Gordon College

Spring 2020 Project Development Plan

Designing a PID Controller using an FPGA to Stabilize Laser Intensity

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1 Background

PID control is a ubiquitous concept in engineering. One survey found that in the refining, chemicals and pulp and paper industries for instance, 97% of regulatory controllers use PID feedback [1]. PID control falls within the domain of control engineering and is used to control mechanical and electrical systems. Any system describing a physical design, whether used in scientific research or professional industry, must obey certain parameters to fulfill its intended purpose. A PID's role is to ensure these parameters are obeyed. PID is an acronym that stands for proportional-integral-derivative because the PID controller uses these three mathematical operations – multiplication, integration and differentiation – to respond to feedback stimuli to adjust the system under control so that the system obeys the design parameters.

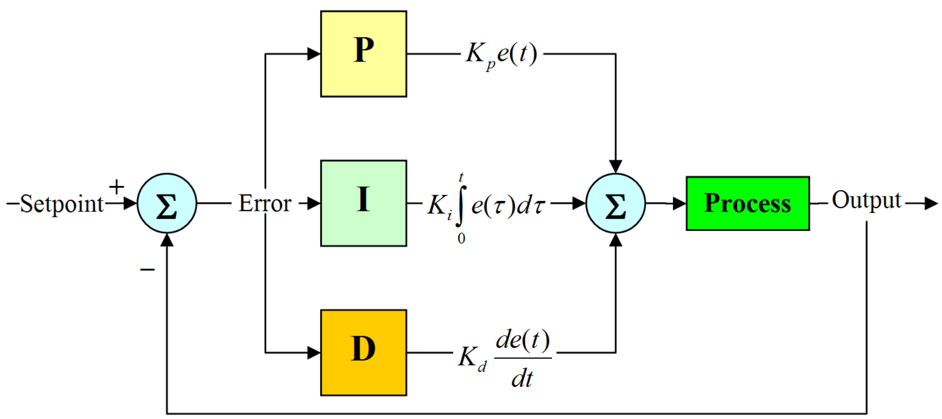

FIG. 1. Schematic of a PID controller [2].

In this project, an FPGA will be used to program these mathematical operations into digital and subsequently analog reality. FPGA is an acronym that stands for Field-Programmable-Gate-Array. These devices are quite complex but suffice it to say that essentially an FPGA is an integrated circuit composed of thousands of programmable logic blocks surrounded by equally numerous input-output pins which may be used to interact with an external circuit. The behavior and internal connections of these blocks and pins are programmed by the user (see Fig. 2 for a block diagram). A PID can be programmed using these logic blocks.

Digital PID's programmed into an FPGA have been used in similar contexts for control of electrical current [3]. Additionally, PID's enable the user to avoid advanced analysis of a system and may be tuned to respond appropriately to system stimuli with simple intuition. This intuition is guided by an understanding of the effect on the controlled signal each mathematical operation has [4]. The "Field Programmable" nature of FPGAs give them the flexibility to be adjusted real time even after being implemented in experiment by reprogramming them. Finally, FPGA's execute code in parallel which enables them to respond faster by executing blocks of code simultaneously rather than sequentially.

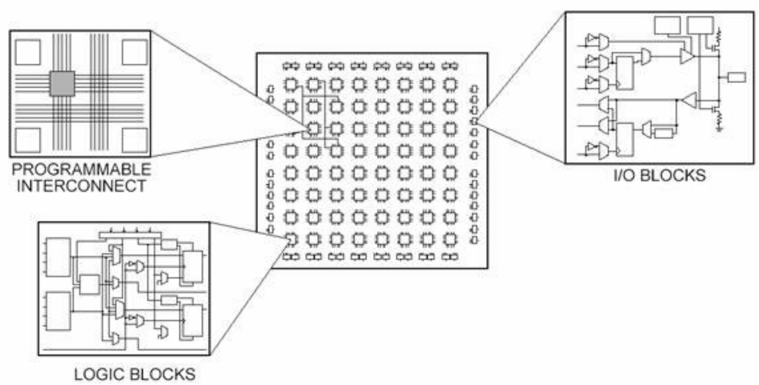

FIG. 2. Diagram of an FPGA and its main parts [5].

