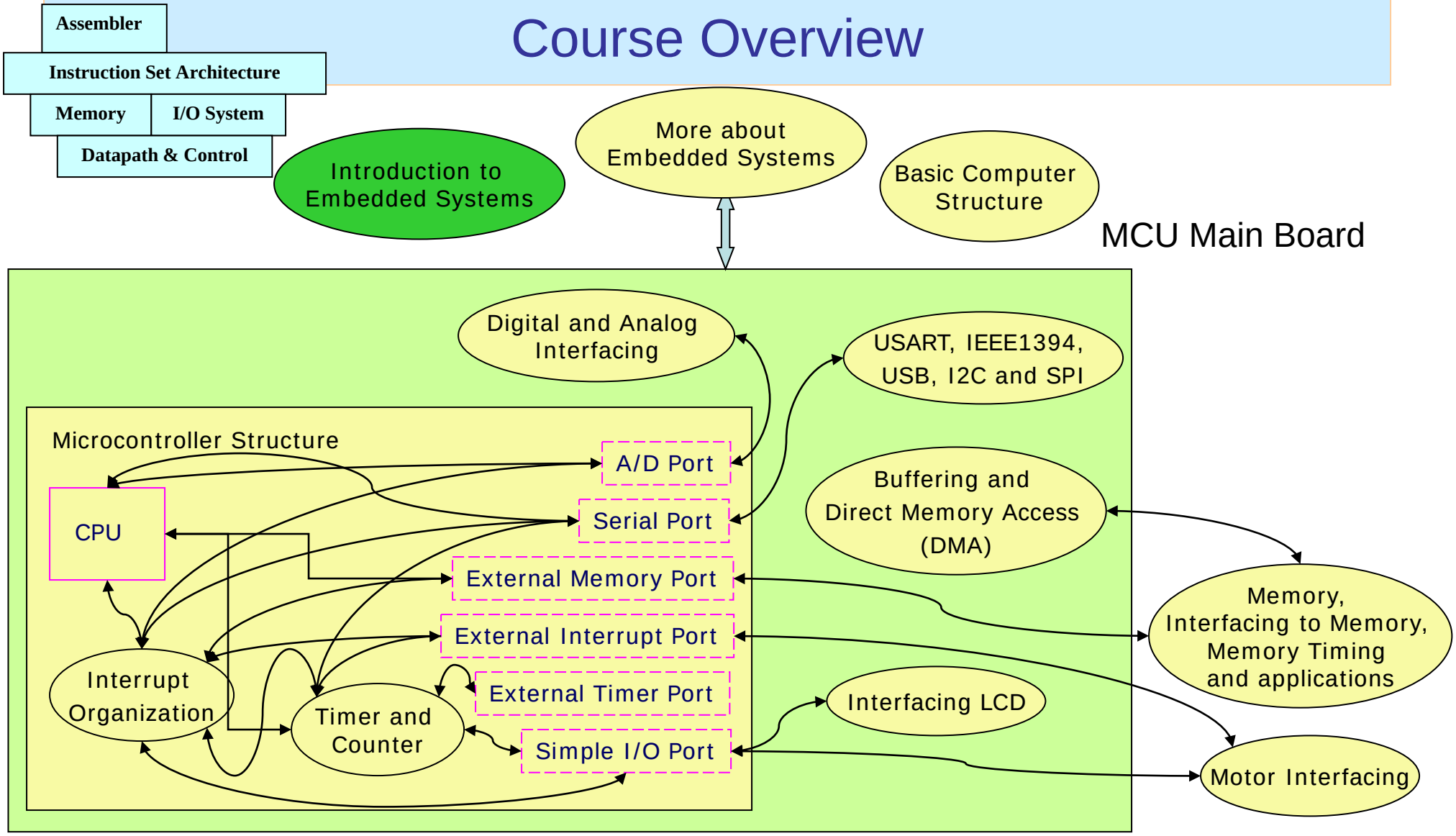
ELEC3300
Introduction to Embedded Systems

Topic 1

Introduction to Embedded Systems

Prof. Tim Woo

Course Overview



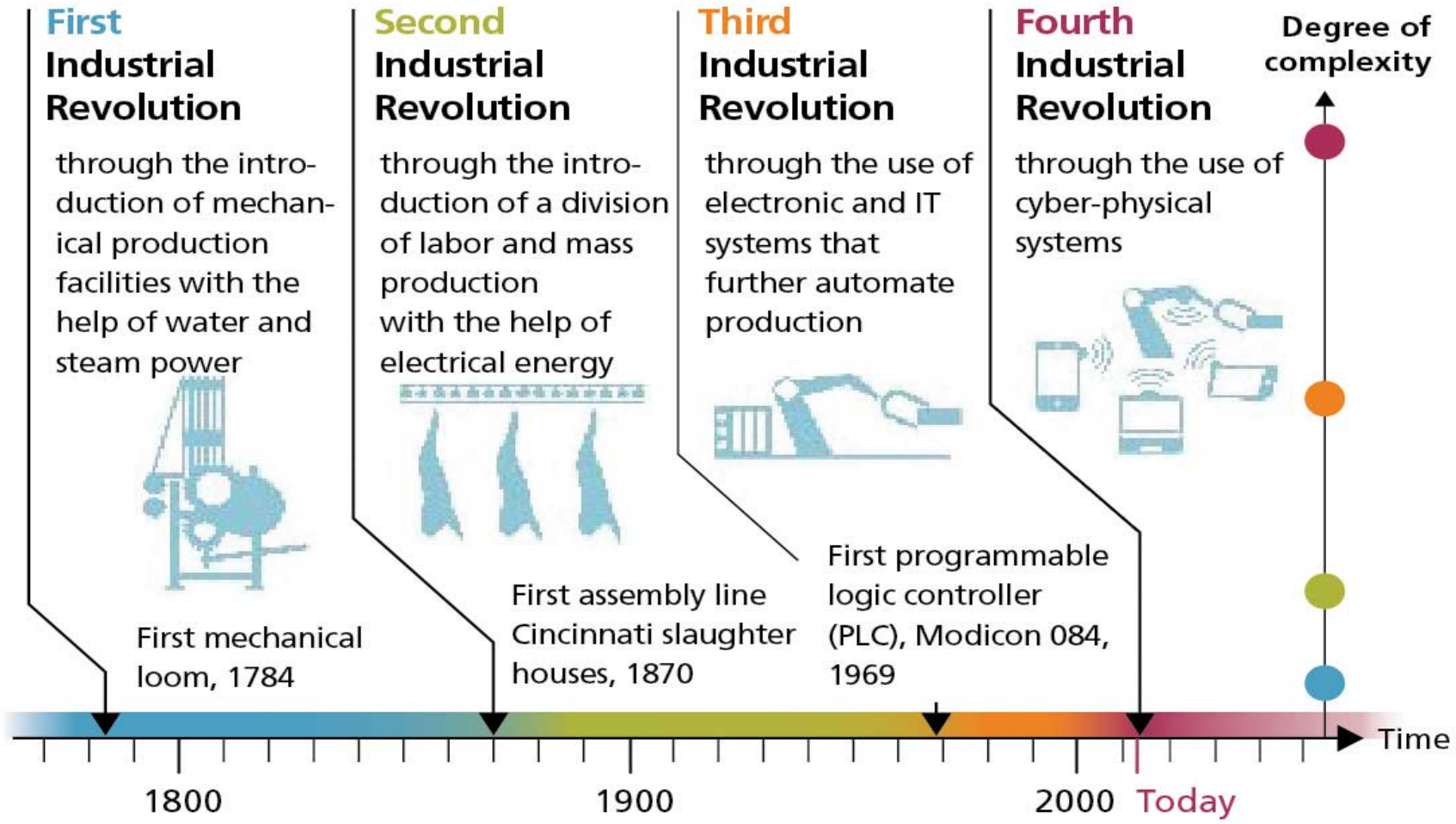
In this course, STM32 is used as a driving vehicle for delivering the concepts.

