

CONTROL OF DC SERVOMOTOR USING RELAY AND POLE PLACEMENT METHOD BY MATLAB SIMULINK

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ABSTRACT

Automation and control is becomes more popular these days in industrial domain. Devices are controlled automatically and functioning according to computer interface guidelines. DC motors are frequently used device in such kind of industries for automation purpose.

For a more efficient speed control, closed loop control system of the servo motor is realized with the help of relay and pole placement method. In this paper we use transfer function to analyse of DC Servomotor. The reason behind it, transfer function is a elegant method of handling non-zero initial condition and it also can handle multiple source (multiple inputs), can solve for multiple outputs (any voltage and current)- MIMO system. For study and experiments use PID controlled closed loop system. The complete system organization and simulation of the proposed system is described in details. The performance of the designed system is evaluated here. Simulation of the system is done in MATLAB Simulink. In this project, we have achieved control of “dc servomotor using relay and pole placement method by MATLAB Simulink”.

KEYWORDS: DC Servomotor, Computer Interface, MATLAB Simulink

INTRODUCTION

Mathematical Modeling of DC Servo Motor

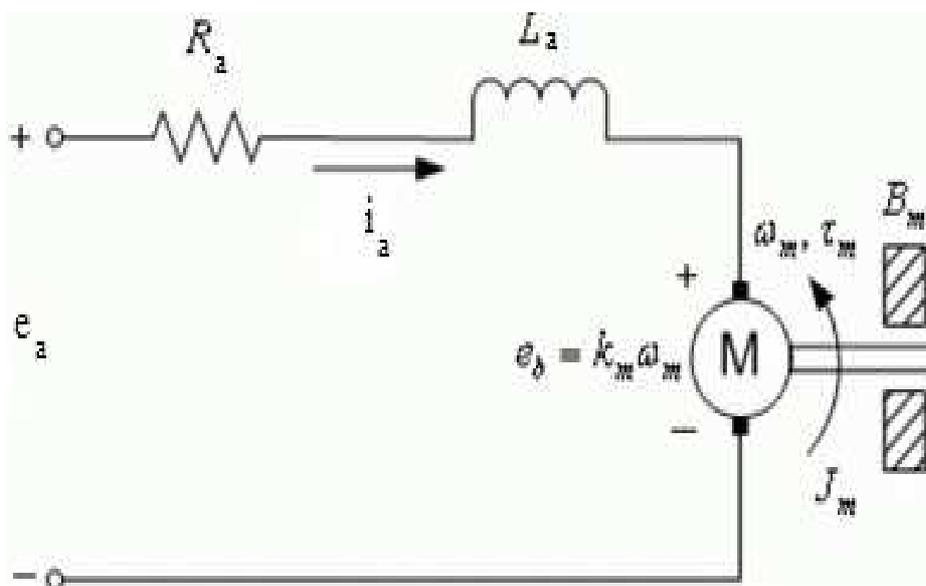


Figure 1

Circuit Analysis

$$T_m = (t) \emptyset (t) \quad (1)$$

Since \emptyset is constant equation (1) is written as

$$T_m = K_i i_s(t)$$

Where K_i is the torque constant in N-m/A.

Starting with the control input voltage $e_a(t)$, the cause-and-effect equation for the motor circuit in figure are:

The KVL Equation for the above Circuit

$$\frac{di_a(t)}{dt} = \frac{1}{L_a} e_a(t) - \frac{R_a i_a(t)}{L_a} - \frac{e_b(t)}{L_a}$$

The Back EMF is Given by

$$e_b(t) = K_b \frac{d\theta_m(t)}{dt} = K_b \omega_m(t)$$

Combining these two equations and taking the Laplace transform,

$$I_a(S) = \frac{(E_a - K_b \omega_m)}{(R_a + sL_a)}$$

The torque equation

$$T_m(t) = K_i i_a(t)$$

$$T_m(s) = K_i \times \frac{(E_a - K_b \omega_m)}{(R_a + sL_a)}$$

The Mechanical Equation

$$\frac{d^2\theta_m(t)}{dt^2} = \frac{1}{J_m} T_m(t) - \frac{T_l(t)}{J_m} - \frac{B_m d\theta_m(t)}{J_m}$$

(Where $T_L(t)$ represents a load frictional torque such as coulomb friction)

$$S\omega_m = \frac{1}{J_m} \left[K_i \times \frac{(E_a - K_b \omega_m)}{(R_a + sL_a)} \right] - \frac{T_l}{J_m} - \frac{1}{J_m} B_m \omega_m$$

$$\frac{\omega_m(S)}{e_a(S)} = \frac{K_i}{(J_m L_a S^2 + (J_m R_a + B_m R_a + B_m L_a) S + K_i K_b)}$$

This is the transfer function for the servo motor using the speed control method, where speed is the output and voltage as the input.

