ELEC3300
Introduction to Embedded Systems

Topic 1

Introduction to Embedded Systems
Prof. Vinod A. Prasad

Course Overview

Assembler

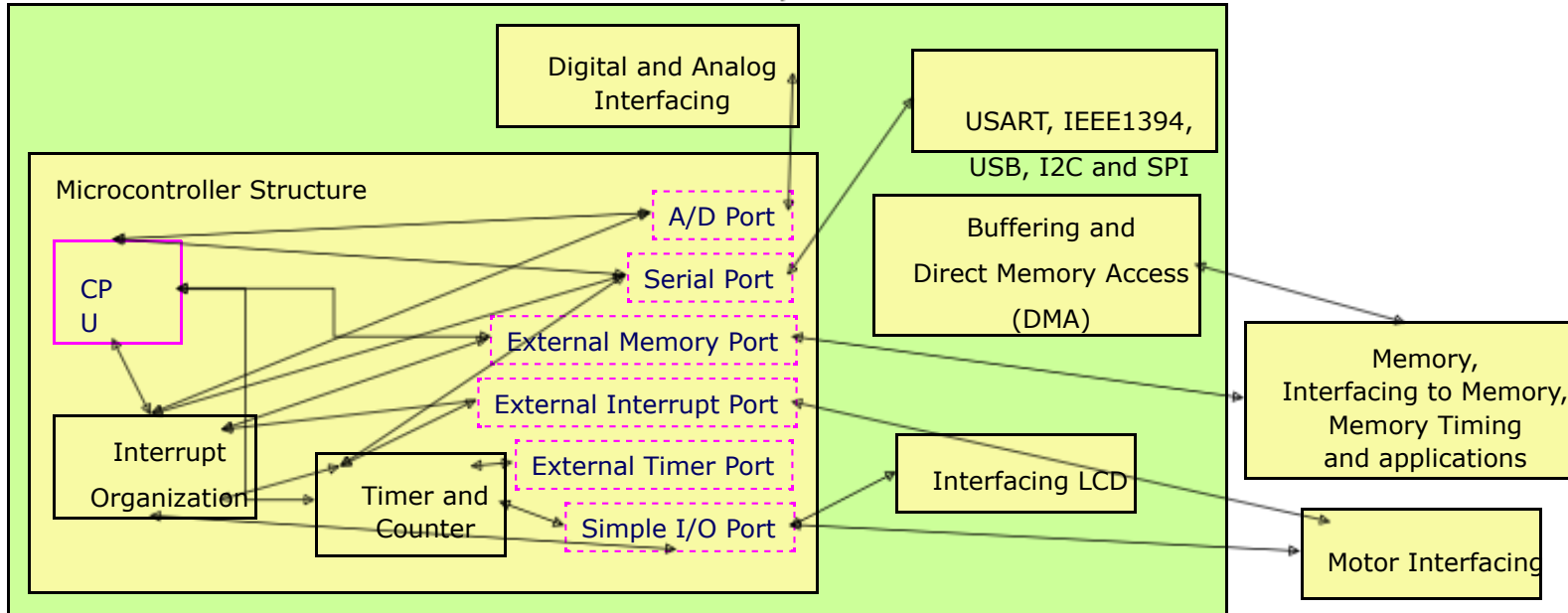Instruction Set Architecture

Memory | I/O System

Datapath & Control

Introduction to Embedded Systems

More about Embedded Systems

Basic Computer Structure

MCU Main Board

Digital and Analog Interfacing

USART, IEEE1394, USB, I2C and SPI

Buffering and Direct Memory Access (DMA)

