ELEC 3300
Introduction to Embedded Systems

Course Introduction

Prof. Tim Woo

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Course Arrangement for Fall 2022-23

All the Lectures, Tutorials, LABs and Project will be running ONLY Face to Face Mode.

ELEC 3300 Introduction to Embedded Systems

- Teaching Team:
  - Course Instructor:
    - Prof. Tim K T WOO (email: eetim@ust.hk , Room 2419)
  - Teaching Associate:
    - Fox C H WU (email: eefox@ust.hk , Room 2395)
  - Technicians:
    - Darwin T W WONG (email: eetwwong@ust.hk, Room 3130)
    - Sam C W LAI (email: eecwlai@ust.hk, Room 3130)
  - Teaching Assistants:
    - CHAN, C. L. Jonathan (email: cljchanac@connect.ust.hk)
    - DUNDA, Gerry W. M. (email: gwmdunda@connect.ust.hk)
    - LIU, Jiaqi (email: jliuel@connect.ust.hk)
    - LIU, Tianyu (email: tliubk@connect.ust.hk)
    - YANG, Bowen (email: byangar@connect.ust.hk)
    - ZHANG, Xinjie (email: xzhangga@connect.ust.hk)

ELEC 3300 Introduction to Embedded Systems

- *Course Notes and Lab Notes: CANVAS system*

- *Course prerequisites and Background Knowledge*
  - COMP2611/ELEC 2300/ELEC2350/ISDN 4000F
    - Basic assembly language programming
    - Basic structure of a processor

- *Background Knowledge*
  - ELEC 1100 Introduction to Electro-Robot Design
    - Digital logic circuits designs
    - Simple circuit timing and timing diagrams
    - Electronic devices measurement

Teaching and Learning Activities

- Teaching activities
  - Lecture: 2 x 1.5-hour sessions (Week 1 to Week 7)
  - Tutorial: 1.5-hour sessions (Week 1 to Week 7)
  - Laboratory experiments: 2-hour sessions (Week 3 to Week 9)
  - Mini-talks: (Week 10 to Week 11)
  - Project: Talent-made schedule (Week 7 to Week 13 inclusive)

- Other activities:
  - Preliminary proposal discussion
  - 1 Final proposal presentation
  - 1 Interim project demonstration
  - 1 final project demonstration

- As there is no examination in this course, your participation and contribution is very important.

Teaching, Learning Activities and their grading scheme

- Continuous assessment: (55%)
  - In-class activities 8%
    - The in-class activities in the first two weeks are the pilot run. The score will be counted toward starting from week 3.
    - There are two criteria in getting the score:
      - First 6% is counted in the percentage of the questions you attempted.
      - The rest 2% will be given if more than 70% of questions are answered correctly.
  - 2 Homework assignments 10%
  - 6 Laboratory experiments 18%
  - 1 Preliminary proposal discussion (peer) 4%
  - 1 Proposal presentation 6%
  - 1 Interim project demonstration 9%

- Final assessment: (45%)
  - 1 Final project demonstration and presentation 40%
  - 1 Final report 5%

Requirements

- To be fair for those students who submit assignment on time, a penalty of late submission is listed as follow:
  - Late submission within 12 hours, Penalty of 25%
  - Late submission between 12 to 24 hours, Penalty of 50%
  - We will not accept any late assignment for more than 24 hours.

- Passing requirements of the course is
  1. Attend all the 6 laboratory experiments with demonstration
  2. Composite score > 45%

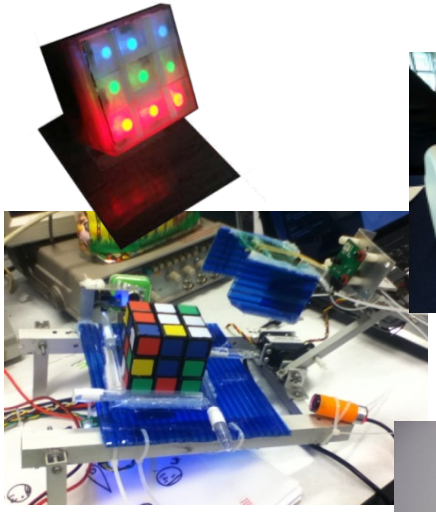
  - If you miss any meetings, a makeup meeting can be arranged if you could provide a supporting document.
  - Only maximum of one makeup meetings can be arranged.

