Project Proposal:
FPGA Motor Control Pinball Machine

Members:
Michael Ozymy (mjo2156), Joseph Han (jh4632), Lennart Schulze (ls3932)

Abstract: We plan to interface the development board with the physical world by building a simple pinball machine. The system will consist of sensors and actuators that serve to update scores and control the game. The FPGA will be used for motor control by potentially implementing a Pulse-Width Modulation module, and the hard processor will be used for game logic, score keeping and interrupt handling.

Motivation: Tapping on the benefits of the FPGA to parallelize signal handling and the interrupt handlers of the ARM architecture to deal with real-time inputs from the physical world. Through this project we would gain a deeper understanding of hardware accelerator designs as well as operating systems. The technical challenge will consist mainly of interrupt handling.

Key Components: The core of this project will be based on the implementation of the physical game of pinball. Our main peripherals will be motors and sensors that either interact with the ball or keep score. The FPGA will be used as a motor controller that activates flippers to strike the ball. To keep score we plan to use sensors or buttons that feed signals to the FPGA. Other possible areas of expansion include VGA score visualization, reactive lighting in the game, and score multiplication based on physical combinations in the game.

Main Expected Hardware:

- Motors (to control flipper bat):
  - Flipper assembly: https://www.pinballlife.com/full-flipper-assemblies.html
  - Possible motor configurations that would be controlled by the logic on the FPGA. We will likely need to configure an external voltage management device to power the assemblies with the correct voltages.

- Sensors (to detect ball movements and interactions with board elements):
  - Optical Infrared: https://www.marcospecialties.com/pinball-parts/160-0010-00
    - To detect the presence of the ball in different areas of the game.
    - Using induction, detect the proximity of conductive objects
  - Roll Over Button: https://www.marcospecialties.com/pinball-parts/25938
    - Will detect when the ball hits a location on the board and can translate into points on the FPGA.

- Display (to show score):
  - FPGA built in hex LEDs or VGA display if time permits.
Other Parts:

- Breadboard, 20-pin header cable, transistor, wires, power source for wiring and power supply to the motor

Timeline / high-level milestones:

**Milestone 1 [25%]: Basic board with button-controllable flipper bats**

→ Via the click of a push button (potentially preliminarily one of those on the board), be able to have a motor move the flipper bat up quickly so that a ball on it would get pushed up. Have power supply and electrical wiring set up.

**Milestone 2 [50%]: MS1 + detection of ball in off + ball reset mechanism**

→ Install at least one sensor such that the FPGA recognizes when the ball is in an area (hole) specified as off. Have a mechanism (likely mechanical-only) to move (push) the ball from the off to the desired start position.

**Milestone 3 [75%]: MS2 + hurdles and trajectories design + points recording and display**

→ Augment the board by installing hurdles and other design elements as desired. Define and implement which triggers (rolling over certain areas, pushing elements with sufficient force/speed, bouncing off parts of the wall) add points to the score. Implement logic to display the score on the FPGA display and reset score when the game ends.

**Final delivery [100%]: MS3 + Optimization of design and advanced game mechanism + user interface**

→ Optimize previous design. Come up with more advanced point awarding mechanisms (e.g. combination of triggers leads to sophisticated add or subtraction of points). Potentially connect an external VGA display and have a simple user interface showing the points and maybe additional elements.