on an aluminium strip placed at the front of the system. The line of sight is toward the ground at an angle. The output of the accelerometer is an analog voltage.

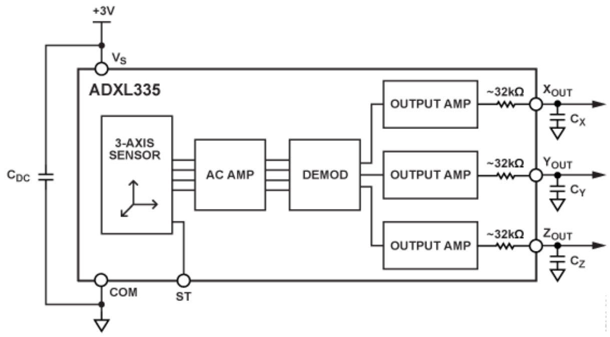

Figure.2. Block Diagram of ADXL 335

The ADXL335 has a measurement range of ±3 *g* minimum. It contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerometer can measure the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock, or vibration. The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration. The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

The accelerometer analog output voltage is measured by the PIC on-board A/D register. The system keeping balance by measuring the level at the left and right of itself and adjusts its position to maintain equal level.

ATmega8L will be used in this project due to its special function registers like 8 Analog to Digital Converter module and 1 PWM generator module which are much needed to build this project.

The output of the accelerometer which is in analog voltage will be connected to the ATmega8L microcontroller A/D input pin. Beside that, one PWM generator will be used to activate the motor. The microcontroller needs 5V power supply and an external 8 MHz crystal oscillator to generate pulse at continuous time intervals. The power supply needed to drive the servo motor is 1A. The spirit level is needed at the end to check whether the balanced system has been perfectly balanced or not. Servo is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes.

IV. CONTROL SYSTEM

To stabilize the system there are three PID control systems implemented. One of the PID control systems is used to control the tilt and angle and the other two PID control systems are used to control the speed of servo motor. The PID algorithm consists of a three part equation with proportional (P), integral (I), and differential (D) terms. The setpoint of the model is the accelerometer's reading when the system is perpendicular to the flat terrain. The equation given is to calculate the PID controller output of the balancing system is simplified as follow:

Error
= Setpoint Reading – Current accelerometer
Reading (1)

The proportional term increases the motor power as the system leans further over and decreases the motor power as the system approaches the upright position. A gain factor, Kp, determines how much power to apply to the motor for any given lean, as follows:

Output Proportional Term = Kp * Error (2)

While the proportional term is effective at responding to the lean, once the system reaches the upright position it will proceed to tip in the opposite direction until the proportional control term increases the motor power enough to reverse the system's motion, rotating it back in the other direction. Therefore, the model will oscillate back and forth, just as a car with worn out shock absorbers bounces for a long time when the car goes over a bump.

The differential term of the PID algorithm acts as a damper reducing oscillation. Another gain factor, Kd, determines how much power is applied to the motor according to the following equation:

Output Differential Term

=Kp Kd * (Error – Last Error) / T (3)

=(Kp Kd/T) * (Error – Last Error) (4)

Simplify as below:

=KD * (Error – Last Error) (5)

Finally, neither the proportional nor differential terms of the algorithm will remove all of the lean because both terms go to zero as the orientation of the system settles near vertical. The integral term sums the accumulated error (error summed over time) and applies power in the opposite direction indicated by the sum to drive the lean to zero, as follows:

Output Integral Term

= KpKi * Sum of Error * T (6)

= KpKiT* (Sum of Error) (7)

Simplify as below:

= KI * (Sum of Error) (8)

The output of the PID controller for balancing the model is

Motor PWM = Proportional Term + Integral Term + Differential Term (9)

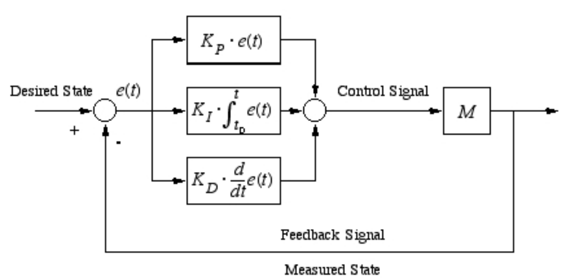

Figure.3 PID Controller

Figure.3 shows the working principle of PID Controller. To tune the PID controller, Ki and Kd must be set to zero first and the Kp is slowly increase until the system start to oscillate. Next, the Ki is slowly increased until the system start to oscillate again. Then the Kd is slowly increased until the system is stable and is not oscillating..