Microcontroller Structure

A/D Port

Serial Port

External Memory Port

External Interrupt Port

External Timer Port

Simple I/O Port

CPU

Interrupt Organization

Timer and Counter

Interfacing LCD

Memory, Interfacing to Memory, Memory Timing and applications

Motor Interfacing

In this course, STM32 is used as a driving vehicle for delivering the concepts.
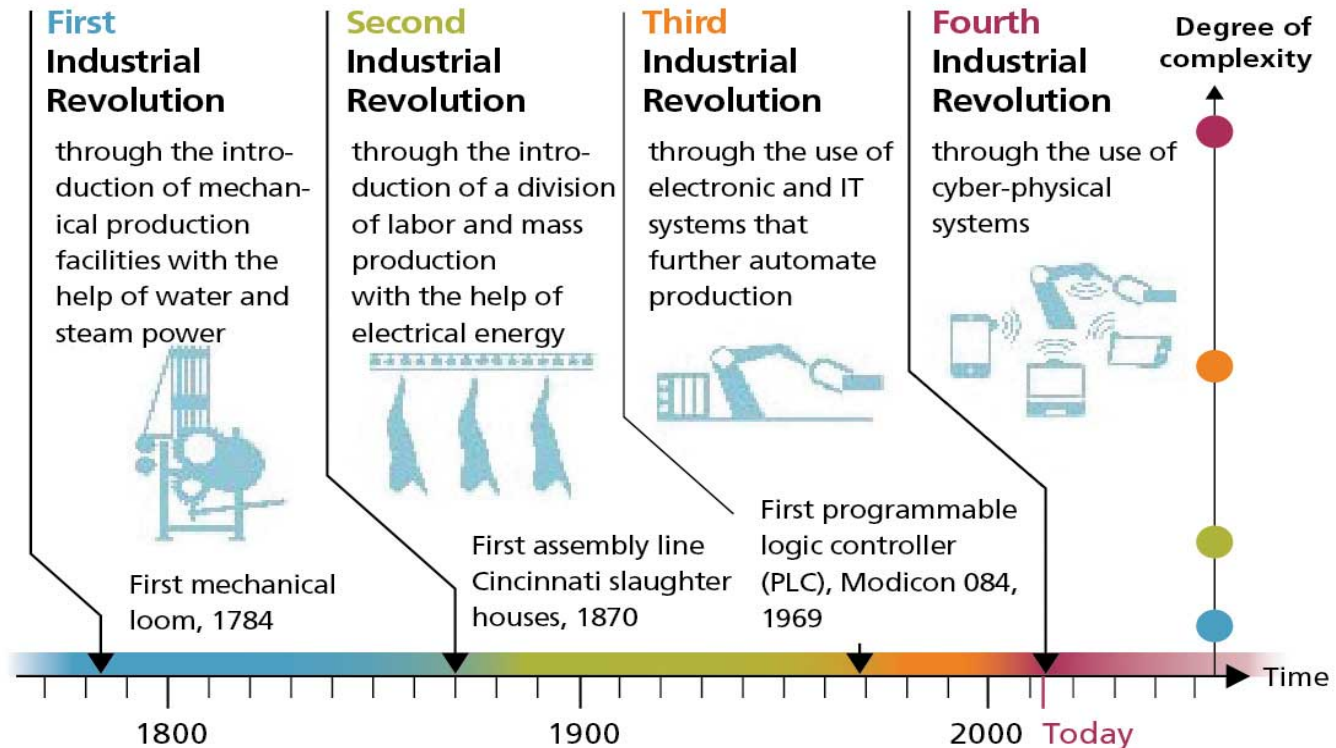
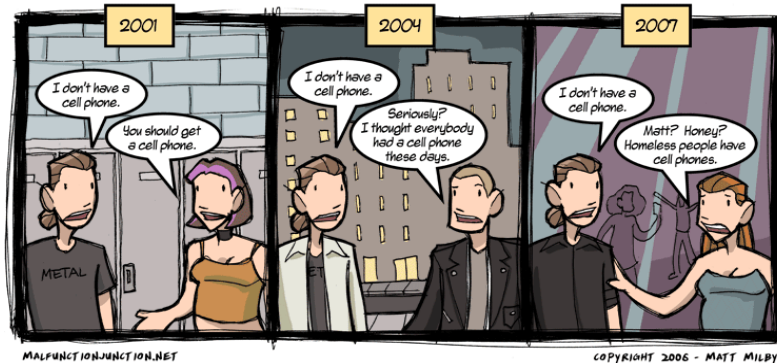| To be covered	In progress	Done

Expected Outcomes

- On successful completion of this chapter, you will be able to
  - Introduction to Embedded Systems
  - Understand the importance of embedded system applications
  - Have different views of embedded system including
    - Market reasons
    - Engineering reasons
  - Summarize the basic architecture of embedded system

Industrial 4.0

First Industrial Revolution through the introduction of mechanical production facilities with the help of water and steam power

