Department of Electrical and Computer Engineering
COMPSYS 305 – Digital Systems Design
Mini project (25%)

Objective

The goal of the mini project is to design a simple game console with a built-in computer game using only digital logics and digital design.

Equipment provided in the project

Apart from computers available in the lab, you will need the following equipment during your project which can be obtained from the ECE Component Store. Each group should have access to only one set of the following equipment:

- A DE0-board (used as the game console), a USB cable and a power supply.
- A PS/2 Mouse.
- A VGA cable

Game description

The game (flappy bird) is controlled and played (or displayed) using a PS/2 mouse, a VGA screen (640 x 480 pixels), DIP switches and pushbuttons as the man-machine interfaces. The game should be displayed on an ordinary computer monitor via the VGA interface. Refer to the web link: http://flappybird.io/ for a possible game setting. The game is a side-scroller where the player controls a bird, attempting to fly between rows of pipes without hitting them. The game you are going to design should follow some preliminary rules:

1. The bird can move up or down (and backwards/forwards to some extent), controlled using a **PS/2** mouse. If the bird is not flapping, it will free fall towards the ground. The bird is dead if he falls on the ground. The bird must not touch anything when flying, or else it will loss life points. When life points are depleted, it will die.
2. The game may consist of different types of obstacle (e.g. pipes) and/or gifts (e.g. dollars/medicine boxes/special flying abilities).
3. The bird consumes energy when it flies which can be replenished from the food/energy items randomly distributed over the path of fly. If bird fails to replenish the energy, it will eventually run out of energy and die.
4. The game may consist of different types of obstacle (e.g. pipes) and/or gifts (e.g. dollars/medicine boxes/special flying abilities).
5. The screen must be kept in motion from left hand side to the right hand side at a constant speed, which increases with the game level.
6. The level of difficultness can be controlled by various criteria, for example, the horizontal screen motion speed, the types of obstacles, and energy.

These preliminary rules can be used as **general guidelines** for your game specifications. However, you are welcome to **introduce changes** in the game rules to make the game more interesting and challenging. Please discuss with the TAs or lecturers regarding changing game rules if you are in doubts. You may need to use a pseudo random number generator (implemented as linear feedback shift register) for generating random types of obstacles and gifts. For practical reasons you can assume a reasonable finite number of possible values. Also remember that for your game bird and simple pipes graphics are sufficient but adding other graphic details may count in your favour.

Game modes

The game should have two operation modes:

1. TRAINING mode
2. Single-Player GAME mode

In **TRAINING mode**, the game allows the player to practice at the lowest game level until the bird's **blood/life** becomes **zero**. The game mode can be determined by using a DIP switch on the console

(i.e. the **DE0** board), provided as a control input. When the game console is powered up or reset, it should automatically go into an initial state with a proper graphical user interface, which requires the player to select a mode and start the game. Start of the game can be indicated by pressing a push-button provided on the console as another control input. Similar to other video games, you may need to provide simple textual messages on the user interface to a player (messages like start, end, mode, score = value, time = value, energy=graphics). While playing the game, another push-button can be used to perform pause/resume functionality in the game.

In the **GAME mode**, a player should try to stay alive. The game will proceed to more advanced levels following certain criterion, such as time, distance, or number of obstacles passed through. Each subsequent level will be more difficult, in terms of screen motion speed, route planning etc. The GAME mode should contain at least three levels.

In this mini project, the hardware platform that you will use for implementing the game console is Terasic DE0 board. The board provides all necessary interfaces (PS/2 for mouse, VGA for monitor, DIP switches and push-buttons) and a relatively large FPGA in which the game logic will be implemented.

Tasks

Your tasks are:

a) Understand and specify the full operations/functionalities of the game (logics) and man-machine interface.
b) Study operations of the input and output devices and features of the DE0 board. Also, you will be given some basic design blocks which you can use as a starting point in your project and speed up the design process.
c) Decompose the game into parts which can be described in VHDL and design those parts (specify/design, implement, simulate, synthesise). In this process identify the elements of datapath and control unit.
d) Implement all design parts and compose the game console by integrating individual parts into a full design.

Project Groups

The project is done in groups with **two students** who at the end have to produce the evidence of individual contributions (who has done what) and a confidential peer assessment in which they evaluate the contribution of his/her peer in terms of design specification, implementation, testing and report writing (grades between 0-minimum and 5-maximum, and short comments and observations if necessary). In case of special concern regarding the performance and involvement of your project partner you can contact lecturers not later than **two weeks** before the project deadline.

Deliverables

The project final deliverables from each team are:

- A zip file including project report soft-copy, all project design and simulation files, additional explanations etc. Details about the submission process will be provided later.
- Soft-copies of individual peer assessment form. The individual peer assessment form should be emailed directly to the lecturer. (muhammad.nadeem@auckland.ac.nz).