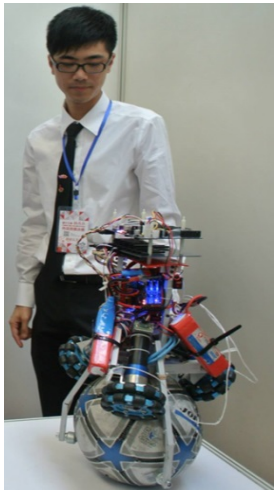
Topics

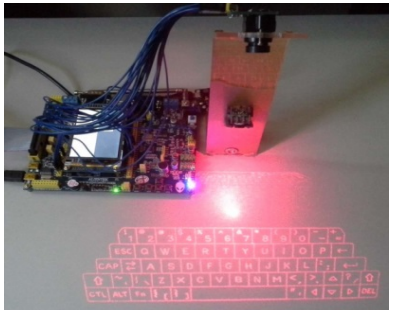
Item	Lecture	Tutorial	Laboratory (Start from Week 2)
1	Introduction to Embedded Systems	Introduction to use of Equipment	Use of Equipment
2	Basic Computer Structure	Number System and STM32 Structure	I/O Interface, Interrupt function of STM32
3	Embedded System Structure	I/O and Interrupt function of STM32	Graphic LCD Interfacing
4	Interrupt Organization	Controlling Graphic LCD using FSMC function of STM32	Timer and PWM Function
5	Interfacing LCD	STM32 Timer and PWM Function	ADC Applications
6	Timer and Counter	ADC of STM32	I2C Interface Programming
7	ADC and Motor Interfacing	Inter-Integrated Circuit (I2C) function of STM32	
8	Serial Communication		
9	DMA		
10	Memory Interface		
11	Applications of Embedded Systems (Experience sharing by TAs)		

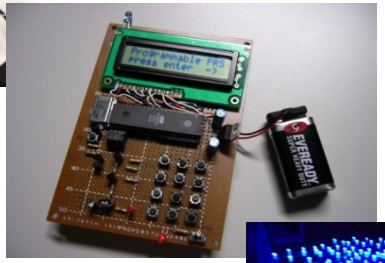
ELEC 3300 Introduction to Embedded Systems

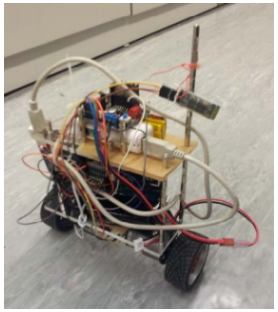
Student initiated projects

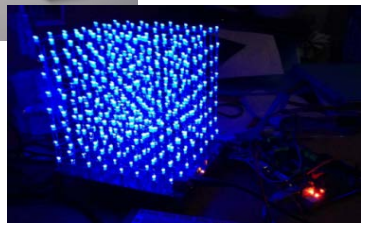












ELEC 3300 Introduction to Embedded Systems

Team size : 2 students Evaluated by Project Grading Rubric

ELEC 3300 Project Grading Rubric

Project Demonstration: Max 32 marks

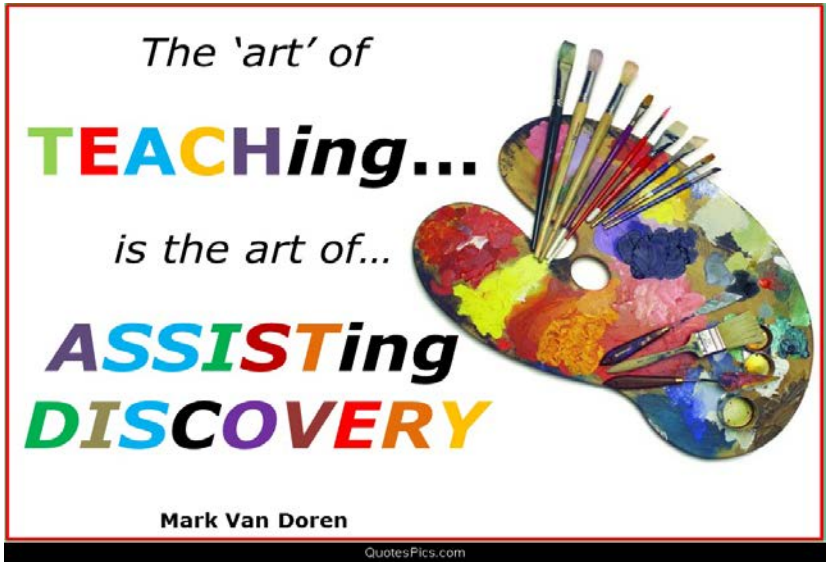
Project Presentation: Max 8 marks

Acknowledgment - This rubric is adopted and modified from the INQUIRY AND ANALYSIS VALUE RUBRIC by Association of American Colleges and Universities. Number in bracket shows the corresponding marks for that level of performance.