DATA ACQUISITION THROUGH THE PCI CARD (PCI 1716)

PCI-1716 is powerful high-resolution multifunction cards for the PCI bus. They feature a 250 kS/s 16-bit A/D converter, and an onboard 1K sample FIFO buffer for A/D. The cards can also have up to sixteen single-ended or eight differential A/D input channels or a combination of these; two 16-bit D/A output channels, 16 digital input/output channels, and one 10 MHz 16-bit counter channel. PCI-1716 is provide specific functions for different user requirement.

Running the Motor in Open Loop

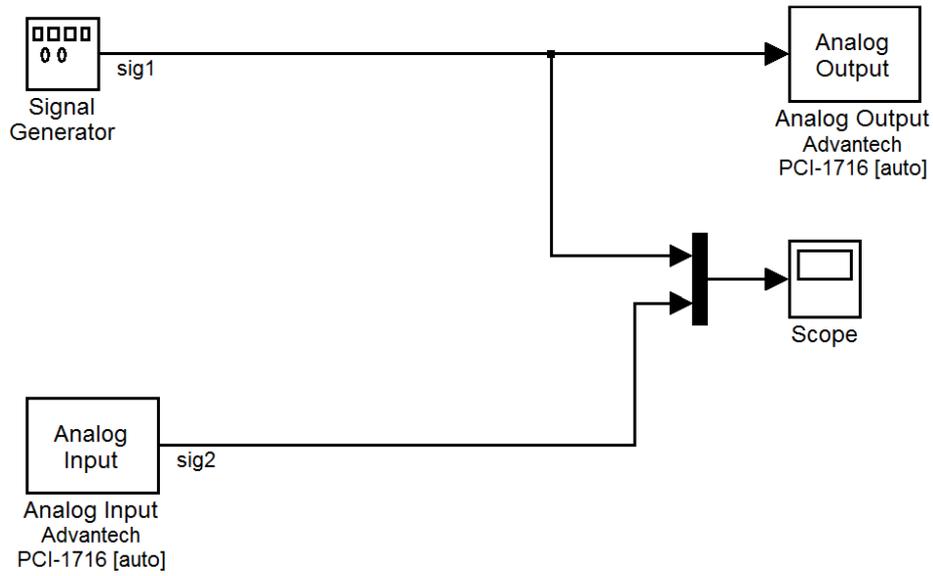