To be covered	In progress	Done

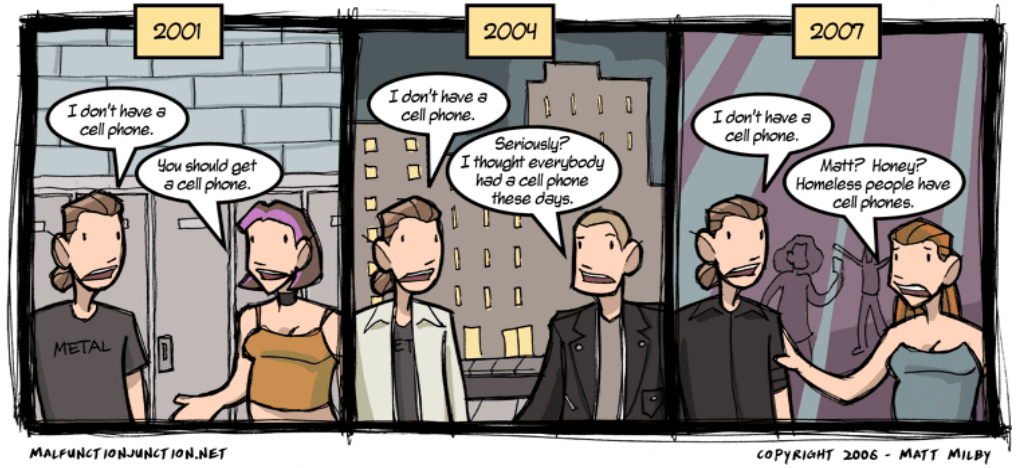
Expected Outcomes

- 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



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

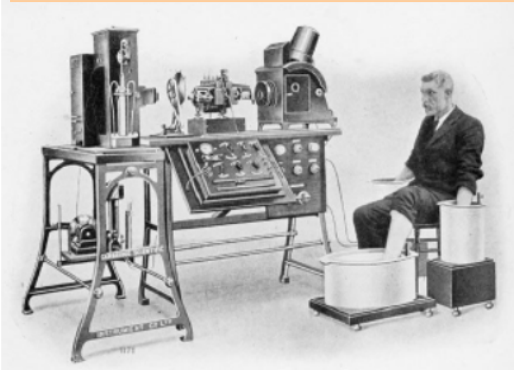
- Tightly constrained (example: Electric toothbrush)
  - Low cost, energy efficient, small, fast, etc.
  - Usually must meet the performance (such as speed)

- 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

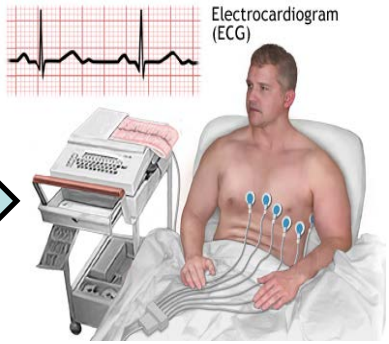
Embedded Systems in daily life

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

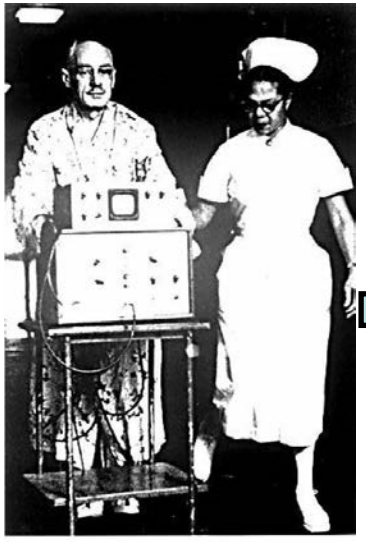
Embedded Systems Examples



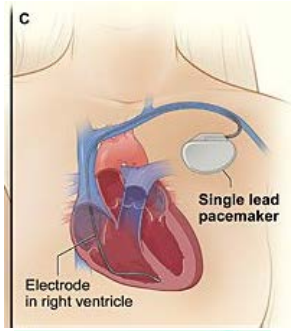
First ECG – Willem Einthoven (1901)
Nobel prize (1924)