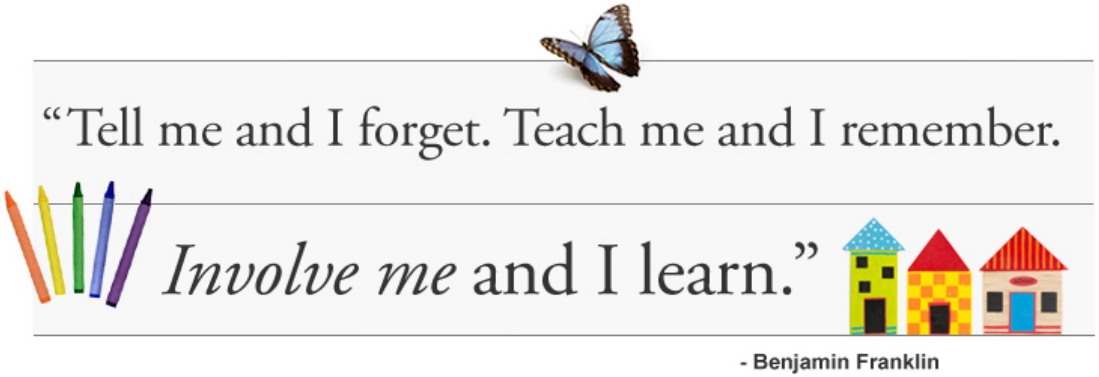
	Capstone	Milestones		Benchmark
	4	3	2	1
Project Complexity (P03)	The whole project consists of a complex hardware and software design. Careful hardware design and software design algorithm is being shown. (12)	Hardware consists of various kind of interface before going to the processor, with software controlling the other interfaces. (9)	Project hardware is a mix of analogue and digital signals, software part used all the features of the processor. (6)	The processor directly controls all the aspects of the hardware, simple controls are used in the software. (3)
Project Understanding (P05)	Clear understanding of the project. System is designed with justification and appropriate use of analog, digital signals and methodology. (10)	System is designed with appropriate use of analog, digital signals, and correct methodology. (6)	System is simply designed according to the LAB understanding. Cannot justify uses of analog or digital signals or methodology. (4)	Little understanding of the project. System is designed without justification of LAB knowledge or methodology. (2)
Project Originality	Application of labs together with extra circuits or software extended to creative design. (6)	Extended integration of lab materials with extra circuits or software. (4)	Project is an application of all the labs done before. (2)	Project is an application of two to three of the lab experiments. (1)
Completeness (P10)	The project can run smoothly without major error. (4)	The project can run with specified inputs. It encounters error with input that is not specified. (3)	The project can run, however, it encounters errors on specified input. (2)	The project cannot run, however, can show partial functionality with forced input with either hardware or software. (1)
Oral Presentation with PowerPoint	Presentation referenced to information or analysis that significantly supports the project work. (8)	Project presentation is clear and consistent with the supporting material. (6)	Fair description of project, still understandable, but is not often repeated and is not memorable. (4)	Project function be deduced, but is not explicitly stated in the presentation. (2)

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

In the course design, we involve



- Student's centered learning
- Experiential learning



Homework Assignments,
Laboratory experiments,
Student's project

I hear and I forget, I see and I remember, I do and ***I understand.***
- Confucius (551 BC to 479 BC)

What do we teach?

We will NOT give you a fish; instead, we will teach you how to fish.

From project idea to prototype design

Developing since 2009

Self-driving car

http://goo.gl/Z0JLsy

Abstract idea:
- How does the car drive? Stop the car? Right steering? Move forward?
- How to guide the car from starting location to the destination?
- How to get the information about the surrounding?
- Can we change the driving path in the real time?
- What is the maximum driving speed?
- Does the car need to communicate with other vehicles?

Hardware devices:
- Which are the suitable / potential hardware devices in addressing each abstract idea?

Description
Abstract idea of project (Define the functionality of the system)
…
…
…
…
Hardware devices (Microcontroller, Peripherals, sensors)

What do we teach?

Self-driving car

http://goo.gl/Z0JLsy

Further information:
https://en.wikipedia.org/wiki/Waymo

From project idea to prototype design

Developing since 2009

Description
Abstract idea of project (Define the functionality of the system)
…
…
…
…
Hardware devices (Microcontroller, Peripherals, sensors)

Other potential devices for:
- global positioning
- Monitoring the tire pressure

Sensors

Automobile

Measurements

- **RPM** (Revolutions Per Minute): How many times the engine's crankshaft makes one full rotation every minute (Tachometer).
- **Speedometer:** Vehicle speed
- **Odometer:** Distance travelled
- **Fuel Level Gauge:** Fuel Tank Level (float and potentiometer / capacitance)
- **Temperature Sensor:** Inside and outside air temperature (Resistance Temperature Detector / Thermistor)

Sensors

Aircraft Instrumentation

Measurements

- **Altimeter:** Altitude above sea level
- **Attitude Indicator:** Aircraft's orientation relative to the Earth's horizon

Heading indicator

- **Heading Indicator:** Aircraft's direction
- **Vertical Speed Indicator:** Rate of climb or descent of an aircraft
- **Horizontal Speed, Fuel level gauge, Pressure, Temperature, Engine Vibration, Cabin Oxygen, Smoke, etc.**

Sensors

Mobile Phone

Modern Mobile Phones have built-in sensors that measure motion, orientation, and various environmental conditions.