Figure 2

Blocks Used

- 1. Signal Generator
- 2. Analog IP/OP
- 3. Scope

Library

Real-Time Windows Target

Analog Input Block

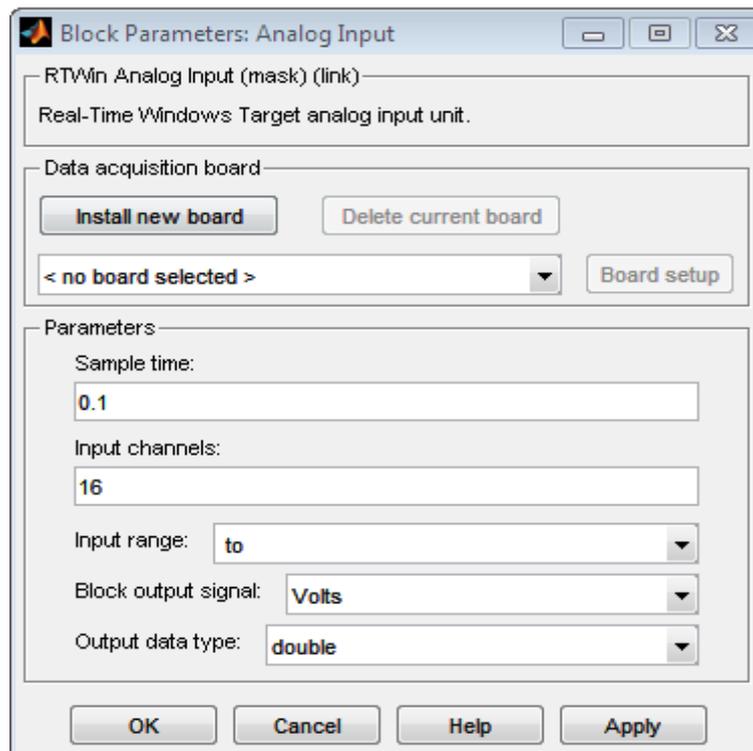


Figure 3

Analog Output Block

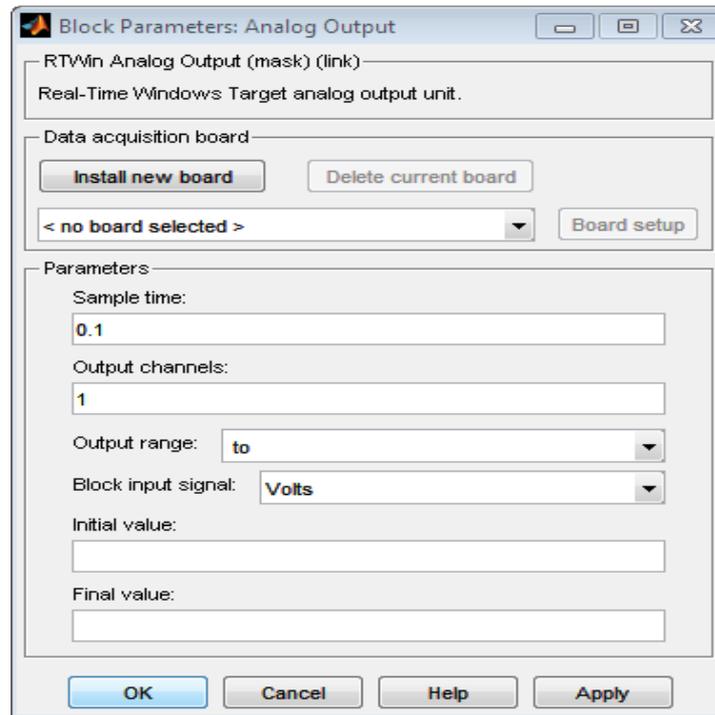


Figure 4

Scope

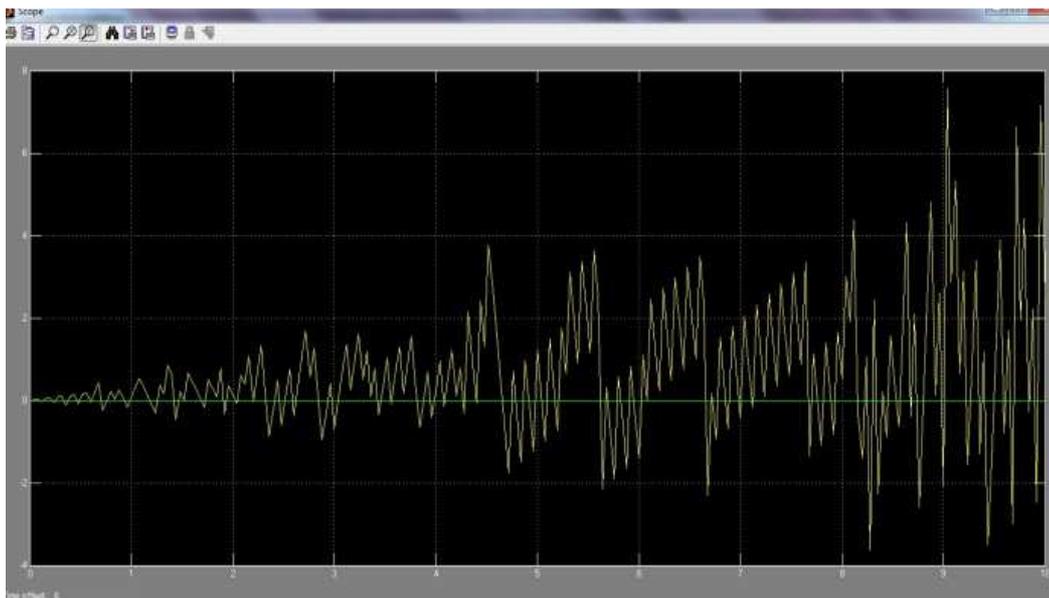


Figure 5

In the given case, from the open loop response of the motor, it is seen that the output (yellow line) of the motor in open loop, does not track the input/reference signal (green line). So, the motor needs to be run in closed loop configuration.

