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POSITION CONTROL OF A DC MOTOR USING PID CONTROLLER

Samadhi Manasa[1], Swapna Rani.T[2] , M. Veda chary[3]

[1] PG Scholar, [2]Assistant Professor,3[2]Associate Professor
Department of ECE, CMR College of Engineering & Technology, Hyderabad

ABSTRACT: *The main objective of this paper is to control the position of a DC motor by using Proportional-Integral-Derivative (PID) algorithm implemented on ARM CORTEX M3 microcontroller. PID attempts to correct the error between the measured position and the desired position by calculating the error and then outputting a pulse width modulated voltage that can adjust the position accordingly. The PID algorithm that is added to the system becomes a closed loop system. By integrating the PID controller to the DC motor we will be able to correct the error made by the DC motor and control the position of the motor to the desired point. PID parameters Kp , Ki and Kd are finely tuned to optimal values by trial and error method .And then a CORTEX M3 microcontroller is programmed by adding the finely tuned PID algorithm to control the position of DC motor.*

KEYWORDS: *PID Controller, Cortex M3, Optical Encoder, Pulse Width Modulation, Quadrature Encoder Interface.*

I. INTRODUCTION

There are many different DC motor types in the market and all with it good and bad attributes. One such bad attribute is the lag of efficiency. In order to overcome this problem a controller is introduced to the system. There are also many types of controllers used in the industry, one such controller is PID controller. PID controller or proportional–integral–derivative controller is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly. So by integrating the PID controller to the DC motor we will be able to correct the error made by the DC motor and control the position of the motor to the desired speed or point. Electronic analog controllers can be made from a solid-state or tube amplifier, a capacitor and a resistance. Electronic analog PID control loops were often found within more complex electronic systems. However, nowadays, electronic controllers have largely been replaced by digital controllers implemented with microcontrollers or FPGAs. In this project, PID controller is chosen as the controller for the DC motor. This is because PID controller helps get the output, where we want it in a short time, with minimal overshoot and little error.

II. DESIGN REQUIREMENTS

We must be able to position the motor very precisely, thus the steady state error due to motor position should be zero. We will also want the steady state error due to a disturbance to be zero as well. The other performance requirement is that the motor must reach its final position very quickly. In this case, we want it to have a settling time of 40ms.We also want to have an overshoot smaller than 16 %.If we simulate the reference input by a unit step input, then the motor position output should have a step response with the above mentioned requirements.

III. SYSTEM DESCRIPTION

DRIVER

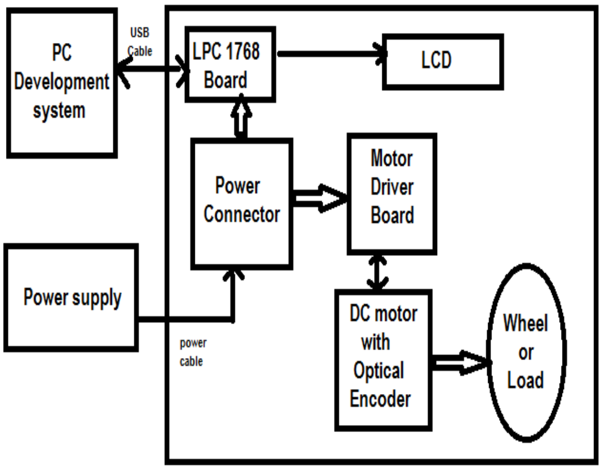

Fig 1: Block diagram

This board drives the quadrature encoder dc motor. It uses PID method for position control, by accepting serial commands on 38400BPS, 8, N, 1 .It is interfaced to computer's serial port via TTL/level converter .On the other side it is directly interfaced to microcontroller's UART. Driver accepts the commands from the host to position the motor at required using hyper terminal software.