Class activity:

Find sensors in your mobile device

Step 1: Install an app “Physics Toolbox Sensor Suite”

Google Play Store

Apple App Store

Step 2: Start an interactive tool - Mentimeter

Go to www.menti.com

Hints: work with your classmate.

One student uses the app
One student writes the answers through Mentimeter

Sensors

Mobile Phone

Modern Mobile Phones have built-in sensors that measure motion, orientation, and various environmental conditions.

Accelerometer for motion detection: Measures the acceleration force applied to a device on all three physical axes (orientation, shake)

Temperature sensor: Air temperature

Light sensor: Ambient light intensity (to control screen brightness)

Pressure sensor: Air pressure

Proximity sensor: Proximity of an object relative to the screen

Humidity sensor: Relative Humidity

What is the scope of this course?

Overview of Computer systems

Applications

Operating Systems

Internal

I/O devices

External

Overview of Computer systems

Modern Computer Systems

Software

Memory Management

Kernel

Computer Architecture, CPU and Memory

Hardware

•Background

Data Representation and Floating Point Standards

Application (IE, MSWord, Apps, UI)

Compiler

Operating System (Window 10, Linux, iOS8)

Assembler

Instruction Set Architecture

Memory

I/O System

Datapath & Control

Digital design

Circuit design

Transistors

Operating Systems and Process Management

I/O and File Systems

Our focus:

Interfacing techniques for system integration

Input, Output and Peripheral Devices

CPU Design and Organization

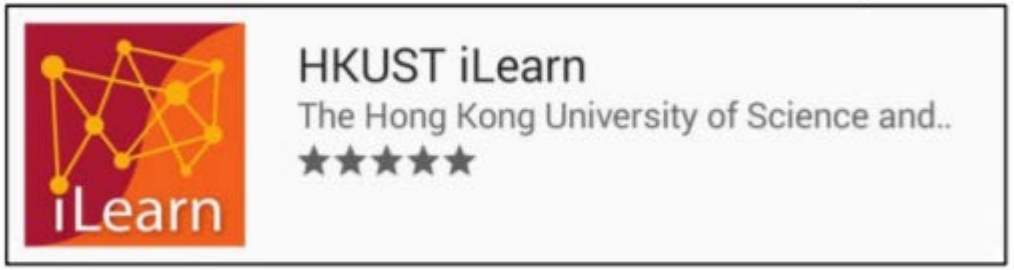
Outcomes Expected from YOU

- On successful completion of this course, you will be able to
  - CILO1: Recognize the marketing and engineering views of embedded system applications.
  - CILO2: Understand and analyze the building blocks of embedded system, and the interfacing techniques of simple external devices.
  - CILO3: Understand and compare different up-to-date computer interfacing technologies.
  - CILO4: Use CAD tools to program and emulate the performance of the micro-controller.

- CILO : Course Intended Learning Outcome

First iPRS in-class activity

For Android devices, search **HKUST iLearn** at Play Store.



For iOS devices, search **HKUST iLearn** at App Store.