Calculations of Desired Transfer Function with Help of System Identification Tool

Transfer function modeling of the plant is one of the methods. It is also an elegant method of handling non-zero initial condition and MIMO system. A transfer function is a mathematical representation, in terms of spatial or temporal

frequency, of the relation between the input and output of a linear time-invariant system. The transfer function that relates the input voltage and the speed of the DC servo motor is a second order one. This transfer function can be estimated in MATLAB using the System Identification Toolbox.

Step 1

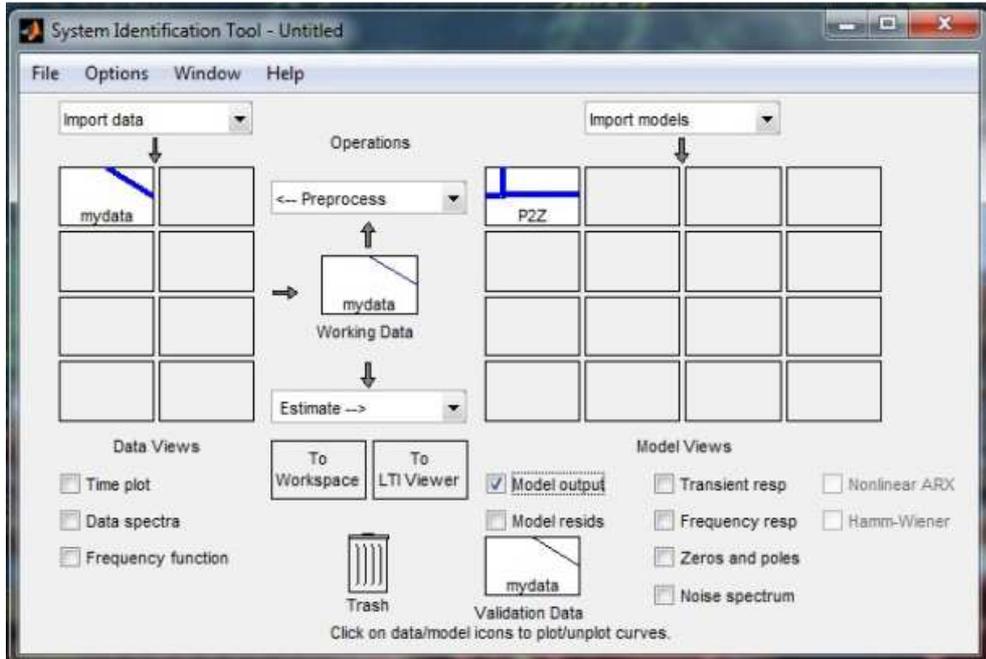


Figure 6