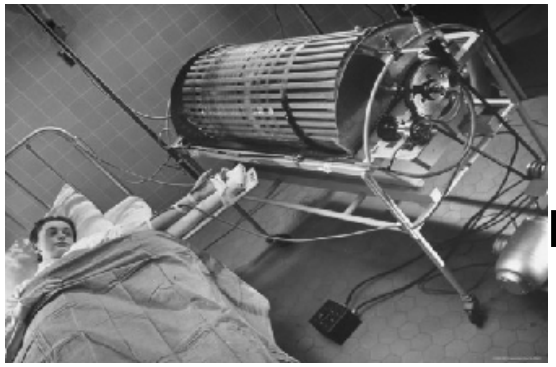
ECG - Today



First Pacemaker – Ake Senning (1958)



Pacemaker - Today



First Dialysis Machine – Willem Kolff (1943)

Dialysis Machine - Today

Embedded systems play a crucial role in these technologies

Pacemaker regulates the rhythm of heart beat by sending electric impulses to heart muscles (Conditions treated: Atrial fibrillation, Bradycardia)

What are the impacts of embedded systems?

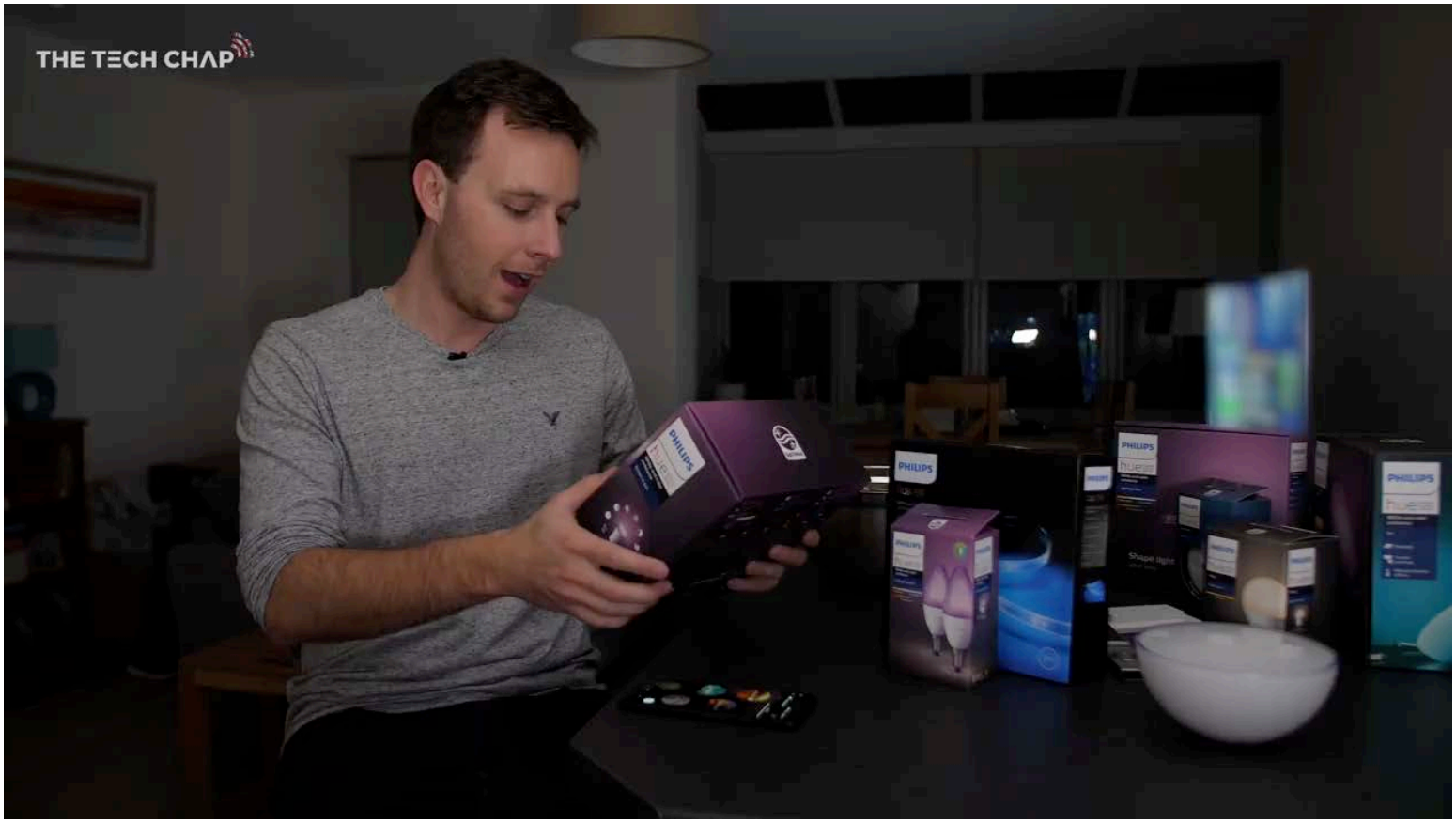
Most famous embedded system

Product: Apple iphone 13

- Operating system (OS)
  - OS: iOS 16
- System on chip (SoC)
  - Apple A15 Bionic (5 nm)
- CPU
  - Hexa-core (2x3.23 GHz Avalanche + 4x1.82 GHz Blizzard)

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

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



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

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.