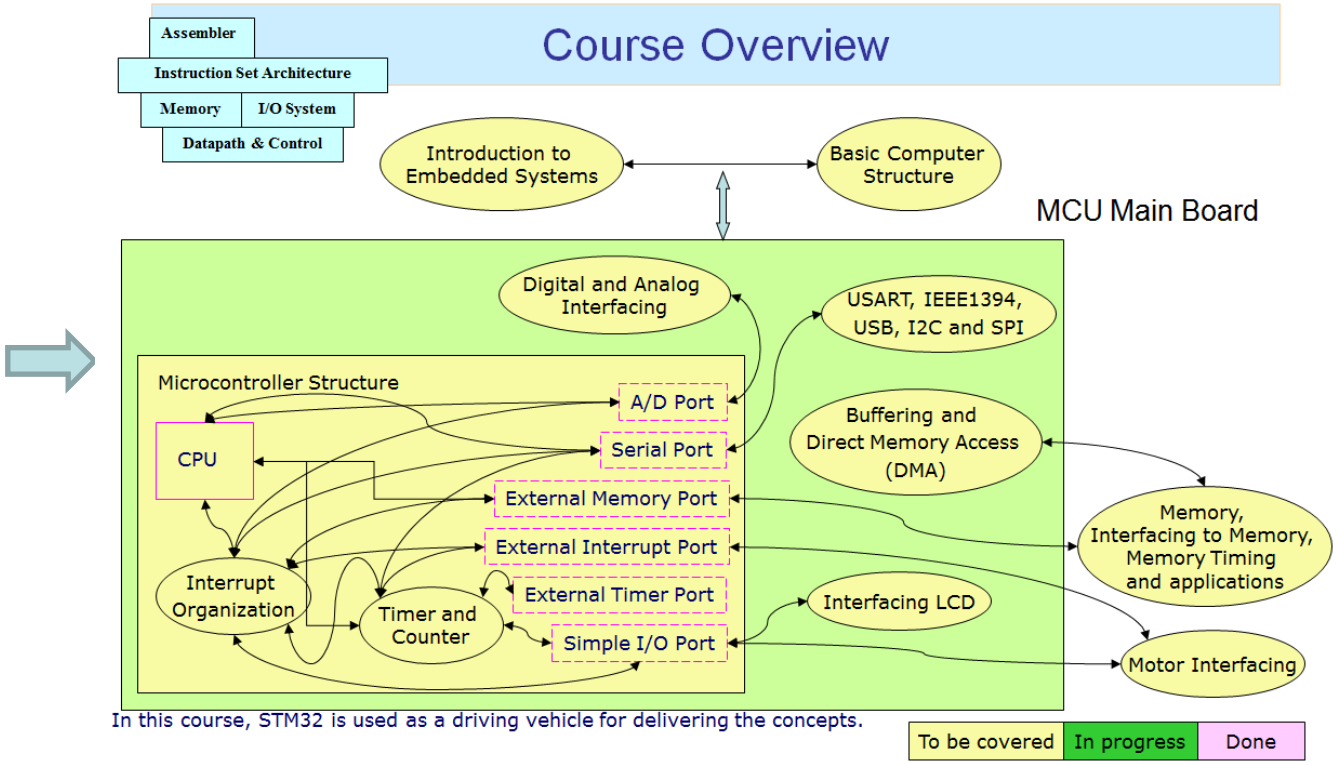
https://ilearn.ust.hk/iLearn/home.html

Course Outline

- Which knowledge do I learn in class and how do they link up?

Course Outline:

1. Introduction to Embedded Systems
2. Basic Computer Structure
3. Microcontroller Structure
4. Interrupt Organization
5. Timer and Counter
6. ……
7. ……
8. Interfacing LCD
9. Motor Interfacing
10. ……



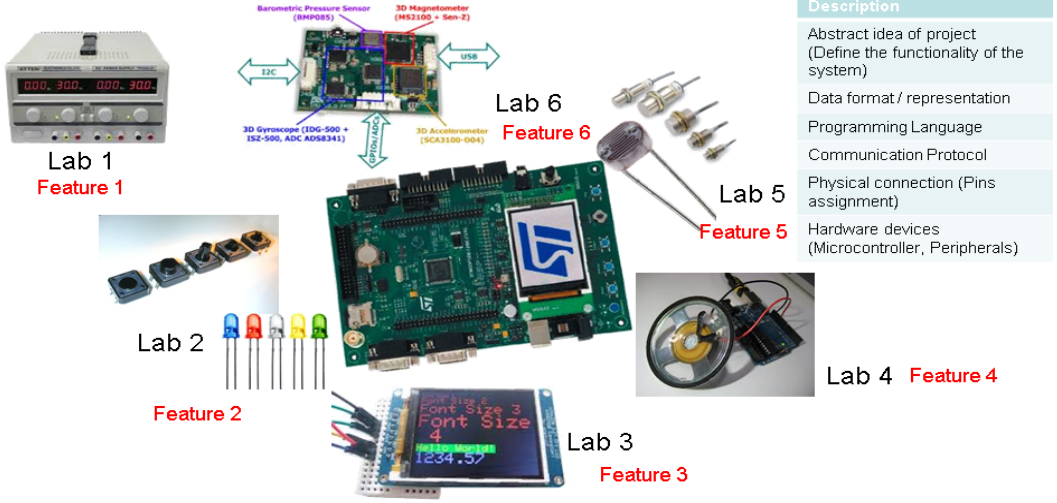
Laboratory

- Objective (CILO2 and CILO4)
  - Enrich your knowledge in the circuit interfacing and basic programming skills with CAD tools

- A brief discussion on the laboratory experiment will be conducted in tutorial sessions.

