

DC servo motor positioning with anti-windup implementation using C2000 ARM-Texas Instrument

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Abstract. One of the most important topics in control system is DC Motor. At this research, a positioning control system for a DC motor is investigated. Firstly, the DC Motor will be parameterized to get the transfer function model, in order to be simulated in Matlab, and then implemented in a C2000-ARM microcontroller from TI (Texas Instrument). With this investigation, students in control system theory will be able to understand the importance of classical control theories, in relation to the real world implementation of the position control for the DC Motor, especially the importance of Anti-Windup technique in real-world implementation.

Keywords: Position Control DC Moto, C2000 ARM-TI, Anti-Windup

1. Introduction

DC motor is used a lot in the industrial world. One of the advantages using DC Motor is the ease to control its speed. For PM-DC Motor, its magnetic field is constant; therefore we only have to regulate the armature voltage, in order to control the speed of DC Motor. In industrial, one of the importances used of DC Motor is in positioning control. Therefore in this investigation, a laboratory experiment is conducted, in order to support the theory of classical control system, for the positioning control system of DC Motor.

We will look at a method to extract the motor parameter manually based on experimental, and then develop a model of the DC Motor, to get the transfer function for the simulation in Matlab, Next, a PID control technique is used in C2000-microcontroller from TI, to implement this position control system of a DC Motor.

2. Mathematical Model of DC Motor

Based on figure 1, we can model the DC Motor as follow:

$$v = Ri + L \frac{di}{dt} + V_e \quad (1)$$

$$T = J \frac{dw}{dt} + T_{load} + b\omega \quad (2)$$



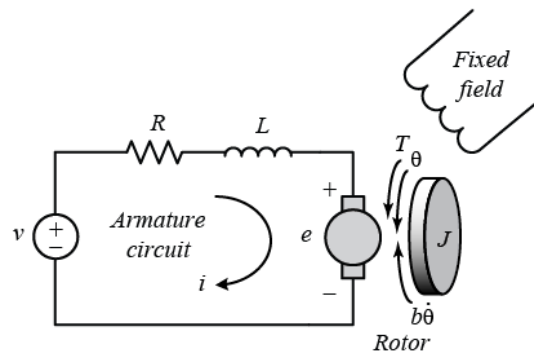


Figure 1 – DC Motor Circuit

3. Parameters of DC Motor

The DC Motor with Electro-craft Model: M1140, is illustrated in figure 2:



Figure 2 – ElectroCraft M1140 DC Motor

The parameter of this DC Motor can not be found in manufacturer web-site; therefore we will take measurement for the following parameters:

1. Resistance
2. Inductance
3. K_e
4. K_t
5. Moment Inertia J_m
6. Total Moment Inertia = $J_m + J_{load}$, assumming $J_{load}=0$
7. Friction B

From the measurement, we have the following results:

1. Resistance = 5 ohm
2. Inductance = 10mH
3. Voltage Constant = 0.065 [volt.sec/rad]
4. Torque Constant = 0.578 [lb-in/amp] = 0.578 [lb-in/amp] . 0.113[Nm/lb-in] = 0.065 [Nm/amp]
5. $J_m = 4.828 \cdot 10^{-6}$ [Nm-sec²/rad]
6. Total Moment Inertia = $J_m = 4.828 \cdot 10^{-6}$ [Nm-sec²/rad]
7. $B = T/w = 7.91 \cdot 10^{-4}$ [Nm-sec]

Figure 3 describes how the moment of inertia of the DC Motor is calculated based on a step input to the DC Motor. As we know:

$$T = J_m * a \quad (3)$$

Therefore, we can calculate J_m , by knowing the Torque and the acceleration. By noting the maximum current during this step signal, we can calculate Torque as follow:

$$T = K_t * I \quad (4)$$

While the acceleration is measureable from figure 3, by looking at the linear region when the change of speed is occurring.