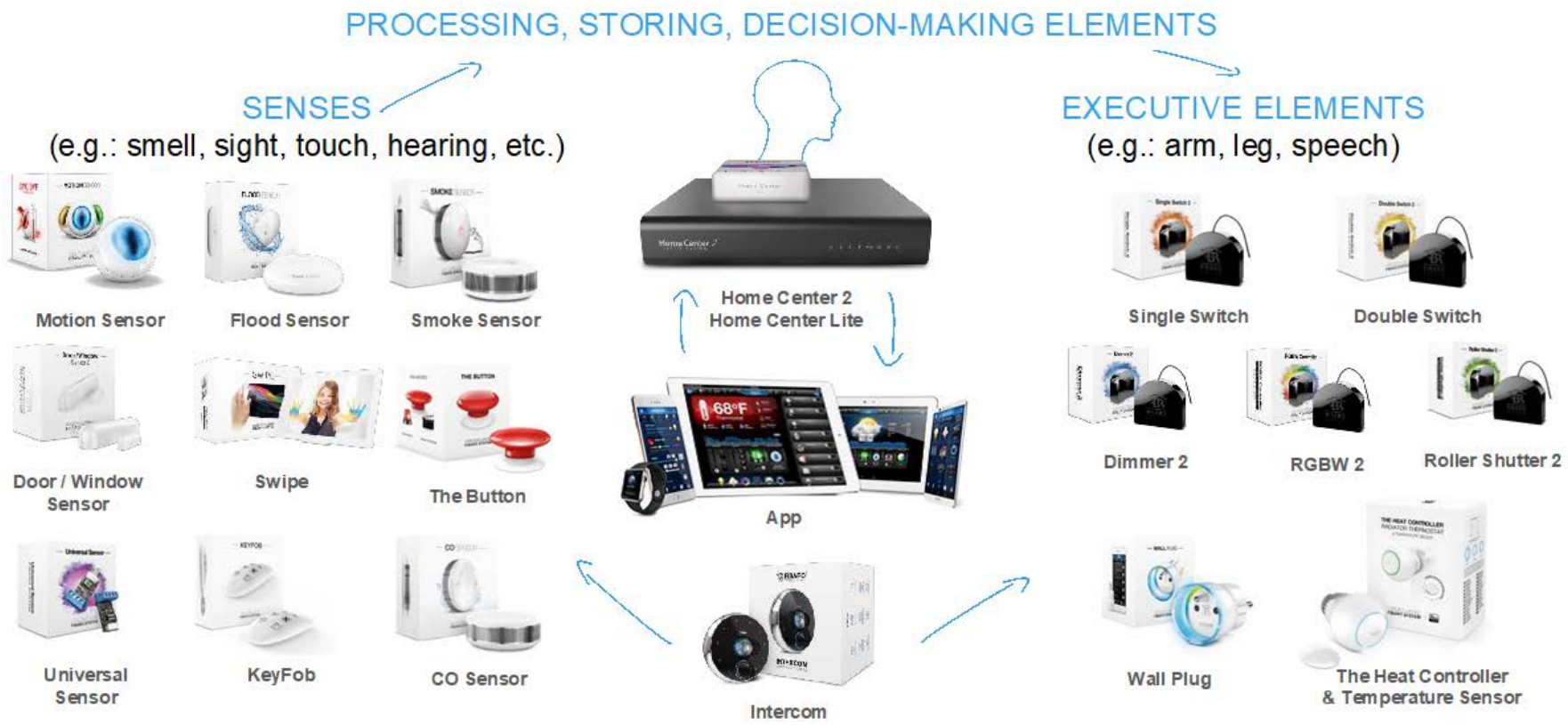

Smart Home 1.0: Internet-Of-Things (IoT)

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



About your embedded systems

- How many embedded systems do you have now?
- Please name two embedded systems you have.

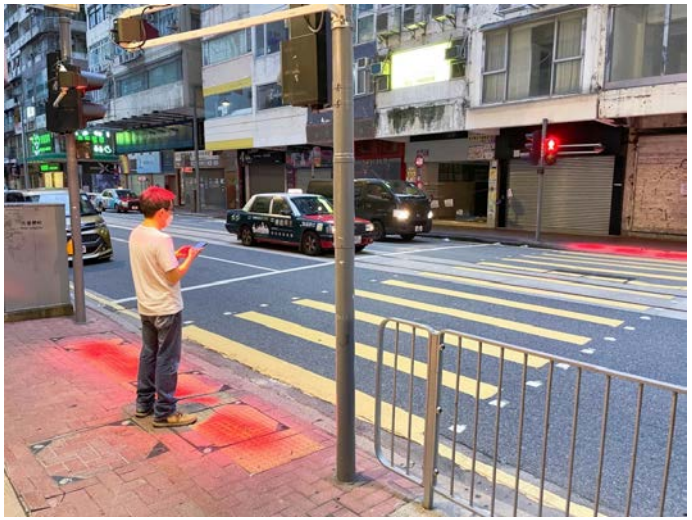
Answer these questions in an interactive tool -
Mentimeter
Please go to www.menti.com

A new challenge

- Some people cross a road when the Traffic lights for pedestrians is red. 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?

Input your suggestion in an interactive tool - Mentimeter
Please go to www.menti.com

A solution at Hong Kong



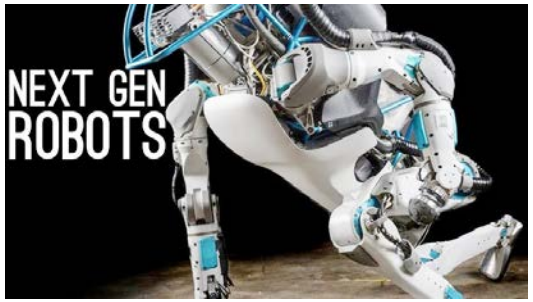
Source:
https://hongkongfp.com/2022/07/09/new-traffic-device-leaves-hong-kong-pedestrians-red-in-the-face/

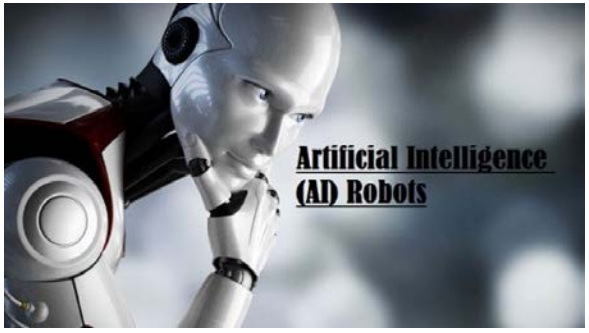
Dancing Traffic Light

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

What's next?