Design architecture of an embedded system

- After completing the laboratory experiments, you are able to integrate

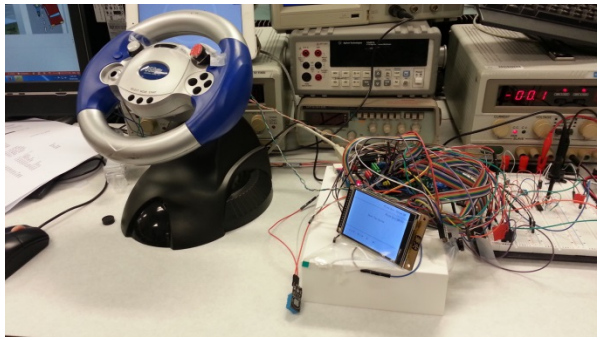


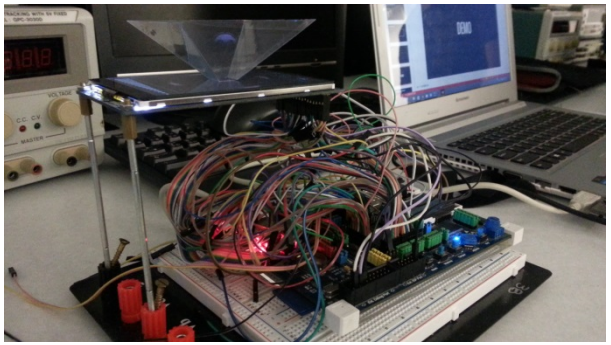
Description
Abstract idea of project (Define the functionality of the system)
Data format / representation
Programming Language
Communication Protocol
Physical connection (Pins assignment)
Hardware devices (Microcontroller, Peripherals)

Course Project

- Objective (CILO5):
  - Put in practice what you have learned in both hardware and software skills in your talent-made project
  - Work effectively in a team and lead a team

- Team size:
  - 2-3 students from same / different laboratory sessions
    - Please submit your team to the Teaching Associate within three weeks. Otherwise, you will be randomly assigned. (Please check the CANVAS)





Course Project

- At the end of the course, you are able to submit:
  - Final Project Demonstration + Power-point Presentation
    - Each team is required to conduct a fifteen-minute demonstration and presentation.
  - A final project report in HTML format
  - Peer-evaluation from your team member (this reflects your overall performance in the project)

You may ask about the grading ……

- What are the grading criteria of project?