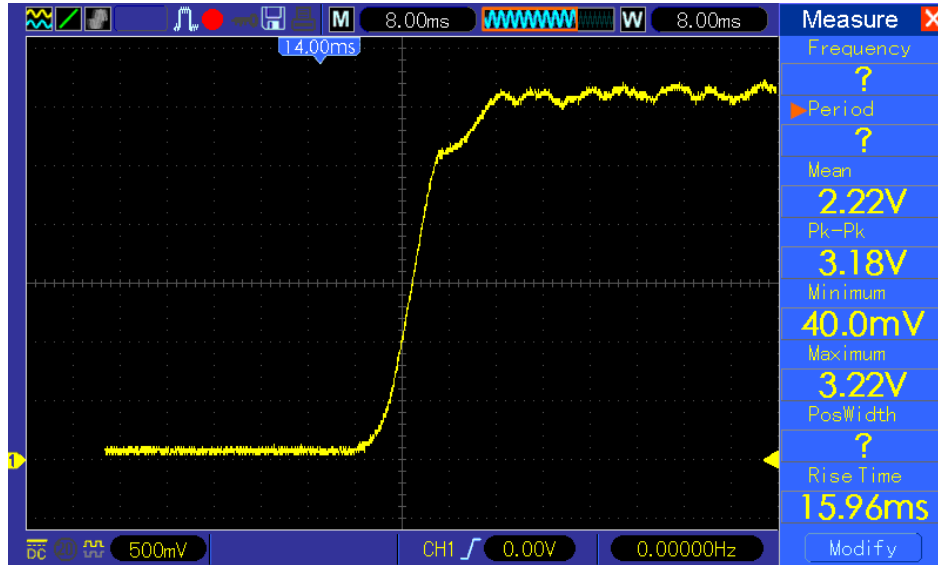


Figure 3 – Tachometer's voltage related to speed (ω)

4. Simulation

With the following transfer function of DC Motor:

$$tf_{motor} = \frac{\theta(s)}{V(s)} = \frac{K}{s((Js+b)(Ls+R)+K^2)} \left[\frac{rad}{V} \right] \quad (5)$$

We can insert the motor parameter into equation 5, to get the following transfer function:

$$tf_{motor} = \frac{0.065}{4.828e^{-8}s^3 + 3.205e^{-5}s^2 + 0.00818s} \left[\frac{rad}{V} \right]$$

We get the following open-loop step response from DC Motor transfer function:

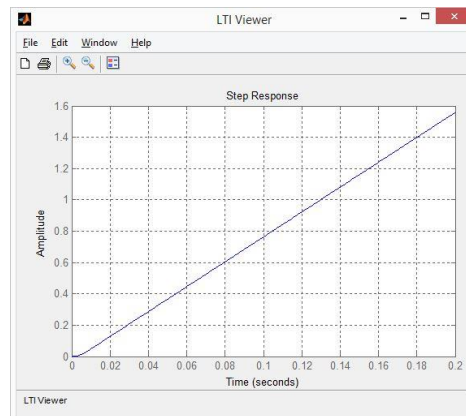


Figure 4 – Open-loop Response Position Servo DC Motor

As we can see from figure 4, the step response of the open-loop is not stable. Therefore a closed-loop step response is needed. The following is a step response for the closed-loop DC Motor using PID in C(s), with $K_p=12$, $K_i=0$, $K_d=0$; with the following z transfer-function (using c2d function in matlab):

$$\frac{2.6483e^{-6}(z + 3.671)(z + 0.2635)}{(z - 1)(z^2 - 1.934z + 0.9358)}$$

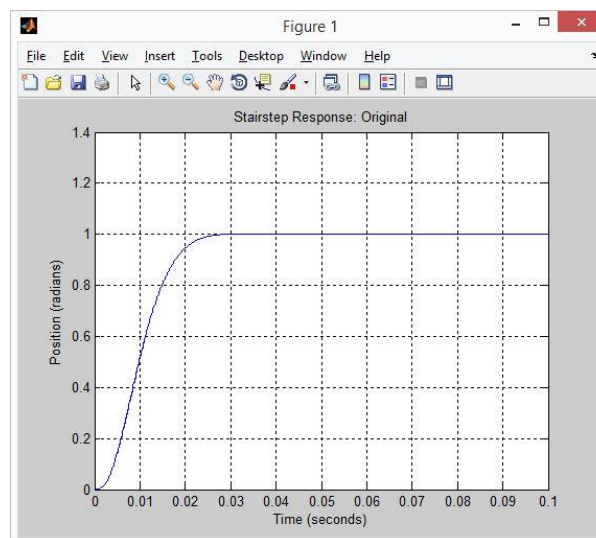


Figure 5 –Close-loop Step response of DC Servo Motor

Figure 6 illustrate the closed-loop block diagram that incorporates disturbance input.

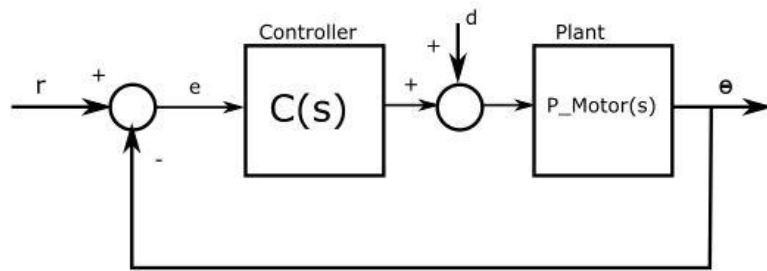


Figure 6 – Closed Loop with Disturbance

While figure 7 verified that the output in position, returns to zero, when subjected with a step disturbance input.