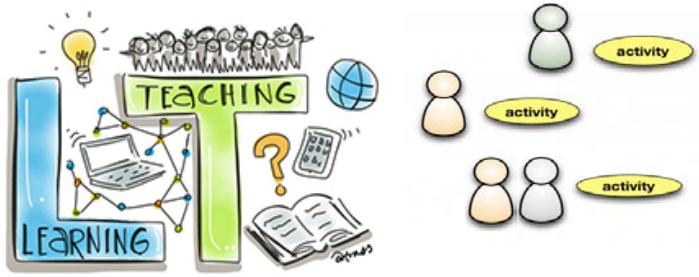
Rapidly Changing World



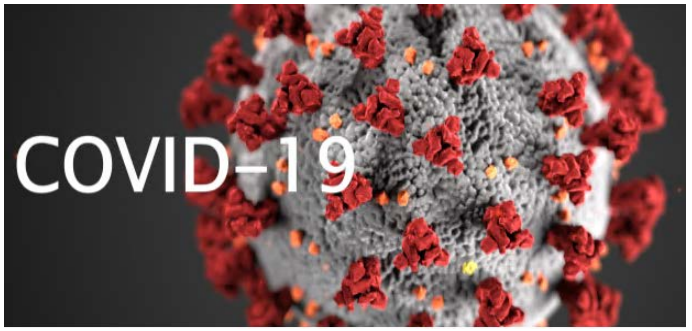


Global Challenges

COVID-19



Robot cleaning - Hospitals



Robot cleaning – Public places (NTU Singapore)

Tim Woo

Global Challenges – COVID 19

Low Cost Hospital-grade Pulse Oximeter (SpO2) – IIT

PCB manufacturing

Prototypes developed

Clinical trials of prototype model in ICUs

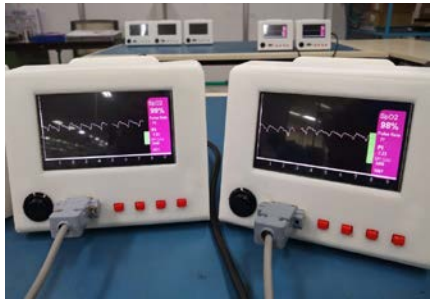
THE HINDU

KERALA

Palakkad IIT pitches in to fight COVID-19

At a time when discussions are on whether technology will destroy the art of medicine, the Indian Institute of Technology (IIT), Palakkad, is tweaking its brains to make an impact on clinical care in the State.

A prototype of the pulse plethysmograph for ICUs develope at the IIT, Palakkad. • SPECIAL ARRANGEMENT



Final product

Validation of final product in ICUs

Clinical trials successfully completed on 300 patients in ICUs of hospitals.

Manufactured by ITI Limited, India (Public Sector undertaking).

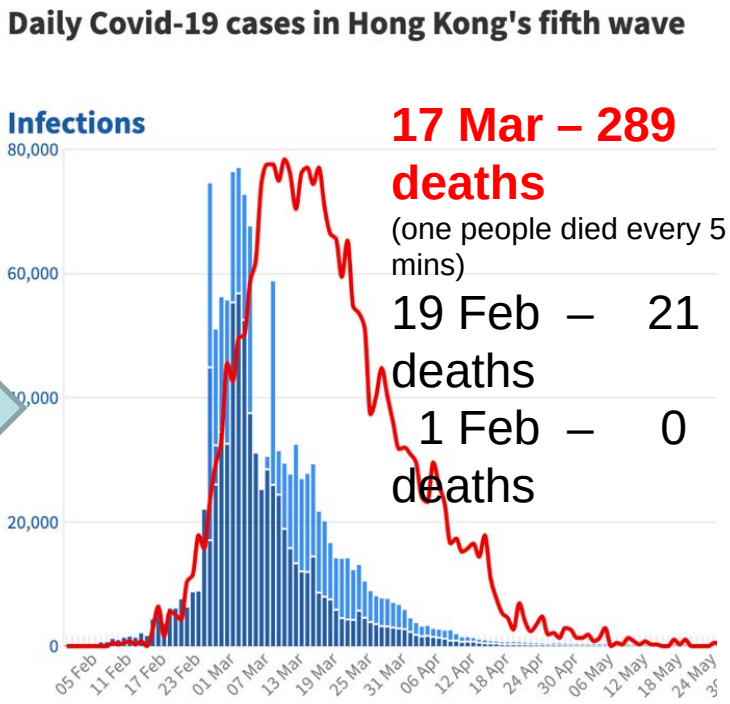
Production cost of oximeter: HKD 1500

Cost of other brands: Nellcor (USA) – HKD 5000

Global Challenges – COVID 19

Limited Isolation facilities during 5th wave

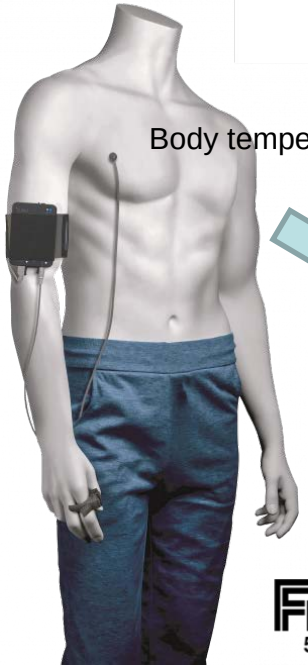
- Hospitals were **overloaded**, isolation facilities were at full capacity
- Residential care homes were **NOT equipped** for **infectious diseases** in both **manpower** & **equipment**



https://www.bloomberg.com/news/articles/2022-03-03/hong-kong-s-nursing-homes-are-unvaccinated-hotbeds-of-covid

