# ENGN8537: Embedded Systems Major Project

## Description

The major project for Embedded Systems will require the students to design and implement an Embedded System centred on an Altera DE2-115 Development Board. The students will critically analyse the structure of their design and justify implementation decisions regarding HDL or procedural implementation, real time constraints, physical interfacing assumptions and others as relevant to the particular project chosen.

The project is designed to allow the student to explore areas of knowledge that have interested them over the course of their degree. There is no fixed task to be accomplished as students are encouraged to formulate projects based on problems they've been exposed to in their study of other areas such as Computer Vision, Control Systems, Telecommunications, Robotics etc. Inspiration for projects may be taken from the list of Project Ideas listed below.

The project may be based on a Verilog HDL implementation, an Embedded C program for a NIOS-II soft-core processor or a combination of both.

The project is to be undertaken by each student individually. The project and lab work will form 35% of the assessment for the course with the breakdown described below. Weekly lab sessions will be available to all students for development and testing of their designs, however it will be assumed that the students continue to develop the project in simulation or otherwise on their own time.

Students are free to make use of code given as part of the example package as well as any other code bases they have access to (including online) so long as the following conditions are met:

- The student must have the right to use and redistribute the code (licence compliance)
- The student must clearly attribute the source of the code, both in the code base itself and in the accompanying documentation
- The student need not completely understand how the used code works, however they must be able to describe what the code does and how it interfaces to the rest of the project and/or the environment.

Code that has not been written by the student will not be assessed, but should be used to facilitate other assessable outcomes.

Students are required to submit a formal project report of approximately 10 A4 pages including figures with architecture details, interface specifications, quantitative performance reviews and benchmarks of different implementation options for critical portions of their design. This will be reviewed by the assessors prior to the project demonstration.

The project will be assessed at a scheduled demonstration. All students will present in their regular lab slot, schedule allowing. Present at the demonstration will be the lecturers, lab demonstrators and possibly external moderators as required.

## Available Hardware

In addition to the DE2-115 board, the following hardware devices are available. If you wish to do a project requiring hardware support but don't see the required peripherals on the list, please discuss with the lecturer as soon as possible.

- Ultrasonic range finders XL-MaxSonar-EZ/AE MB1200
- Microphones, Speakers
- Infrared remote controls
- PAL Camera device (limited numbers)
- TurtleBot mobile robotic platforms (limited numbers)

Note that the audio peripherals on the board may be used as general purpose analogue I/O, within the voltage and bandwidth limitations specified by the codec device. In addition, the VGA DACs may be used as general purpose high speed, high resolution Digital to Analogue converters.

## Deliverables

| Item | Date |
|---|---|
| Report | 17th October |
| Final Demonstration | 20th October |

## Report

Students are required to submit a formal report of approximately 10 pages, including diagrams. This should cover at least the following:

1. Intended function and operational instructions
2. Architecture and design
3. Functionality and functional limitations
4. Analysis of implementation options with respect to stated metrics (performance, FPGA utilisation, accuracy of results etc.).
5. Conclusion of design success including suggestions for future work or improvement
6. A one-page Executive Summary and full references.

Full marking criteria are found in the rubric included with the project package.

The report is to be submitted before the demonstration. The project may change in minor ways between the submission and demonstration (e.g. a bug has been fixed, an implementation detail changed). If this is the case, the student should simply mention the changes at demonstration time.

## Project Ideas

Students are encouraged to design their own projects, the ideas below are mostly for inspiration.

### Doppler velocity meter

A key item in robotics is object detection and avoidance. Using the microphone and speakers, a system may be created to determine the distance to, and velocity of, a remote object by round-trip delay and Doppler shift. This information may be combined with range data from Sonar or IR range finders by means of a Kalman Filter, Monte-Carlo algorithm or otherwise.

### Sonar Localisation

Sonar sensors give a single distance measurement as output, but a collection of sensors may be used to find the 2D location of a target. An implementation will have to deal with noise and filtering. If more than two sensors are used, clustering, filtering and/or outlier rejection may be examined.

### Audio effects board

Using the audio interface and implementing a selection of filter algorithms, the DE2-115 may be used as an audio effects board. The parameters of such filters and effects engines should be able to be selected by the user at run time and the current parameter set could be shown on the VGA display. Visualisation of the audio streams and effects via time domain, frequency domain and/or Bode plots could form part of an advanced implementation.

Analysis of different implementation options (e.g. combinatorial FFT vs. sequential/pipelined) could be investigated for performance and complexity.

### Computer Vision

The field of CV has many algorithms that may be accelerated using FPGA technology. A project may investigate the implementation of edge detection, feature detection, object recognition or many other such algorithms in the highly parallel FPGA environment.

### Instavideo

Video input can be taken from a camera, transformed and displayed on a VGA monitor. The transformation could include the application of “Instagram”-like filters, noise reduction, sharpening, brightness and contrast adjustment etc. An implementation should explain the limitation of FPGA design, especially memory, when applying such transformations.

### Crypto-coin Miner

An FPGA is suited to implementing the mining algorithms for Bitcoin, Dogecoin and other modern crypto-currencies. An implementation should examine the throughput of an FPGA design vs the power consumed.

## Project Notes

### Quantitative Data

Students should, where possible, use proper statistical methods to justify claims such as “Implementation B is faster than implementation A”. At the most basic level, the experiment should be repeated several times with averages and variances (standard deviations) noted.

If a difference between two sets of numbers is asserted, the means should be more than one standard deviation away from each other. In an HD-level justification of the difference of two implementations, a “Student’s Two-Sample t-Test” could be used. If the student is not familiar with this method, a summary can be found at [1] while the MATLAB function ttest2 can perform the calculation. Your choice of alpha value (confidence interval) should be justified.

[1] http://www.socialresearchmethods.net/kb/stat_t.php

## Marking

Marking will be split in to three parts. The project itself and the report form 30% and 5% respectively of the student’s overall grade for the semester. They will be marked according to the rubric supplied with the Project Package.

### Learning Outcomes

The student is able to:

1. Analyse the strengths and limitations of Microcontrollers and FPGAs for Embedded Systems
2. Construct real time constraints from problem specifications
3. Effectively integrate sensor, actuator and interface devices with Microcontrollers and FPGAs
4. Optimise the interaction of Embedded hardware designs with their software