MOTOR WITH OPTICAL ENCODER

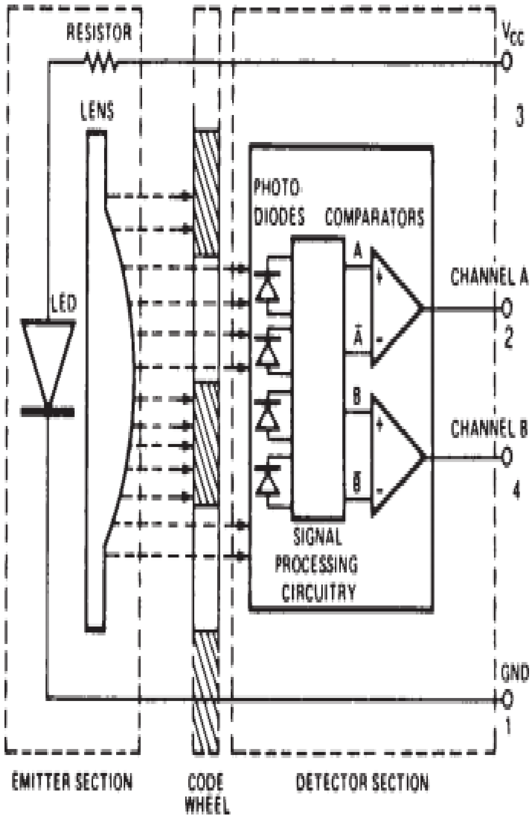

Fig 2: Block Diagram of Shaft Encoder

An optical encoder/quadrature encoder, also known as a 2-channel incremental encoder, converts angular displacement into two pulse signals. By monitoring both the number of pulses and the relative phase of the two signals, we can track the position, direction of rotation, and velocity. The encoder disk is firmly connected to the back-shaft of the motor, so that both the shaft and the encoder disk rotate at the same r.p.m. The rotation of the motor causes the beam of light to be periodically intercepted by the solid parts of the encoder disk creating a sequence of pulses of light that will be translated by the photo couple's receiver into pulses of electricity.

LPC 1768-CORTEX M3

The quadrature encoder interface of LPC 1768 decodes the digital pulses from a quadrature encoder wheel to integrate position over time and determine direction of rotation. In addition, the QEI can capture the velocity of the encoder wheel. UART transmits serial commands to position the motor. If the motor turns faster than the required velocity, the controller will deliver less power to the motor and if motor turns slower than the required velocity, the controller will deliver more power to the motor. Controlling the electrical power delivered to the motor is usually done by Pulse Width Modulation.

IV. PID CONTROLLER DESIGN

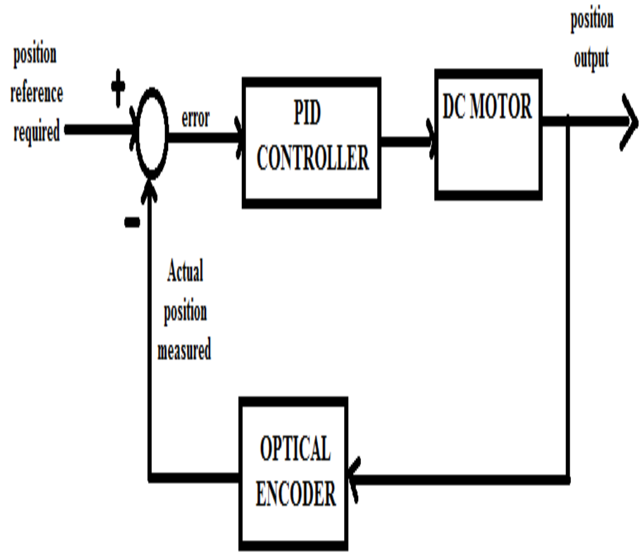

Fig 3: Position Control System

The steps to be followed to design a PID Controller [1] are,

- Obtain open loop response from the mathematical model of DC Motor and determine what needs to be improved.
- Add a proportional constant to improve the rise time.
- Add a derivative control to improve the over-shoot.
- Add an integral control to eliminate the steady state error.
- Adjust each of K_p, K_d, K_i until the design requirements are met.