Second Industrial Revolution through the introduction of a division of labor and mass production with the help of electrical energy

Third Industrial Revolution through the use of electronic and IT systems that further automate production

Fourth Industrial Revolution through the use of cyber-physical systems

Degree of complexity

First mechanical loom, 1784

First assembly line Cincinnati slaughter houses, 1870

First programmable logic controller (PLC), Modicon 084, 1969

Time

1800   1900   2000 Today

An Era of Embedded Computing Systems

Computing system	Mainframe	Minicomputer	Personal computer	Embedded system
Era	1950s on	1970s on	1980s on	2000s on
Form factor	Multi-cabinet	Multi-board	Single board	Single chip
Resource type	Corporate	Departmental	Family	Personal
Users/system	100s – 1000s	10s – 100s	1s	1/10s
Cost	$ 1 million +	$ 100Ks +	$1Ks – $10Ks	$1s – $100s
Total units	10Ks +	100Ks +	1 billions +	1 Trillions +

*The table is adapted from J. A. Fisher, P. Faraboschi and C Young with some modifications

Embedded System Overview

- Embedded system
  - A short name for embedded computing system
  - Different from general-purpose computing system, such as desktop computers.
  - Hidden or embedded into the system and the user is often not even aware that a computer is present
  - Carry one or a fixed set of specific tasks by either design or usage

- Billions of units produced yearly, versus millions of desktops

Characteristics of Embedded System

- Limited functions (example: Smart Mobile)
  – Doing a specific set of tasks repeatedly
  – High-end embedded systems are often multi-functioned systems

- Tightly constrained (example: Electric toothbrush)
  – Low cost, energy efficient, small, fast, etc.
  – Usually must meet the performance (such as speed)

- Reactive and even real-time (Example: Auto-pilot system)
  – Continually reacts to changes in the system's environment
  – Some systems must compute certain results in real-time without delay

IR Projector   RGB Camera   IR Sensor

XBOX 360

KINECT

360°
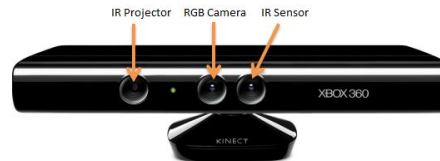
Embedded Systems in daily life

- Class activity: List some examples in
  - Consumer electronics
  - Automobile
  - HealthCare
  - Military and Defense
  - Telecommunication
  - Robot
  - Computer accessories
  - Transportation

What are the impacts of embedded systems?

Most famous embedded system

Product: Apple iphone X

- Operating system (OS)
  - OS: iOS 11.2.5

  System on chip (SoC)

  Apple A11 Bionic

  CPU

  2.39 GHz hexa-core 64-bit

Smart Home 1.0: Internet-Of-Things (IoT)

https://www.youtube.com/watch?v=3BJVTypIMI4

Advantages of Smart Home - Safety

system provides the highest security level. With the integration of all the devices, you have the full control of your home from any place in the world.
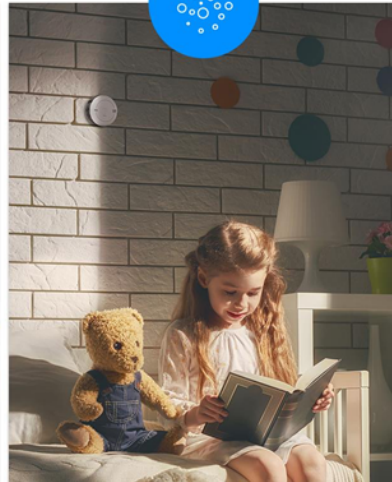
Smart Home 1.0: Internet-Of-Things (IoT)

Advantages of Smart Home - Comfort

...system provides exceptional comfort. It is much more than convenience and time-saving solutions. It is also a feeling that everything at home is under control.

Smart Home 1.0: Internet-Of-Things (IoT)

Embedded System Component Of Smart Home Solution

PROCESSING, STORING, DECISION-MAKING ELEMENTS

SENSES
(e.g.: smell, sight, touch, hearing, etc.)