Step 2

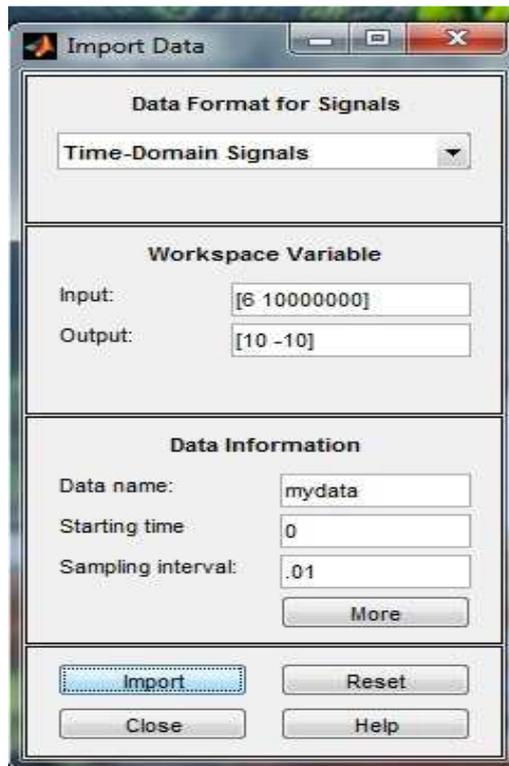


Figure 7

Step 3

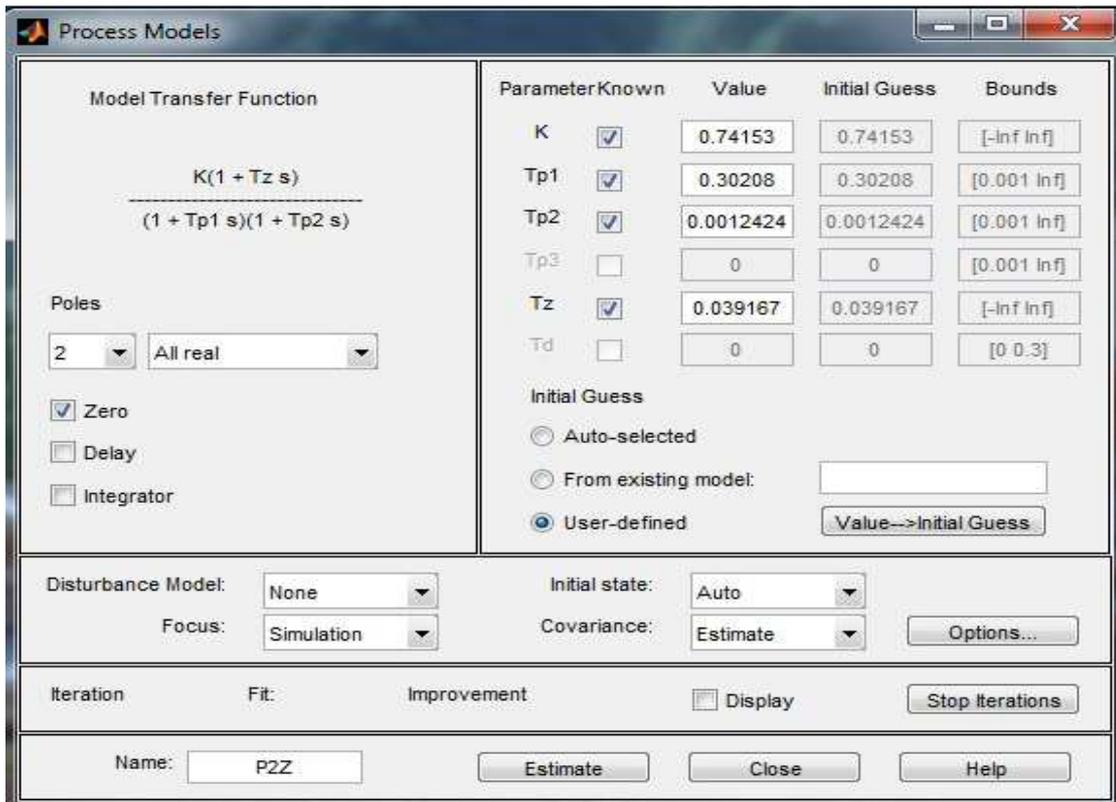


Figure 8

Step 4

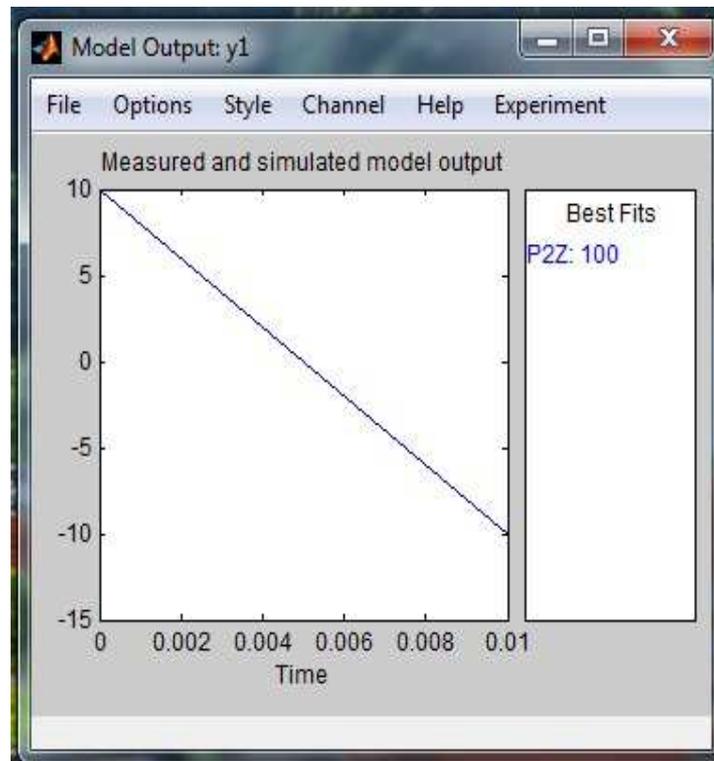


Figure 9

Estimated Output

- With the chosen configuration of 1 zero and 2 poles, and no delay or integrator, as shown above, a best fit of 100% is obtained. This is a satisfactory estimation.
- If the fit had been less than satisfactory, then changing of the configurations would have been required. Once, a satisfactory fit is obtained, the next and final step is followed.
- For the fit of 100% shown above, the transfer function parameters are:
- $K_p = 0.74153$
- $T_{p1} = 0.30208$
- $T_{p2} = 0.0012424$