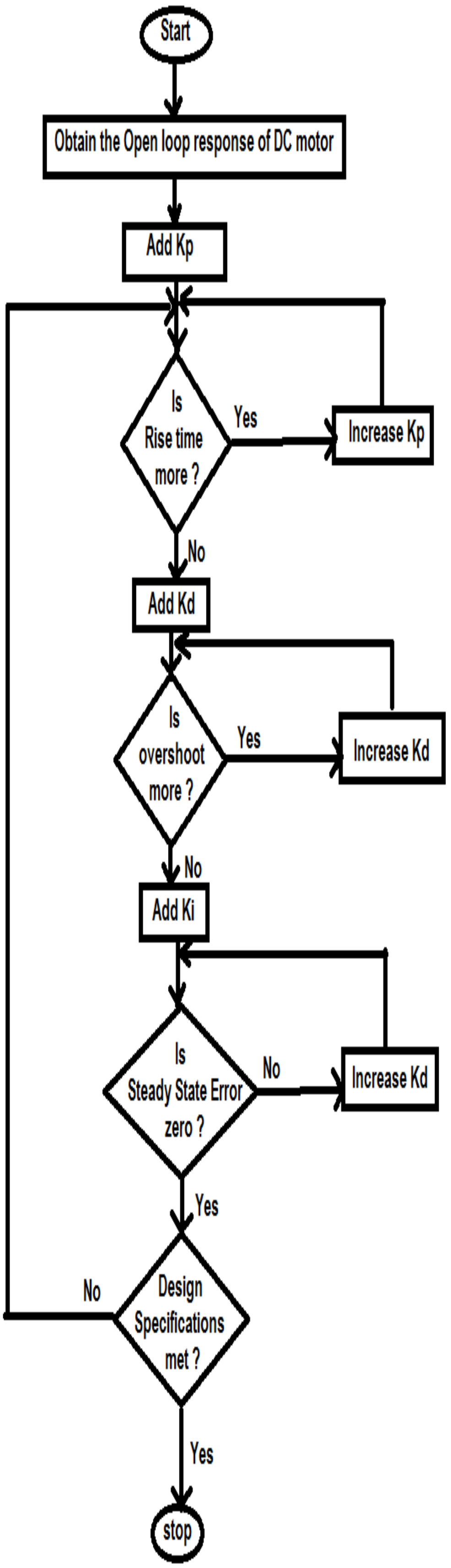

Fig 4: Flow Diagram of PID Algorithm

MODELING DC MOTOR POSITION

Electric circuit of armature and free body diagram of rotor is shown below.

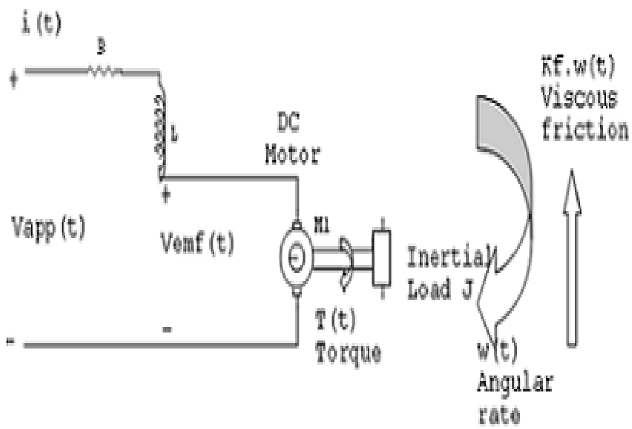

Fig 5: Schematic of DC Motor

Motor's physical parameters are usually specified by the manufacturer.

SYSTEM EQUATIONS

Motor torque T is related to armature current-I by a constant factor K_t [2] as follows

$$T = K_t .i$$

Back emf –e is related to rotational velocity by;

$$e = K_e .\theta'$$

By newton's law combined with kirchoff's laws, we can write

$$J. \theta' + b. \theta' = K_i$$

$$L\frac{di}{dt} + R.i = V - K. \theta'$$

Taking Laplace transform, we get

$$JS^2\, \theta(s) + bS\, \theta(s) = K.I(s)$$

$$S(JS+b).\, \theta(s) = K.I(s)$$

Similarly,

$$(LS+R)\, I(s) = V(s) - KS.\ \theta(s)$$

Here,

θ(s) – Rotating speed , output

V(s) – voltage, input

By solving the above two equations;

$$\frac{\theta(s)}{V(s)} = \frac{K}{(JS+b)(LS+R)+K2}$$

If position is the output, the position can be obtained by integrating θ'

i.e., we just need to divide the transfer function by ‘S’

$$\frac{\theta}{V} = \frac{K}{S[(JS+b)(LS+R)+K2]}$$

These equations can be represented in state space form [3]. Choosing motor position, motor speed, armature current as state space variables,

$$\frac{d}{dt}\begin{bmatrix}\theta\\ \theta'\\ i\end{bmatrix} = \begin{bmatrix}0 & 1 & 0\\ 0 & \frac{-b}{J} & \frac{K}{J}\\ 0 & \frac{-K}{L} & \frac{-R}{L}\end{bmatrix}.\begin{bmatrix}\theta\\ \theta'\\ i\end{bmatrix} + \begin{bmatrix}0\\ 0\\ \frac{1}{L}\end{bmatrix}$$

$$Y = [1\ 0\ 0]\ .\begin{bmatrix}\theta\\ \theta'\\ i\end{bmatrix}$$

After obtaining the transfer function, PID parameters were obtained by trial and error method using MATLAB.

V. IMPLEMENTATION

In a closed loop system, a microcontroller will have two main tasks:

- Constantly adjust the average power delivered to the motor to reach the required velocity.
- Precisely calculate the position/angle of the motor’s output shaft [4].

The shaft encoder will provide the microcontroller’s internal counter with a sequence of pulses that correspond to the rotation of the motor. A timer is set to execute two software routines every 1/10th of a second (which is just an arbitrary value). One of these software routines is to recalculate the actual angle of the shaft or the total number of revolutions.