EXECUTIVE ELEMENTS
(e.g.: arm, leg, speech)

Motion Sensor

Flood Sensor

Smoke Sensor

Home Center 2
Home Center Lite

Single Switch

Double Switch

Door / Window
Sensor

Swipe

The Button

App

Dimmer 2

RGBW 2

Roller Shutter 2

Universal
Sensor

KeyFob

CO Sensor

Intercom

Wall Plug

The Heat Controller
& Temperature Sensor

A new challenge

- If there are a lot of people who never stop at red light when they cross a road, how do you encourage to stay on pedestrian road?
  - Introduce some penalties?
  - Have some road safety guards?
  - Build some interesting device?
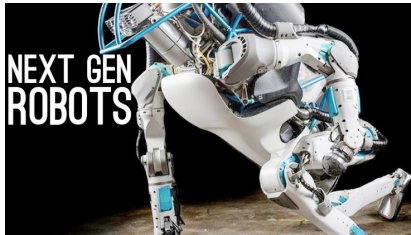 - Show some advertisement / entertainment?

Dancing Traffic Light

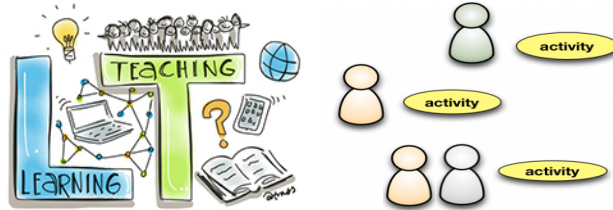https://www.youtube.com/watch?v=SB_0vRnkeOk

What's next?

Rapidly Changing World
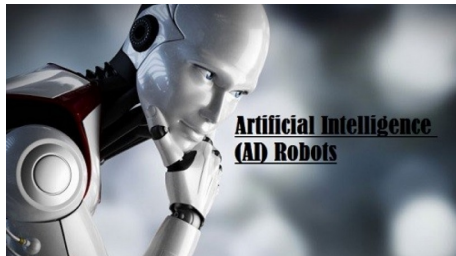
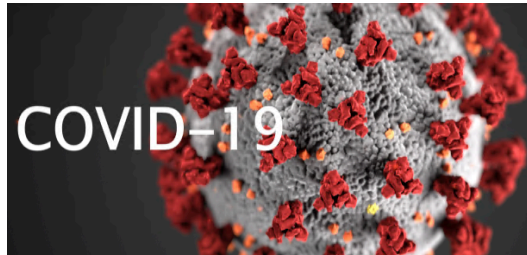Technologies only?

Global Challenges
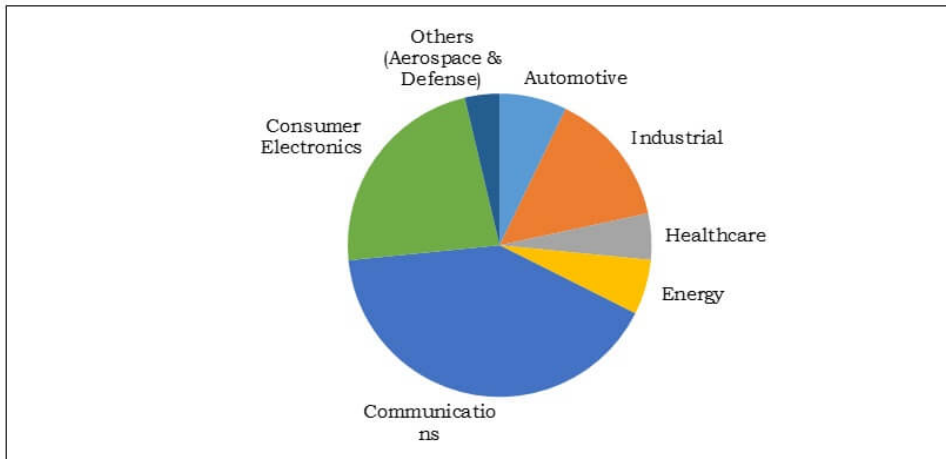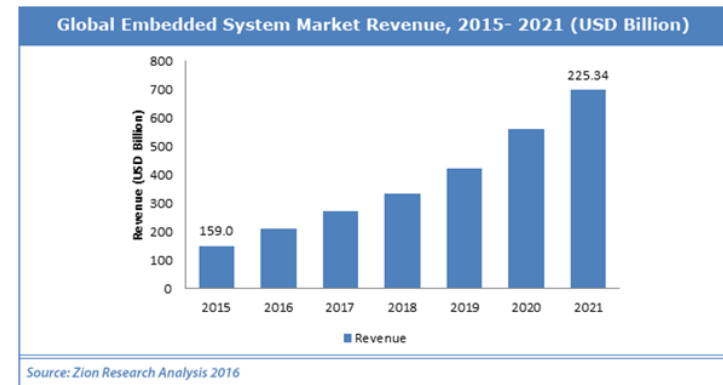
COVID-19

