Digital Electronics

XMUT-ECEN 202 - 2024 T1

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School of Engineering and Computer Science

Victoria University of Wellington

What's the course about?

At the completion of the course, students should be able to:

- Design both combinatorial and sequential digital circuits.
- Be able to practically implement these designs by the construction and testing of prototype circuits.
- Understand the basic architecture of a microcontroller by using the 8051 microcontroller as an example.
- Be able to program a microcontroller in assembly language and to interface it in a real-world application.

Where we are headed?

- ECEN 202 is just the start.
- The ability to program devices is crucial to rapidly iterate electronics design.
- Hardware by the programming of digital logic! EEEN (ECEN) 402
- Software by the programming of microcontrollers! EEEN (ECEN) 301

Admin: People

- Coordinator and Lecturer: Mohammad Nekooei
  mohammad.nekooei@vuw.ac.nz
- Lecturer: Pawel Dmochowski
  pawel.dmochowski@ecs.vuw.ac.nz
- Co-teacher Dr Jiang Huali (XMUT)
- Tutors XMUT and VUW
- Course URL: https://ecs.wgtn.ac.nz/Courses/XMUT202_2024T1/

Lectures

- Tuesdays, Thursdays
- Slides
  - on course webpage (pdf for each week)
- Video recordings
- Questions:
  - WeChat, or
  - Emails
- Goals
  - Provide a framework for your learning
  - Provide key content/explanations/demonstrations

Assessment

- Attendance [10%]
- Assignments [10%]
- Labs [20%]
- Test [30%] lecture time
- Final Exam [30%] 2 hours, in exam period

Mandatory Requirements

- 1 day after the deadline will receive a maximum mark of 90%,
- 2 days after the deadline will receive a maximum mark of 80%,
- 3 days after the deadline will receive a maximum mark of 70%,
- 4 days after the deadline will receive a maximum mark of 60%.
- 5 days after the deadline will receive a maximum mark of 50%.
- **No work will be accepted after releasing the solutions unless previously arranged with the course organizer.**

Labs and Assignments

- Critical for your learning!
  - Labs and Assignments ➔ total of 30%
- Labs are in groups, and you must present your projects to co-teachers or tutors in the lab.
- Assignments must be your work.
- First Lab: starts this week
  - Choose your group and your Kit box
  - Working with simulator

Getting Help.

Co-teacher and Lecturer

- Ask questions and answers (During lectures or labs, emails and WeChat)
- **NO** posting chunks of **ANSWERS** to assignments!

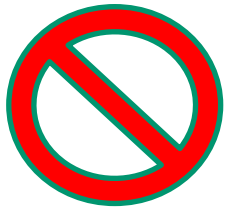
Text Book (optional)

- *Digital Systems Principles and Applications*
  by R J Tocci
  - 12th edition is best

- Electronics A Systems Approach
  by Storey

PLAGIARISM UNACCEPTABLE

- We want you to LEARN, TALK to each other, learn TOGETHER, and HELP each other, but