Assessment

The project is done in two stages:

Stage A (10%):

Interim progress review will be scheduled during the lab time of **week 9 (Tuesday, 14th May)**, where each group will present their progress. It includes demonstrating the ability to use all man-machine interface devices (i.e. VGA display, mouse, DIP switches, push-buttons or even seven-segment display if necessary).

Evaluation criteria guidelines

Interim report (4%) with at least the following three items (2-page max, design ideas can be reused in final report, proper report structure is not required but writing should have a logical flow).

- Design specification: Providing a definition and requirements of the system that you are designing (definitely not a copy of the given project description).
- Block diagram showing all the components of the game and interface between them (you do not need to show all the signals)
- Clearly outline the game strategy
- High-level **state machine** of the game

Artefacts developed for the interim report can be reused when preparing final report.

Note: Bring the hardcopy of your two page interim report and hand it over to examiner during the interview. If your ASM does not fit in two pages, you can attach it as appendix.

Interim Interview (4%) will generally be evaluated based on:

- Functionality of man-machine interface devices
    - Display the moving ball (provided) on the VGA display and show some sort of the control of the ball showing the ball behaves differently than the provided design
    - Working mouse (you can use the data packet received from the mouse to control ball movement or display the packet on seven segment display)
    - Evidence of working DIP switches, push-buttons or even seven-segment display (you can think of a way to demonstrate their working).
    - Display the text on the VGA display
- Familiarity with the design resources
- Explanation of your design and design plan
- Quality of the design plan and initial implementations

Altera FPGA Resources Understanding (2%)

- Answer questions related to Embedded Memory Blocks, Clocking Networks, and PLL available in the target FPGA board

Stage B (15%):

1. The final report (5%) and other deliverables should be zipped in a file before **week 11 Thursday 30th May 1 pm**. The report should be no longer than 6 pages, following the template provided on Canvas.
2. Final demonstration and interview (10%) will be held during the lab time of **week 11 Thursday 30th May 2 – 4 pm**.

The final demonstration presented should be based entirely on the submitted deliverable and you are not allowed to change the code after submission.

Evaluation criteria guidelines:

- Good understanding of the game (i.e. the system) requirements and functionalities that "you are designing" and the provided development board features in order to implement the game.
- The ability to decompose the problem (i.e. the game, the system) to small functional blocks by providing a block diagram with clear definition of relations/interfaces between functional blocks.

- Go through different reports generated by the synthesis tool (Quartus II) to understand the performance of the designed system (e.g. resource usage, operating frequency) and give some comments for future improvements (or even perform reasonable optimisation in this project).

The **final report** (5%) is expected to be more detailed especially with regard to:

- The final system design and implementation. It should also provide information about the FSM for controlling the overall operations of the system.
- Explaining your design decisions/trade-offs and the merits of your design specification/decomposition.
- The resource usage and performance (max. operating frequency etc.) of your implementation to indicate the quality of your design and suggest possible improvements.
- Provide at least five references.
- The report should be 4-6 pages using the report template provided. You can reuse the material from the interim report.

Following are the guidelines for the report format:

- Abstract
  - Summary of major aspects of the paper in sequence (usually one sentence from each section)
- Introduction
  - A very brief introduction of mini-project and rules
  - Mention contributions (anything implemented apart from what was provided to you. it does not mean your individual contribution but that of group)
- Game strategy
  - Your Rules and Features of The Game (including description and justification for any variation from the spec)
  - Description of man-machine interfaces (for example mouse, push button and VGA display etc.)
  - Textual description of how to play the game
- Implementation
  - High-level system block diagram (NOT a screenshot of the block diagram)
  - Diagrams and brief description of any FSMs in the system
  - Overview and brief description of each block implemented
- Results
  - Statement of resource consumption (and some analysis as to why)
  - Description of timing analyses (critical path, operating frequency etc.)
  - And any other design decisions and justifications
- Conclusion and Future Work
  - Restate the topic, restate theses, and summarize main points,
  - A reminder that conclusions in our reports are in prose (not bullet points
  - What would you add to existing game if given more time
- Appendix
  - Create an ASM chart of the **vga_sync** component

The emphasis during **final interview** (10%) would be on:

- The quality of the game and its features
- Clear understanding of your code and design (and whether the coding follows the design)
- Design performance (resource usage and operating frequency). You should be able to explain which component of your design is using most of the resource.
- Presentation quality (you might prepare a few slides to explain your design)
- Answer questions related to Embedded Memory Blocks, Clocking Networks, and PLLs available in the target FPGA board

Support

Additional information, documentations, useful notes and hints that can help in implementing this project will be provided on Canvas. For the purpose of getting feedbacks for your design decisions, TAs (Nicholas Harvey, Maryam Hemmati) will be available during the fixed weekly lab time (Tue/Wed 2-4pm). You can consult with them within those given hours.

Academic integrity notice

The University of Auckland will not tolerate cheating, or assisting others to cheat, and views cheating in coursework as a serious offence. The work that a student submits for grading must be the student's own work, reflecting his or her learning. Where work from other sources is used, it must be properly acknowledged and referenced. This requirement also applies to sources on the world-wide web.