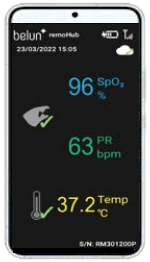
Global Challenges – COVID 19

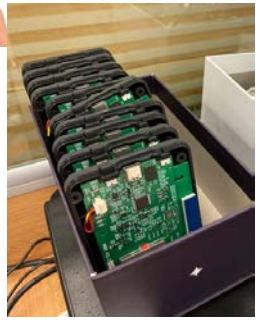
A Medical IoT System



Body temperature

Plug-and-play

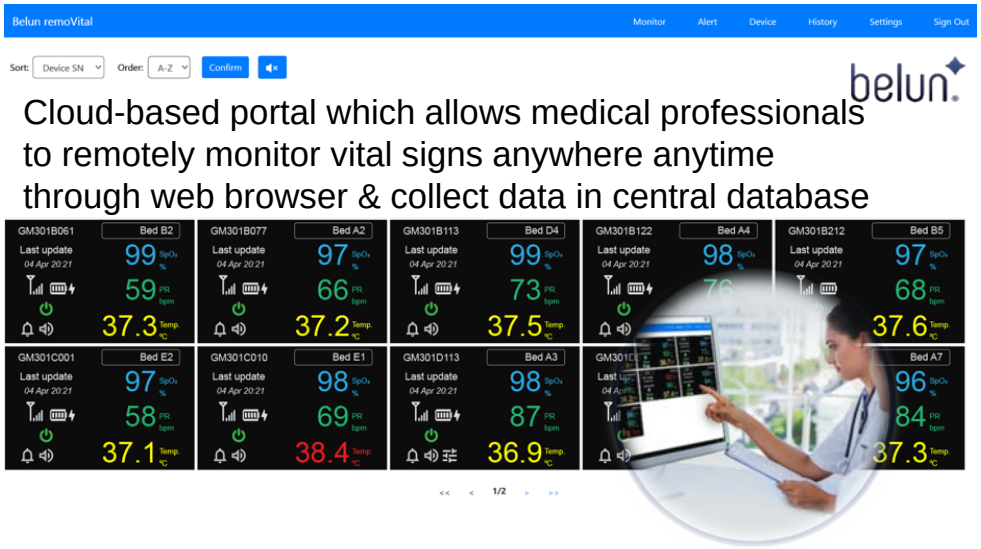




FDA 510(k)

Belun® Ring:

- Blood oxygen saturation
- Pulse rate
- Movement



Cloud-based portal which allows medical professionals to remotely monitor vital signs anywhere anytime through web browser & collect data in central database

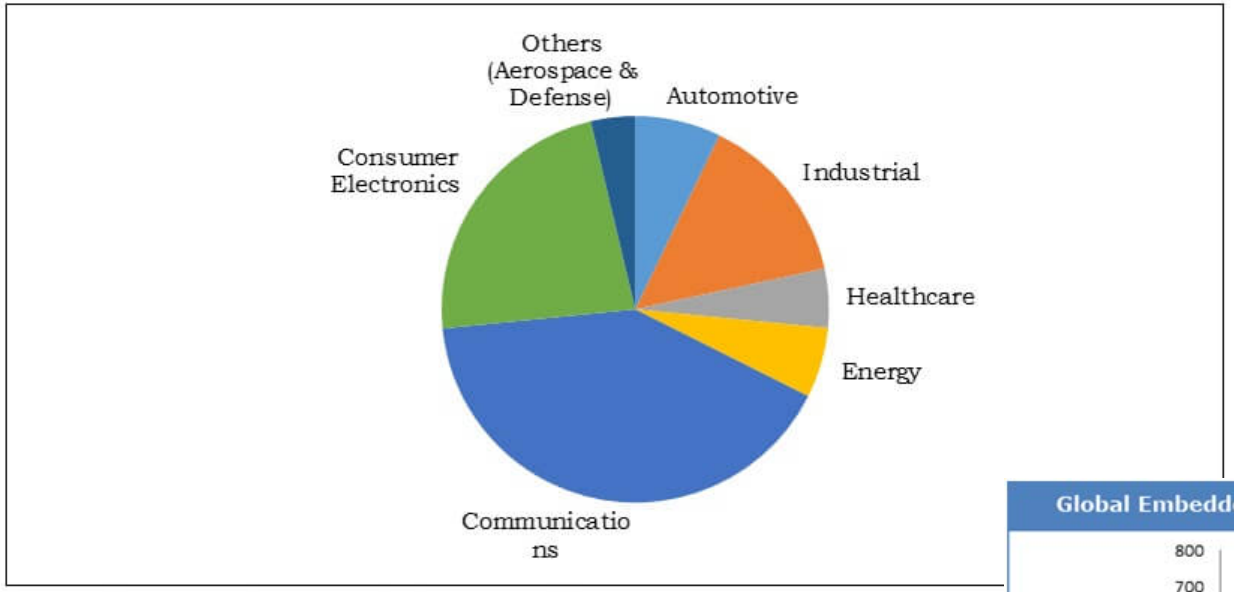
System has been tested in Taiwan, US and Singapore

In Feb/Mar 2022, 1,000+ system have been deployed to 50+ residential home, Asia Expo and Kai Tak as one of the combat COVID-19 government measures

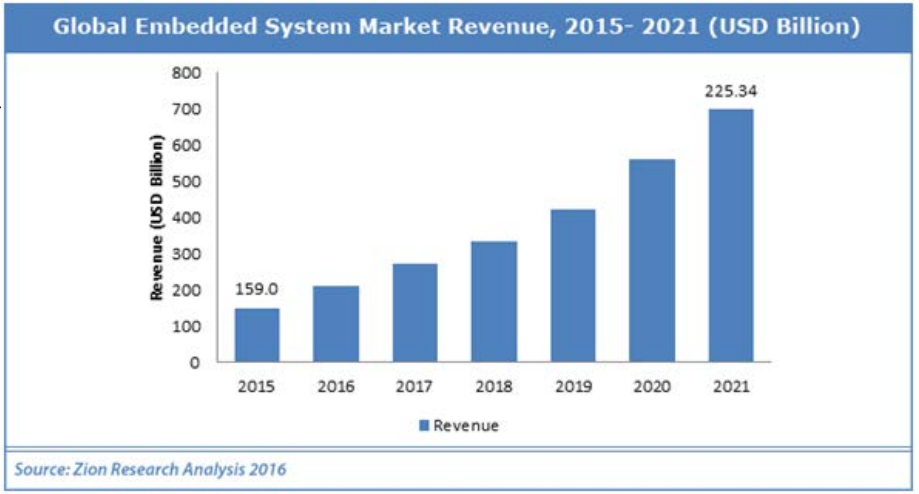
https://www.info.gov.hk/gia/general/202202/19/P2022021900538.htm?fontSize=1
https://www.sino.com/en/media-centre/press-release/2022/sino-group-and-ng-teng-fong-charitable-foundation-partner-with-hkcss-and-social-welfare-department-to-distribute-500-belun-removital-remote-monitoring-systems-to-care-homes%20/