ELEC 3300 Project Grading Rubric

Project Demonstration: Max 32 marks

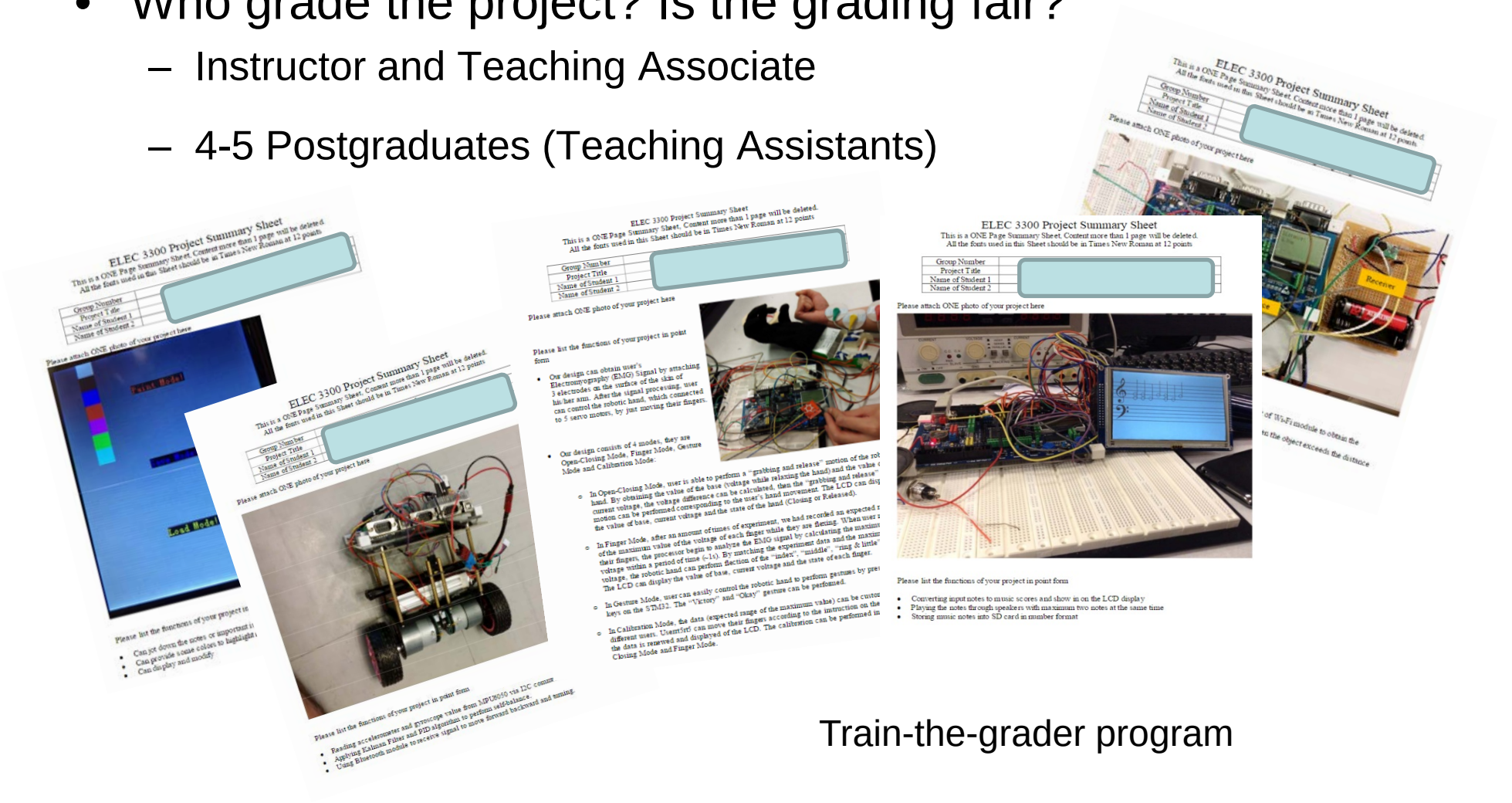
Project Presentation: Max 8 marks

Acknowledgment - This rubric is adopted and modified from the INQUIRY AND ANALYSIS VALUE RUBRIC by Association of American Colleges and Universities. Number in bracket shows the corresponding marks for that level of performance. **Students may ask to modify their codes during the project demonstration in need.**

	Capstone	Milestones		Benchmark	Below Benchmark
	4	3	2	1	0
Project Complexity	The whole project consists of a complex hardware and software design. Careful hardware design and software design algorithm is being shown. (12)	Hardware consists of various kind of interface before going to the processor, with software controlling the other interfaces. (9)	Project hardware includes extra hardware/software components and other features of the processor. (6)	Project hardware is a mix of analogue and digital signals, software part used majority lab-covered features of the processor. (3)	The processor directly controls all the aspects of the hardware, simple controls are used in the software. (0)
Design Justification	System is designed with clear and correct justification. Students show the appropriate use of analog, digital signals and methodology. (10)	System is designed with appropriate use of analog, digital signals, and correct methodology. (6)	System is designed only according to the LAB material. Little justification and demonstration the use of I/O in the design. (4)	Little understanding of the project. System is designed with weak justification and demonstration of LAB knowledge or methodology. (2)	No understanding of the project. System is designed without any justification of LAB knowledge nor methodology. (0)
Project Originality	Application of labs together with extra circuits or software extended to creative design. (6)	Extended integration of lab materials with extra circuits or software. (4)	Project is an application of all the labs done before. (2)	Project is an application of three or more of the lab experiments. (1)	Project is an application of less than three lab experiments. (0)
Completeness	The project can run smoothly without major error. (4)	The project can run with specified inputs. It encounters error with input that is not specified. (3)	The project can run smoothly, however, it encounters errors on specified input. (2)	The project can run, however, it encounters errors on specified input. (1)	The project cannot run, however, can show partial functionality with forced input with either hardware or software. (0)
Oral Presentation with PowerPoint	Presentation referenced to information or analysis that significantly supports the project work. (8)	Project presentation is clear and consistent with the supporting material. (6)	Project functions are described clearly with explanation of special features.	Fair description of project, still understandable, but is not often repeated and is not memorable. (2)	Project function can only be deduced, it is not explicitly stated in the presentation. (0)