The output of the Motor PWM as equation (9) above will be used as the setpoint for the motor. The Back EMF method used to detect the current speed of the motor. The Back EMF refers to using the voltage generated by a spinning motor (EMF) to check the current speed of the motor rotation .

Error of Motor Speed = Setpoint of motor – Current Speed Reading of Motor (10)

Output Proportional Term of Motor

= Kp * Error of Motor Speed (11)

Output Differential Term of Motor =

Kd * (Error of Motor Speed – Last Error of Motor Speed) (12)

Output Integral Term of Motor

= Ki * Sum of Error for Motor Speed (13)

Motor Speed = Proportional Term of Motor + Differential Term of Motor + Integral Term of Motor (14)

For tuning the PID control of motor speed, the value of Kp, Ki and Kd is get by trial and error method. Although this is not efficiency method but it can control the speed of motor very well.

V. CONCLUSION

Singular Axis Self Balancing System could balance in limited conditions. One of the major limitations was the sensing of balance. Using a single accelerometer is not the best way to do this. One of the huge complications of just using a single accelerometer is that there is a lot of acceleration due to the movement of the load. On top of that the Freescale accelerometers are notoriously not the best accelerometers for accuracy of fine acceleration changes. The time taken to attain the stable position is done within limited time and accuracy after the load is being placed and it has been checked with the help of spirit level. In the future, we would try to go for gyroscope to sense where balance is.

REFERENCES

[1] S. M. Metev and V. P. Veiko, Laser Assisted Microtechnology, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2] C. M. Lin and C. H. Chen, "Robust fault-tolerant control for a biped robot using a recurrent cerebellar model articulation controller," IEEE Trans. Syst., Man, Cybern. B,Cybern., vol. 37, no. 1, 2007.

[3] K. Loffler, M. Gienger, F. Pfeiffer, and H. Ulbrich, "Sensors and control concept of a biped robot," IEEE Trans. Ind. Electron., vol. 51, no.5, pp.972–980, 2004.

[4] Nawawi, S. W., Ahmad, M. N. and Osman, J. H. S (2008) "Real-Time Control of Two-Wheeled Inverted Pendulum Mobile Robot" World Academy of Science, Engineering and Technology 29, 214 - 220.

[5] T.Emura, T.Sakai, "Study on Inverted Pendulum that Maintains Erect position using Reaction Wheel," Biomechanism, 1973, pp321–328 (in Japanese).

[6] C.Y.Chung, J.W.Lee, S.M.Lee, B.H.Lee, " Balancing of an Inverted Pendulum with a Redundant Direct-Drive Robot," Proc. ICRA 2000,2000, pp 3952–3957.

[7] G. Nguyen, J. Morrell, K. Mullens, A. Burmeister, S. Miles, N,Farrington, K, Thomas, and D. W. Gage, "Segway Robotic MobilityPlatform" SPIE Proc. 5609:Mobile Robots XVII, Philadelphia, PA,October 26-28, 2004.

[8] M. G. Mehrabi, A. G. Ulsoy, Y. Koren, "Reconfigurable manufacturing systems: Key to future manufacturing", Journal of Intelligent Systems, Vol 11, Nr 4, pp 403-419, August, 2000.

[9] R. C. Ooi, "Balancing a Two-wheeled Autonomous Robot", School of Mechanical Engineering, The University of Western Australia, 2003.

[10] G. F. Franklin, J. D. Powell, A. Emami-Naeini, Feedback Control of Dynamic Systems, 4th ed., Prentice Hall, New Jersey, 2002.

[11] J. L. Meriam, L. G. Kraige, Engineering Mechanics: Dynamics, 5th ed., John Wiley & Sons, Inc., New Jersey, 2003