The Embedded Systems – Market Reasons

Embedded Computing market segments (Global 2015-2022)

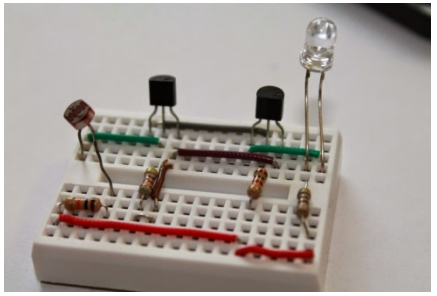


Source: Primary & secondary research, and AMR Analysis

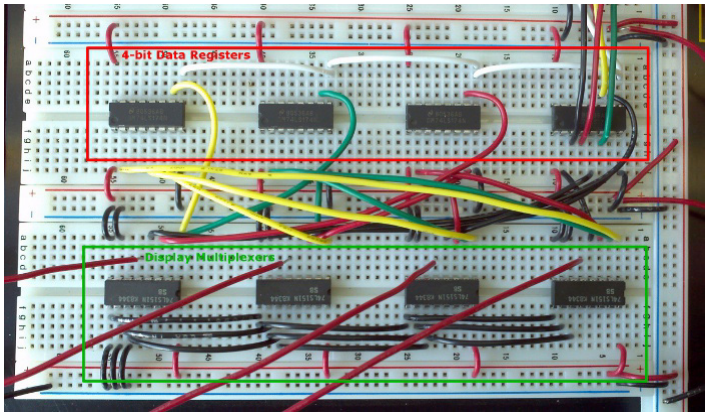


The Embedded Systems - Engineering reasons

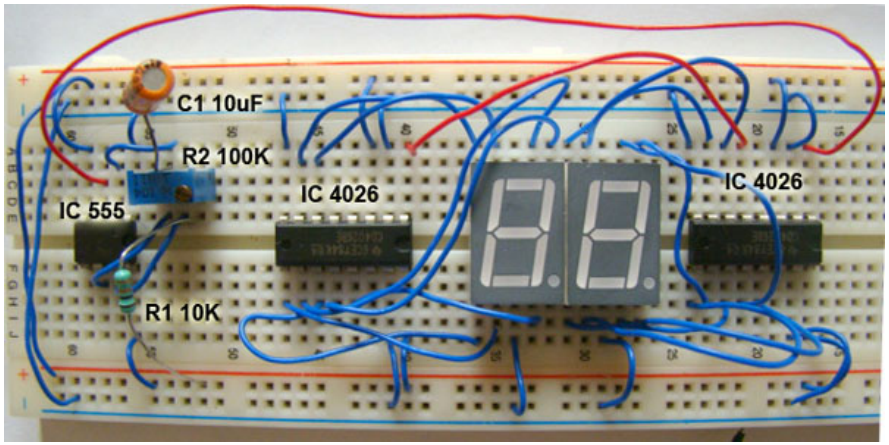
- Reduce engineering costs in several aspects
  - Increased flexibility (programmability)
  - Upgrades of software while keeping the same hardware
  - Better controllability