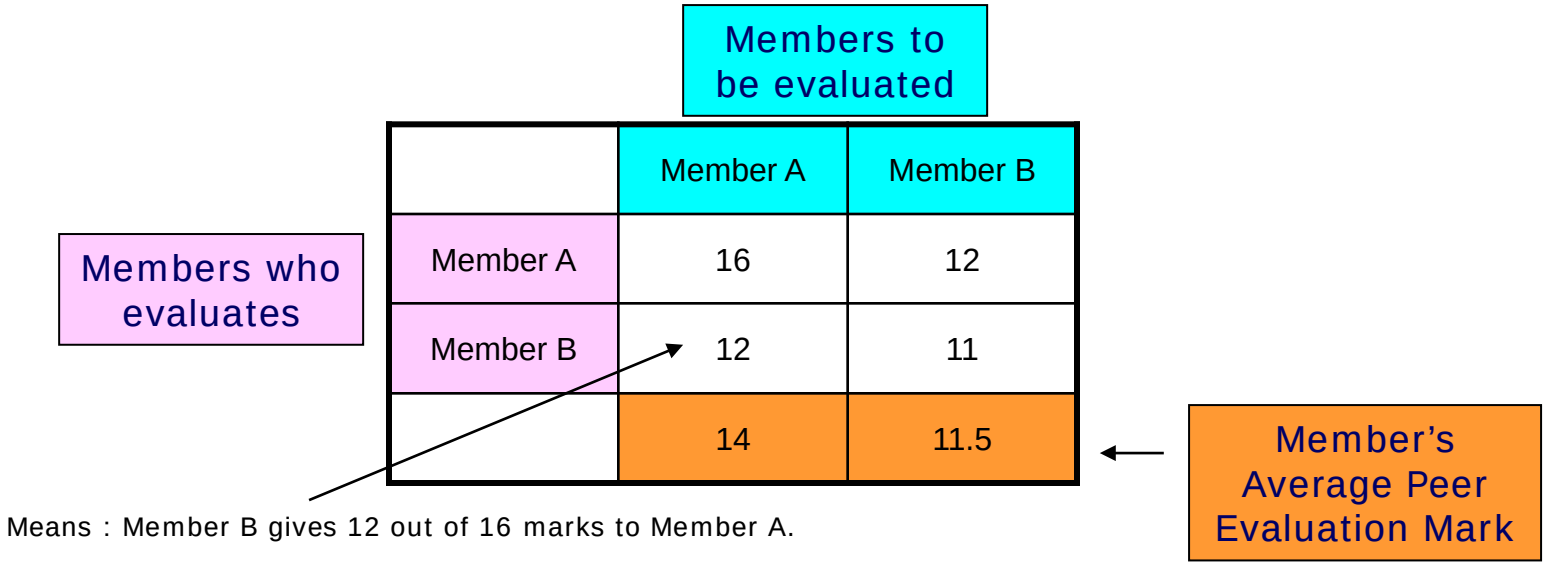
You may ask about the grading ……

- Who grade the project? Is the grading fair?
  - Instructor and Teaching Associate
  - 4-5 Postgraduates (Teaching Assistants)



Project Assessment – Peer evaluation

- You are required to do peer evaluations to your group member during the project period.
- Below shows an example, each evaluation mark will be from 0 – 16.



Group's Average Peer Evaluation Mark = (14 + 11.5) / 2 = 12.75

Members Difference percentage = (14 – 11.5)/12.75 = 19.6%

Project Assessment – Peer evaluation

- You are required to do peer evaluations to your group member during the project period.
- Below shows an example, each evaluation mark will be from 0 – 16.

Example 1

Members to be evaluated

	Member A	Member B	Member C
Member A	16	12	14
Member B	12	11	13
Member C	14	12	12
	14	11.67	13

Members who evaluates

Member's Average Peer Evaluation Mark

Member C gives 14 out of 16 marks to Member A.

Group's Average Peer Evaluation Mark = (14 + 11.67 + 13) / 3 = 12.89

Members Difference percentage for student A = (14 – 12.89) / 12.89 = 8.61%

Members Difference percentage for student B = (11.67 – 12.89) / 12.89 = -9.46%

Members Difference percentage for student C = (13 – 12.89) / 12.89 = 0.85%

Project Assessment – Peer evaluation

- You are required to do peer evaluations to your group member during the project period.
- Below shows an example, each evaluation mark will be from 0 – 16.

Example 2

Members to be evaluated

	Member A	Member B	Member C
Member A	16	10	14
Member B	12	10	13
Member C	14	10	12
	14	10	13

Members who evaluates

Member's Average Peer Evaluation Mark

Member C gives 14 out of 16 marks to Member A.

Group's Average Peer Evaluation Mark = (14 + 10 + 13) / 3 = 12.33

Members Difference percentage for student A = (14 – 12.33) / 12.33 = 13.51%

Members Difference percentage for student B = (10 – 12.33) / 12.33 = -18.92%

Members Difference percentage for student C = (13 – 12.33) / 12.33 = 5.41%

Project Assessment – Peer evaluation

- Based on the difference in percentage, the project mark that got by the member will be multiplied by a factor as shown in the table

Difference (Absolute value)	Factor for Member who has more contribution	Factor for Member who has less contribution
0 – 10%	1	1
10 – 20%	1 + X	1 – X
20 – 30%	1 + Y	1 – Y
> 30%	1.15	1 – 2Z

- Note: $0 < X < Y < 0.15 < Z < 0.5$

Project Assessment

- We will also monitor the progress and the reflection from peer evaluations in order to achieve a fair environment.
- A special meeting will be arranged if some abnormal case is observed.
- You should seek for help as early as possible if you have any difficulties. There is nothing we can help in the last minutes.
- A normalization of progress marks among different assessor will be done.

Outcomes and Means

- Outcomes:
  - To be a well-trained UG student and get success, you need …….
    - Teamwork, Discipline, Both theoretical and technical knowledge, Creativity, Good Presentation skill, Good in Time Management
- How can we help you in this course?

	Lecture / Tutorial	Lab experiment	Project
Teamwork		✓	✓
Discipline		✓	✓
Theoretical knowledge	✓	✓	✓
Technical knowledge	✓	✓	✓
Creativity			✓
Presentation skill			✓
Time Management	✓	✓	✓

- Important Note: Curve fitting is NOT applied in the letter grade. The grade is assigned by criteria referencing. Much effort you put, higher grade you get.