The Embedded Systems – Market Reasons

Embedded Computing market segments (Global 2015-2022)

Source: Primary & secondary research, and AMR Analysis
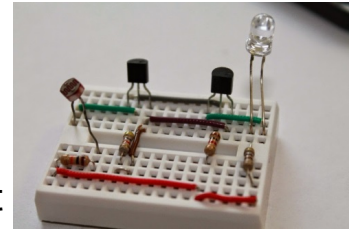

ELEC 3300 : Fall 2021

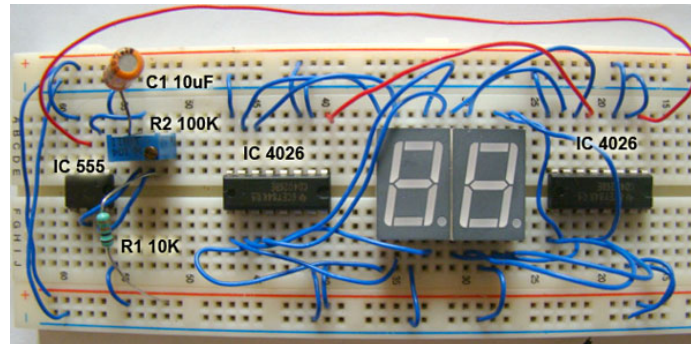# The Embedded Systems - Engineering reasons

- Reduce engineering costs in several aspects
  - Increased flexibility (programmability)
  - Upgrades of software while keeping the same hardware
  - Better controllability

Light Senor Circuit
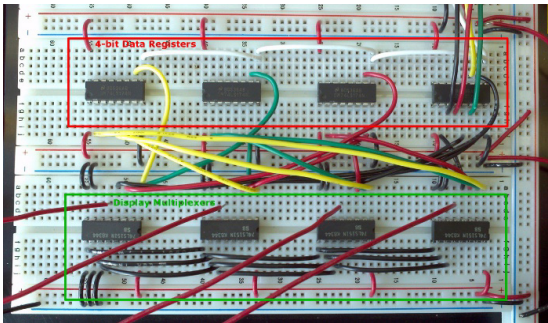
Pulse Width Modulation Circuit

Digital Pulse Counter Circuit

Design Engineers' View: Embedded System

- Mea~~sured~~ ... y size

Embedded System Example: Washing Machine

Input: Buttons

Output: Display, Motor

Control Unit: Processor, RAM, ROM With Software

RAM

ROM

Software

Actuators

Peripherals

Analog S... A/...

Source: Electronics Hub

- More advanced: measured by cost (e.g. power, size and weight), performance and time-to-market

  It takes inputs from the user like wash cycle, type of clothes, extra soaking and rinsing, spin rpm etc., performs the necessary actions as per the instructions and finishes washing and drying the clothes.

Inside the embedded systems

- ## Processor

- ## Memory
  - Storage for the software that it will run
  - Storage for the data as program variable, intermediate results and status information