- $T_z = 0.039167$
- And the corresponding transfer function is:

$$\frac{0.02904 s + 0.7415}{0.0003753 s^2 + 0.3033 s + 1}$$

RELAY OSCILLATIONS METHOD

Here relay act as a bang-bang control, where whatever the response, the relay block pushes it in the opposite direction. Doing so the magnitude of output is fixed. This gives automatic oscillations of the process output.

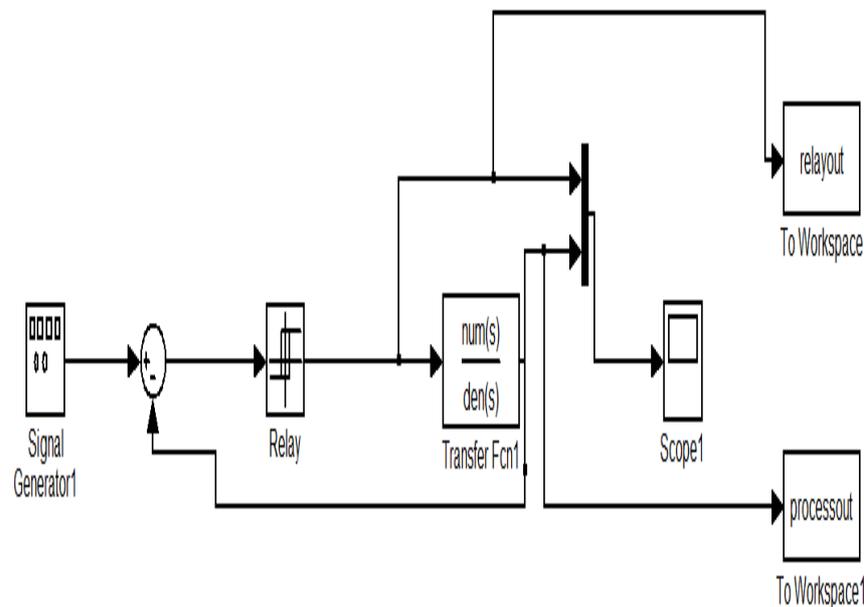


Figure 10

The Scope Output Showing the Relay Output and the Process Output is as Shown Below

Say, the relay output (shown in green) oscillates with an amplitude of d , and the process output (shown in blue) oscillates with an amplitude of a .