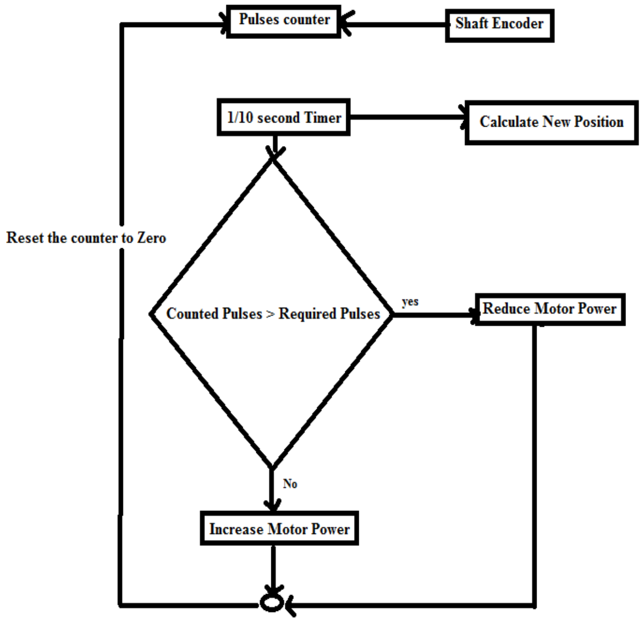

Fig 6: Flow Diagram for Position Control of DC Motor

Then, another software routine is executed to control the speed of the motor by comparing the number of counted pulses with a fixed number which is referred to as the “required pulses”. The “required pulses” corresponds to the desired speed, and the “counted pulses” corresponds to the actual speed of the motor.

VI. RESULTS

WITHOUT PID CONTROLLER

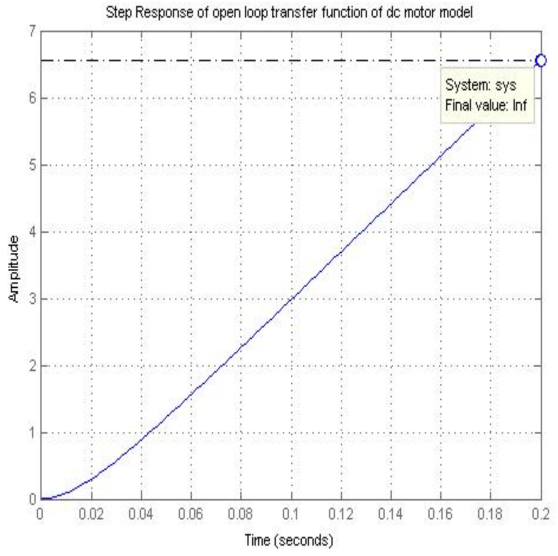

Fig 7: Step Response without PID Controller

WITH PID CONTROLLER

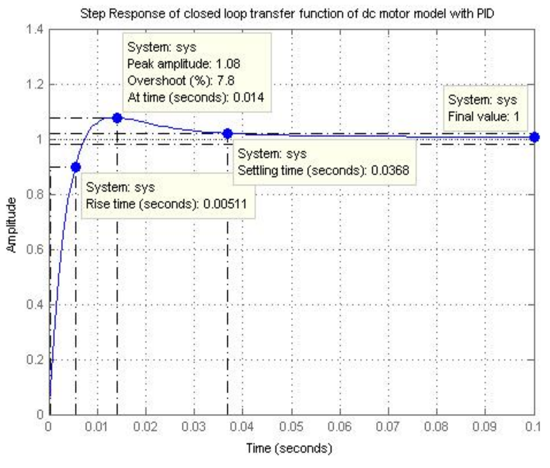

Fig 8: Step Response with PID Controller

VII. CONCLUSION AND FUTURE SCOPE

CONCLUSION

In this work, optimal PID parameters were obtained by trial and error method. The simulation results indicate that the presented approach works effectively and provides a good relation between the objective function that optimizes the PID Controller and dynamic response of the system to be controlled.

It is demonstrated that the position of the DC Motor is accurately controlled due to the finely tuned PID parameters [8], and the motor could reach the required position as quickly as possible without any error.

Despite the enormous interest that modern control techniques have sparked among academics during the last three or four decades, PID controllers are still preferred in industrial process control. The reason is that controllers designed with the aid of modern control techniques are usually of high order, difficult to implement, and virtually impossible to re-tune on line. PID controllers, on the other hand, are simple, easy to implement, and comparatively easy to re-tune on line.

FUTURE SCOPE

Another advantage of PID controllers is that two PID controllers can be used together to yield better dynamic performance. This is called cascaded PID control. In cascade control there are two PIDs arranged with one PID controlling the set point of another. A PID controller acts as outer loop controller, which controls the primary physical parameter, DC Motor speed. The other controller acts as inner loop controller, which reads the output of outer loop controller as set point. It can be mathematically proven that the working frequency of the controller is increased and the time constant of the object is reduced by using cascaded PID controller.

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