2 Statement of Work

The system under control is a laser whose intensity must remain within a specified range. Its intensity is current controlled via an Acoustic Optical Modulator (AOM). The intensity of the laser will be detected with a photodiode and the resulting current will be fed to the FPGA. Based on the level of this current, the FGPA will adjust the current fed to the AOM to ensure the AOM outputs the desired intensity of light. Prior to programming the FPGA, a mathematical model of the PID will be developed and simulated using MATLAB's PID Simulink. This model will then be programmed into the FPGA. Lastly, Digital to Analog and Analog to Digital converters with sufficient resolution must be added to allow the FPGA to receive and output electrical signals.

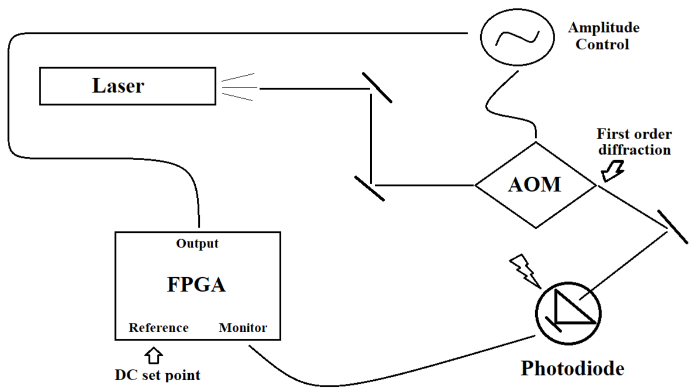

FIG. 3. Simplified diagram of the planned setup.

3 Timeline of Deliverables

Listed below is a confirmed presentation. More presentations may be added.

- Spring, 2020: Oral presentation of research at Gordon College's Physics Department Senior Seminar.
- May 6, 2020: Showcase research at Gordon Undergraduate Research Symposium.

4 Resources and Expenses

This project is funded by a grant from the National Science Foundation. Principal investigator is Oleksiy Svitelskiy.

Expenses include FPGA board, analog components and travel.

5 Grading Rubric

Student's grade for research course will be determined by the following rubric. Due to unforeseen developments in the research process and the ongoing global epidemic, this rubric is subject to revision.

• 5%: Completion of comprehensive and well written Project Development Plan.
• 20%: Thorough laboratory notebook entries throughout semester, including time log and experimental data.
• 20%: Proper modeling of system, PID tuning and simulation in MATLAB or other simulation program.
• 20%: Successful programming of PID into FPGA.
• 10%: Organized and understandable presentation on background and current status of project at Gordon College Senior Seminar.
• 10%: Poster presentation of research at Gordon College Undergraduate Research Symposium.
• 15%: Successful installation of device at MIT-Harvard Center for Ultracold Atoms.

6 References

[1] L. Desbourough and R. Miller. Increasing customer value of industrial control performance monitoring - Honeywell's experience. In "Sixth International Conference on Chemical Process Control." AIChE Symposium Series Number 326 (Volume 98), 2002.

[2] "PID Controller Design Using Simulink MATLAB : Tutorial 3." Microcontrollers Lab, 11 Jan. 2019, microcontrollerslab.com/pid-controller-design-simulink/.

[3] R. Thomas and N. Kjærgaard, "A digital PID controller for stabilizing large electric currents to the ppm level for feshbach resonance studies" (2019), arXiv:1909.11257[physics.atom-ph].

[4] Li, Y. , Ang, K.H. and Chong, G.C.Y. (2006) "PID control system analysis and design." IEEE Control Systems Magazine, 26(1), pp. 32-41. (doi:10.1109/MCS.2006.1580152)

[5] "FPGA Fundamentals." FPGA Fundamentals - National Instruments, www.ni.com/en-us/innovations/white-papers/08/fpga-fundamentals.html.