Learning PID digital motor control using launchpad C2000 ecosystem from Texas-instruments

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Abstract. Control System and Microcontroller courses have no close relation in our curriculum, based on the content of those two courses. Therefore, students have difficulty to relate the control system theory with its implementation in digital circuit, especially using microcontroller. With the funding from Binus and the laboratory support on Matlab simulation, our students are expected to be able to implement control algorithm solution, into a real control system implementation, which in this case, a PID for a Servo DC Motor. The Ecosystem Launchpad-TI helps students in their first year, to learn about control system, where the experiments can be conducted with a ready hardware named “Launchpad” and its associated software, which are packed in a digital control library (DCL) format.

Keywords: microcontroller, PID, servo DC motor, Digital Control Library (DCL)

1. Introduction

From the previous paper [8], an unknown DC motor parameter, can be calculated based on experimental procedures. This time, the DC motor is connected to a ball-screw linear guide, to change from a rotary into a linear motion and with it, the inertia of the whole system increased. The objective of this is to have a proof of concept that PID control algorithm can be indeed used in a practical application, such as in a CNC machine [11-12].

The goal of this research is to relate between the mathematical transfer function of the DC motor, with its control algorithm implementation using C2000 TI microcontroller. The ability to understand the relation between the Z transform analysis tools with its difference equation, becomes an important foundation in bridging the simulation control algorithm model into coding. Because without the skill to implement the algorithm in microcontroller, students will not understand the essential of Z transform as an analysis tool. And more importantly, students will be more motivated to learn control theory, because they know its importance in our industrial society.

For the simplest algorithm, we will focus only on the PID algorithm applied to a Positioning DC Servo Motor. Because we used a linear ball screw (figure-1a), the students will be able to directly see if their PID implementation works in real system. While figure 1b shows the rest of the experimental setup, which include a C2000 TI microcontroller and a DC servo driver.
A literature study [1-5], shows that it is important for undergraduate student to see that control system really works as in mathematical model. This approach greatly motivate students to learn further in the direction of control engineering. During this experiment, it is realize that a good understanding in Laplace Analysis in Electronic circuit has become a foundation to link between the classical analog control analysis with the digital control analysis, in which nowadays a solution in the form of digital control system is a must in industrial world [6].

2. **Hardware System**

Creating a positioning control system for DC Motor, requires multidispline in electronic, mechanic, mathematical analysis, and also in programming skill. Therefore students who take an introductory of control system, must be exposed with a project guide that led them to successful implementation of their first PID positioning system.

Fortunately, Texas instruments has created a launchpad ecosystem, that benefit students and universities who has no capabilities to produce their own professional electronic prototypes. And moreover, TI has a full support for a free compiler and debugger tool at their disposal. The launchpad itself cost only between USD 10 up to USD 20, depending on the power of the microcontroller.

For the electronic of motor driver, we use a H-bridge system with mosfet driver IR2184 design by UHU [13]. Figure-2 highlights one important function, i.e. a current limiter. The current flow into the motor is sensed by a passive low value resistor. If the voltage drop across the sense resistor is greater than the setpoint voltage value, then the system will turn off the entire MOSFET that form the H-bridge.
Figure 2 – A snapshot of current limiter circuit using a Comparator Op-Amp

Figure 3 – Another snapshot of H-bridge using Mosfet Driver IR2184

Figure 3 shows the usage of a 4-quadrant PWM in this system [14]. In a 4-quadrant PWM, a 50% duty cycle, means that the DC Motor position is equal with its tracking reference \(r\). Therefore to determine the direction of rotation, it is only based on the left and the right value from its center point, which is a duty cycle of 50%.

3. Software System

A Launchpad F28027 is used as the brain controller for this experiment. A chosen control scheme is PID, which is a professional PID implementation based on chapter 3 from C2000™ Digital Controller Library User Guide [7].

Figure 4 shows the design of digital PID block from C2000 DCL. Notice, that in the classroom, it is very important to show the students how to translate from \(z\)-transform into a difference equations, and then into a block diagram. This skill is needed for students to be able to use the PID library in C2000 microcontroller.
The PID tuning procedures are as follows:
1. Set Kp to a safe value (Kp = 1000) and set Ki and Kd to zero.
2. Apply a disturbance transient into the DC Servo Motor via its rotor, by jerking the rotation of its motor.
3. If oscillation occurs, then lower the Kp value by 10%.
4. Increase Ki to eliminate steady-state error.
5. If an oscillation occurs, then lower the Ki value again by 10% from its point that the oscillation occurs.
6. Set Kd only if the values of Kp and Ki can not eliminate the oscillation.

It is important that students have experiences to tune a PID controller, before advancing to a more modern control theory, such as state-space model.

4. Conclusion

With a real show-case of DC Servo Positioning control, directly coupled with a linear ball-screw guide, students understand better about the relation between mathematic analyses with the programming implementation in microcontroller.

With the use of TI Launchpad ecosystem, the difficulty in making professional PCB (Printed Circuit Board), can be avoided. And the PID programming library has lessen the student effort to write the programming from scratch. Therefore, students have more time to compare the simulation data with the actual output implementation.

With this literature research accomplishment, it is hoped that in the future, modern control system theory can be explore in undergraduate students level, to solve a more complex control problem such as an inverted pendulum.

5. References

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