- ## Peripherals
  - Communication interface adapters, sensors, actuators, LCDs

- ## Software
 - Operation system (OS), *initialization routines*, application software and *device drivers*
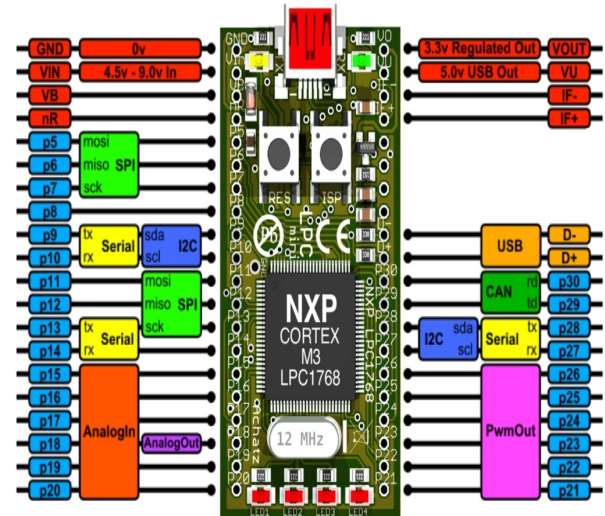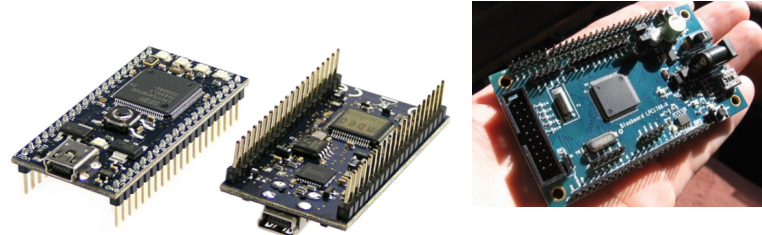
mbed NXP LPC1768
Cortex-M3 Microcontroller Module with Web-Toolchain

Inside the embedded systems

- Software (Cont'd)
  - Operation system (OS), *initialization routines*, application software and *device drivers*

  - *initialization routines* : software programming for hardware devices

    - Tell the Processor which devices are connected to the processor

    - Example 1: Configure an I/O port as output port only
    - Example 2: Configure the resolution of LCD, says 1024 x 768 or 640 x 480

  - *device drivers* : Software that directly interfaces with and controls the hardware.
 - All embedded systems must have device driver software in their system software layer.

| Application Software Layer |
| System Software Layer |
| Operating System Layer |
| Device Driver Layer |
| Hardware Layer |
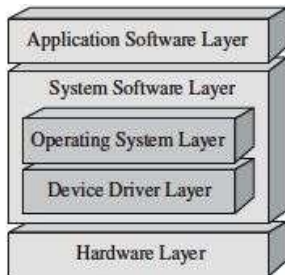
- Different types of hardware will have different device driver requirements that need to be met.

Examples: Memory and chemory management drivers, bus initialization and transaction drivers, and I/O (input/output) initialization and control drivers (such as for networking, graphics, input devices, storage devices,

- Even the same type of hardware that are created by different manufacturers can require substantially different device driver software libraries to support within the embedded device.

Never assume existing device drivers in the embedded system will be compatible for a particular hardware part.

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In-class activity

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

HKUST iLearn
The Hong Kong University of Science and..
★★★★★
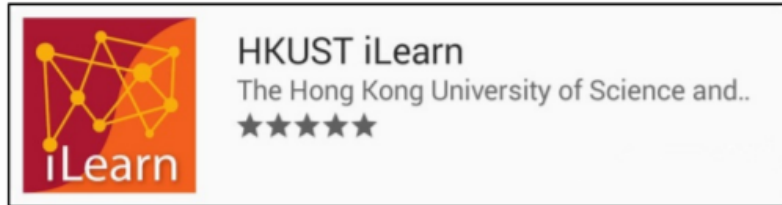
For iOS devices, search **HKUST iLearn** at App Store.

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Questions - Lecture 2

Advantages of embedded systems

Small size: As the embedded system is specifically designed for a particular application, the components used for designing system is small – size optimization can be done.

High accuracy: When compared to computer systems and other computational products.

Low power: Small size   low power consumption.
Example: Power consumed by computer system is 60 W and 230 AC approximately and the power consumed by embedded system is less than 1 W and 3.3V.

Low cost: Small size, less components, large-scale manufacturing.

Portability: Small size

High speed: Designed for performing some particular task and at the time the system performs only one task the processing speed is very fast.