Light Senor Circuit



Pulse Width Modulation Circuit

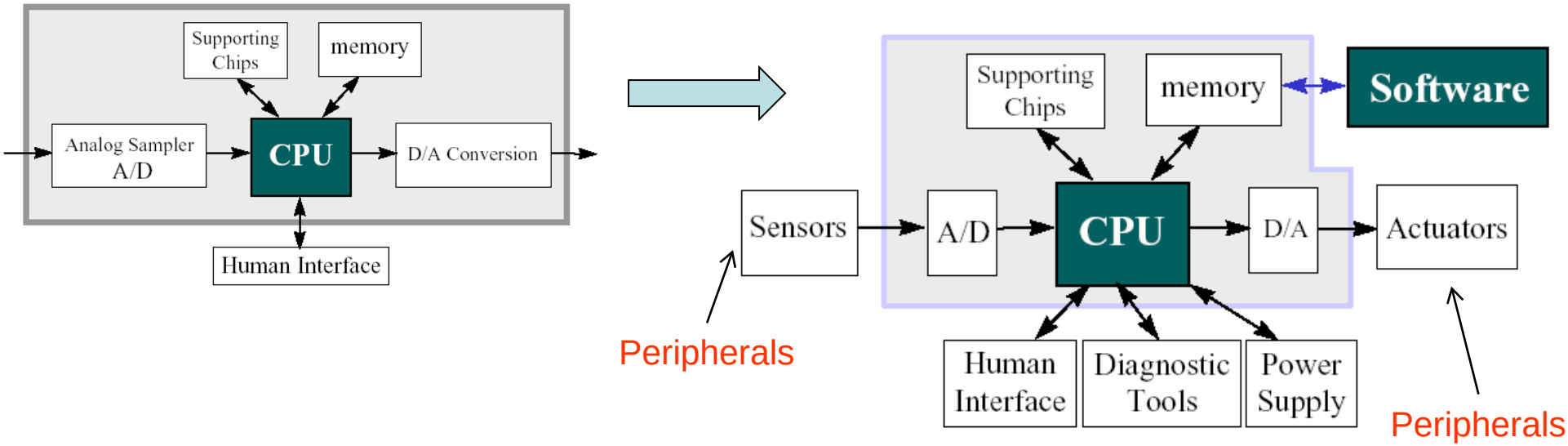


Digital Pulse Counter Circuit

All the above circuits can be easily implemented in microprocessor

Design Engineers' View: Embedded System

- Measured by performance, cost, I/O interconnections and memory size



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

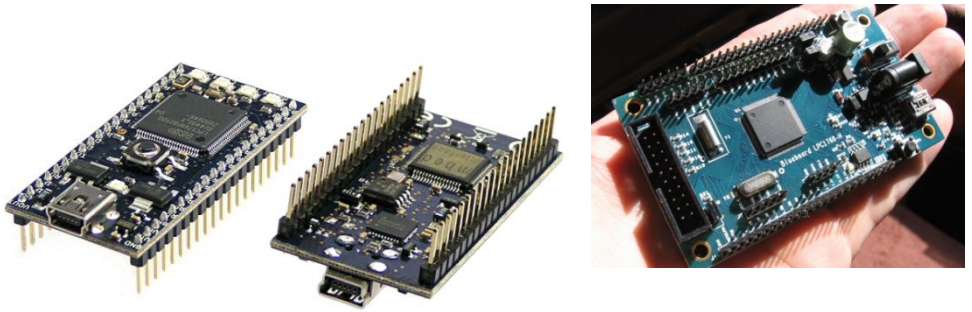
Design Engineers' View: Embedded System

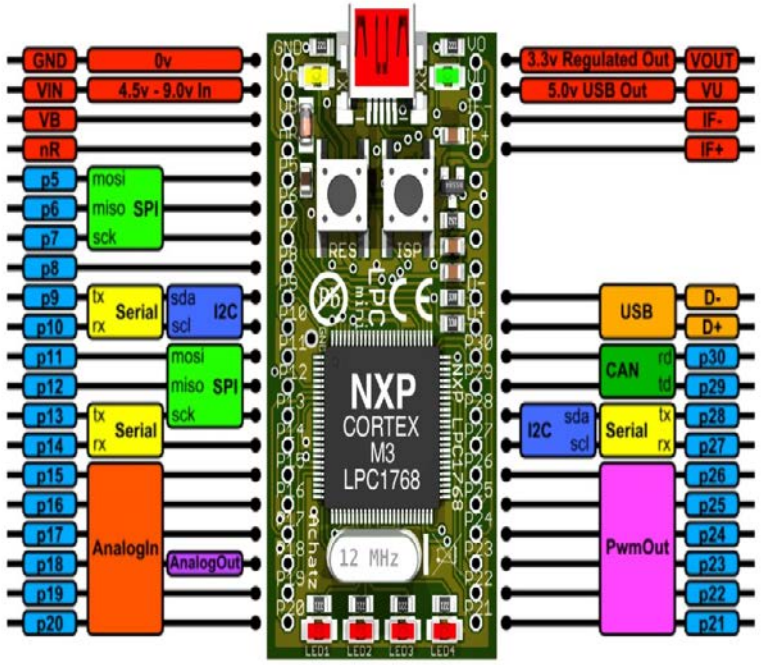
Source: Electronics Hub

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*

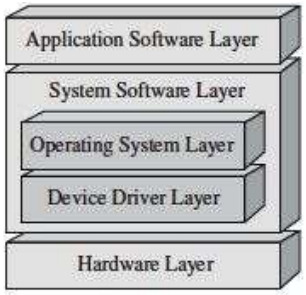




mbed NXP LPC1768
Cortex-M3 Microcontroller Module with Web-Toolchain

Inside the embedded systems

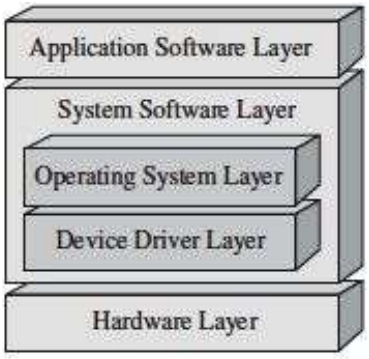
- Software (Cont'd)
  - Operation system (OS), *initialization routines*, application software and *device drivers*
  - *initialization routines* : software programming for hardware devices
    - Tell the Processor which devices are connected to the processor
    - Example 1: Configure an I/O port as 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.



Examples: Memory and memory 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,

Inside the embedded systems

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

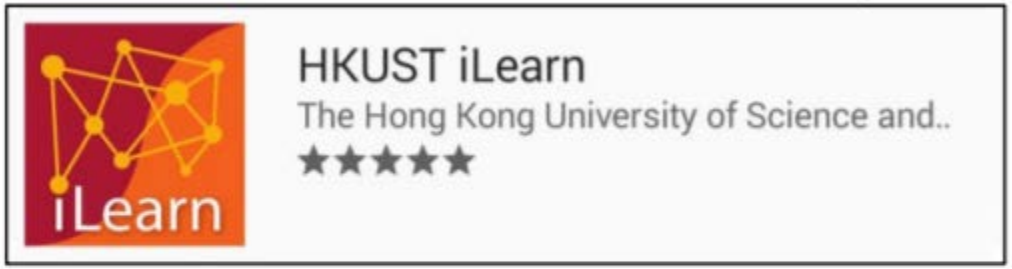


- Different types of hardware will have different device driver requirements that need to be met.
- Even the same type of hardware that are created by different manufacturers can require substantially different device driver software libraries to support within the embedded device.

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

In-class activity

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



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

Questions – Topic 1 Introduction to Embedded Systems

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

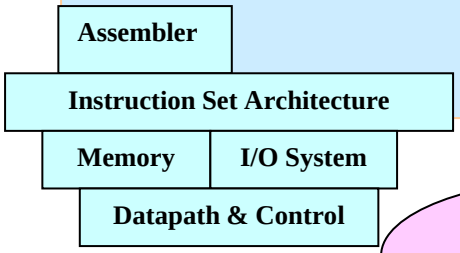
Some soft skills you need to grasp

- 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 ?

Course Overview



Introduction to Embedded Systems

More about Embedded Systems

Basic Computer Structure

MCU Main Board

Digital and Analog Interfacing

USART, IEEE1394, USB, I2C and SPI

Microcontroller Structure

A/D Port

Serial Port

CPU

External Memory Port

External Interrupt Port

Interrupt Organization

Timer and Counter

External Timer Port

Simple I/O Port

Buffering and Direct Memory Access (DMA)

Memory, Interfacing to Memory, Memory Timing and applications

Interfacing LCD

Motor Interfacing

In this course, STM32 is used as a driving vehicle for delivering the concepts.

To be covered	In progress	Done