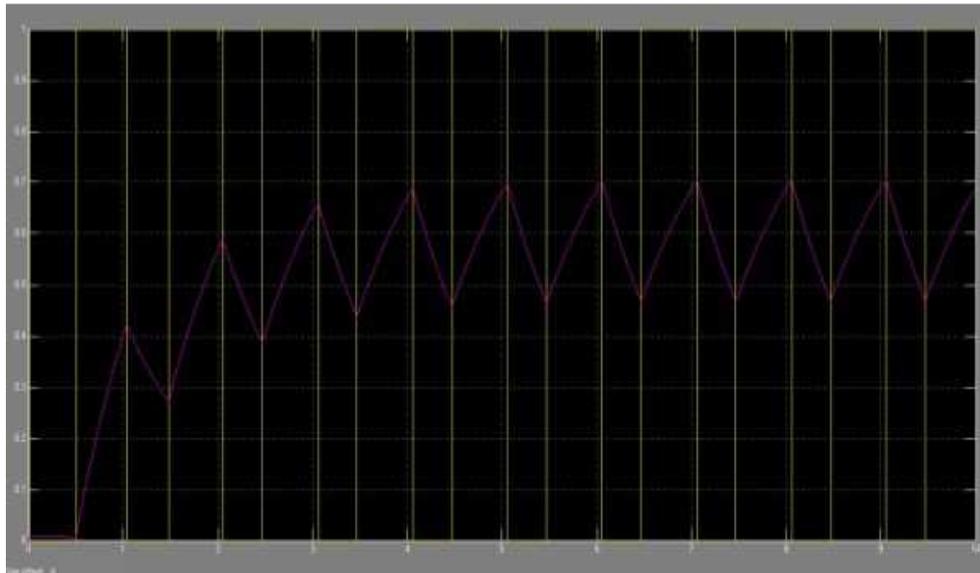


Figure 11

Here the output (pink line) of closed loop system doesn't follow exactly the input from the signal generator (yellow line).

Pole-Placement Method

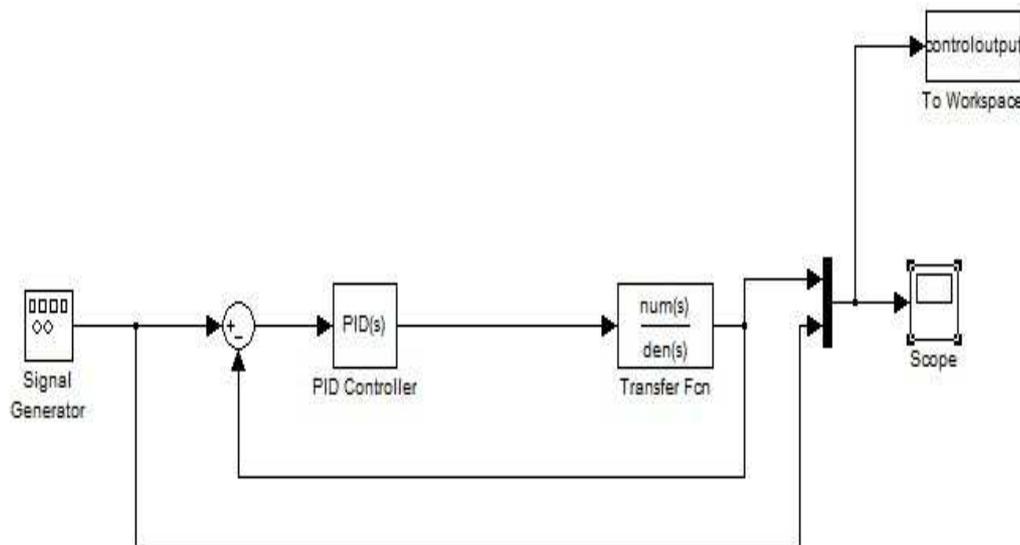


Figure 12

For this system, the open loop transfer function is given by:

$$G = G(\text{PID}) \times G(\text{MOTOR})$$

Where

$$G(\text{PID}) = K_p + (K_i/s) + (K_d s)$$

$$G(\text{PID}) = (K_p s + K_i + K_d s^2)/s$$

$$\text{And } G(\text{motor}) = \frac{.029s + .74}{.004s^2 + .3s + 1}$$

$$G = \frac{(K_d \times S^2 + K_p + K_i)(0.03 \times S + 0.74)}{(0.004 \times S^2 + 0.3 \times S + 1)}$$

$$= \frac{[0.03 K_d \times S^3 + (0.03 \times K_p + 0.74 \times K_d) \times S^2 + (0.03 \times K_i + 0.74 \times K_p) \times S + 0.74 \times K_i]}{(0.004 \times S^2 + 0.3 \times S + 1)}$$