System Design

- In any embedded system application:
  - Choosing a embedded system (many choices)
  - Designing a specialized interface (many design methodologies)
  - Designing application programs (also many ways to do it)
- In this course, both hardware and software aspects of interfacing are considered
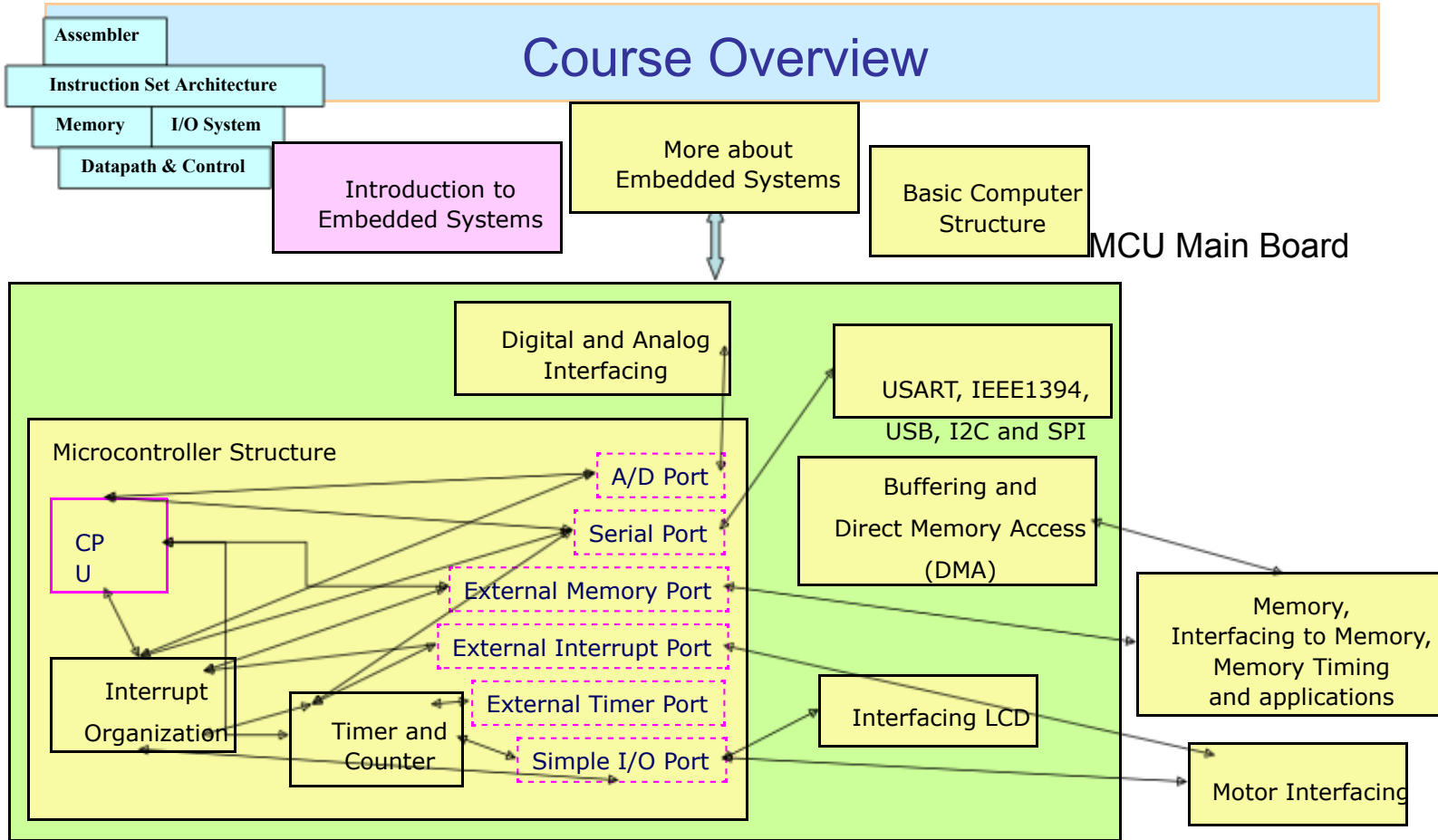- You will learn from the lectures, the labs and also the class project

Some soft skills you need to grasp

- Understanding embedded system
- Getting familiar with basic tools (emulator, debuggers, assemblers, etc)
- Skills in machine interfacing and C programming
- Designing sizable project with appropriated embedded system

Reflection (Self-evaluation)

- Do you ……
  - Understand the importance of embedded system applications ?
  - List out more examples of embedded systems in daily life?
  - Get the market and engineering reasons of embedded system ?
  - Describe the building blocks of a typical embedded system ?

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