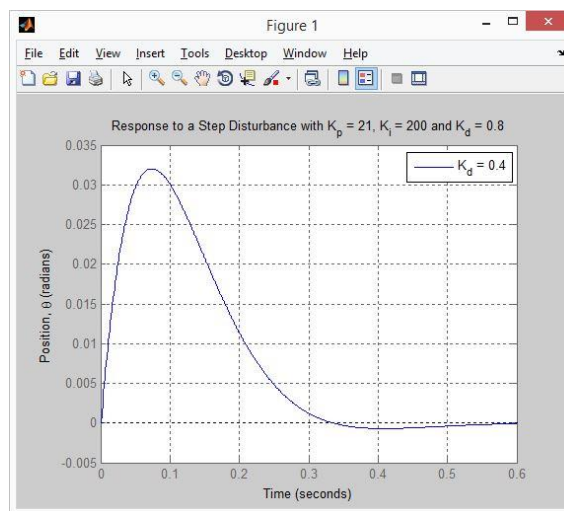


Figure 7: Disturbance Response from a step disturbance input

5. Implementation using C2000

C2000 is a 32-bit ARM microcontroller with a powerful frequency of 60Mhz. Figure 8 show the set-up of Position DC-Servo Motor System.

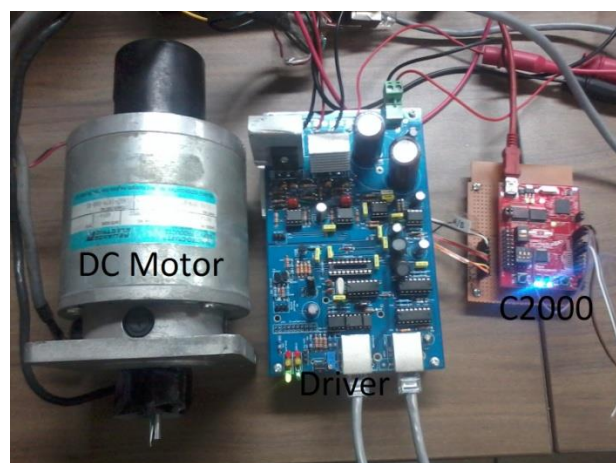


Figure 8 – Position DC Servo Motor

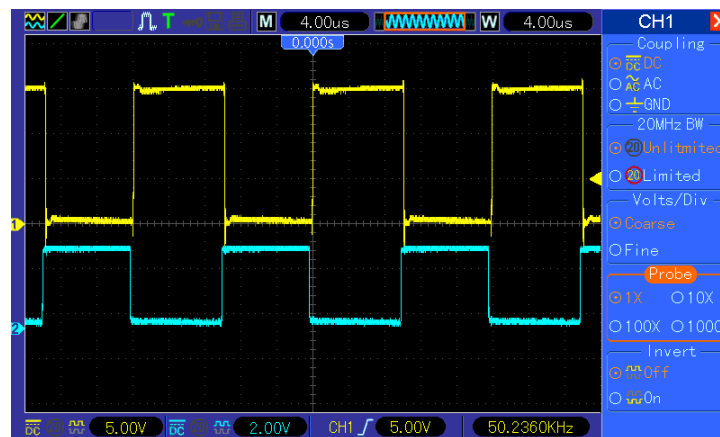


Figure 9 - PWM signal during stationary

Figure 9 shows the PWM signal coming out from C2000 microcontroller at stationary (blue signal), while the yellow one is the PWM signal at the DC Motor terminal. It can be noticed, that the frequency of PWM signal is about 50 KHz, which is far above the audible frequency of human.

Figure 10 graphically shows how accurate the positionings are, using Ziegler-Nichols Method in finding the value of K_p , K_i , and K_d .

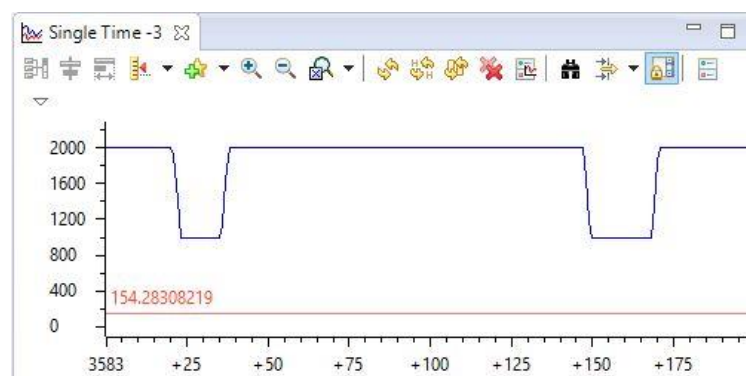


Figure 10 – Stepping back-and-forth 1 cycle with 1000ppr encoder

6. Conclusion

A control PID with C2000 is capable to do positioning without an overshoot, using ZN-method to get good PID parameters of K_p , K_i , and K_d . The motor parameters are measurable with the oscilloscope and the multimeter in our laboratory. With the development of this experiment, the students will understand better about the servo control system that is being used in the industry.

7. References

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