And the feedback transfer function $H = 1$

So, the characteristic equation in terms of PID gains is given by:

$$1 + G \times H = 0$$

$$0.004 S^2 + 0.3 \times S + 1 + 0.03 K_d \times S^3 + (0.03 \times K_p + 0.74 \times K_d) \times S^2 + (0.03 \times K_i + 0.74 \times K_p) \times S + 0.74 \times K_i = 0$$

$$0.03 K_d \times S^3 + (0.03 \times K_p + 0.74 \times K_d + 0.004) \times S^2 + (0.03 \times K_i + 0.74 \times K_p) \times S + 0.74 \times K_i = 0 \quad (2)$$

Let us consider the desired poles are $(-3+j)$ and $(-3-j)$. But, since the characteristic equation is cubic equation, so another pole needs to be chosen such that it does not affect the speed of the response, and also does not bring about much change in the overall system-response. For this, it needs to be located at an optimally large distance from the dominant poles. Let, the third pole is at (-10) . So, the desired characteristic equation is:

$$(S + 10)(S + 3 + j)(S + 3 - j) = 0$$

$$(S + 10)(S^2 + 6S + 10) = 0$$

$$(S^3 + 16S^2 + 70S + 100) = 0 \quad (3)$$

Comparing the characteristic equation in terms of PID gains (1) and the desired characteristic equation (2),

we get.....

$$K_p = 0.34 K_i = 0.097 K_d = 0.024$$

Closed Loop PID Controller

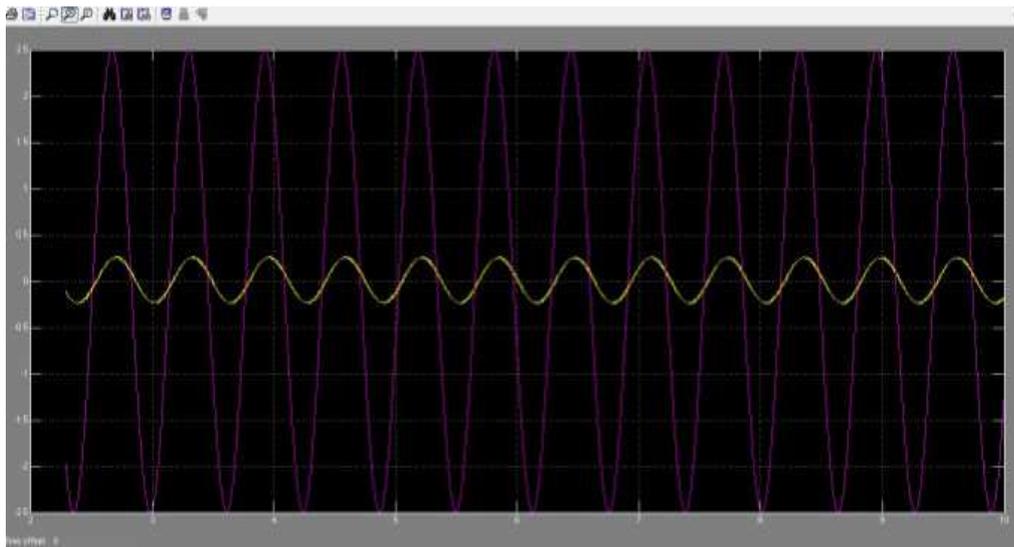


Figure 13

When this model is run, the output (yellow line) of the closed loop system is seen to closely follow the input (pink line) from the signal generator. This indicates optimum performance of the system.

CONCLUSIONS

By the mathematical analysis of DC SERVOMOTOR, we found that the system was second order.

After that we used Peripheral Control Interfacing device (PCI- 1716) for data Acquisition.

Additionally to achieve more accurate system, the system was modelled using System Identification Toolbox of MATLAB, and a PID controller was designed for the model.

After that PID controller was designed for the control of speed of motor and environmental error also. First relay and another pole placement method. Then the system is run in closed loop configuration. It was observed that the speed output of the closed loop control system successfully tracks the reference.

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