 **PLAGIARISM is UNACCEPTABLE!** 

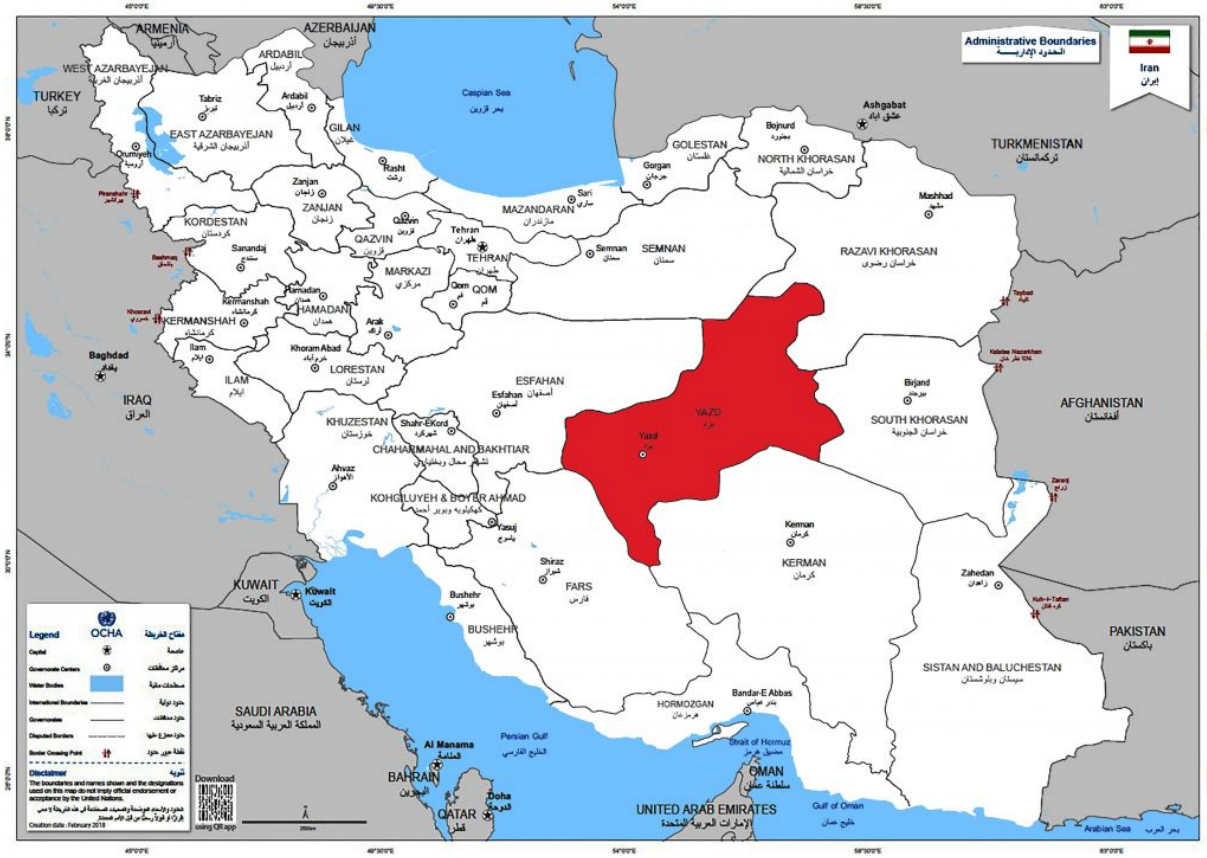
- Got help from anybody other than lecturer or tutor?

STATE IT ON THE ASSIGNMENT!

- Copied bits of code from anywhere other than lecture slides or textbook?

STATE IT ON THE ASSIGNMENT!

About Me


Administrative Boundaries
Iran
ARMENIA
AZERBAIJAN
WEST AZARBAYEJAN
ARDABIL
TURKEY
EAST AZARBAYEJAN
GILAN
Caspian Sea
GOLESTAN
NORTH KHORASAN
TURKMENISTAN
Ashgabat
Bojnurd
Gorgan
Rasht
ZANJAN
MAZANDARAN
Sari
Mashhad
KORDESTAN
QAZVIN
Qazvin
Tehran
TEHRAN
SEMNAN
Semnan
RAZAVI KHORASAN
MARKAZI
QOM
Qom
KERMANSHAH
HAMADAN
Arak
Baghdad
LORESTAN
ILAM
IRAQ
ESFAHAN
Esfahan
YAZD
Yazd
Birjand
SOUTH KHORASAN
AFGHANISTAN
KHUZESTAN
Shahr-Ekord
CHAHARMAHAL AND BAKHTIAR
Ahvaz
KOHGILUYEH & BOYER AHMAD
Yasuj
Kerman
KERMAN
Shiraz
FARS
KUWAIT
Kuwait
Bushehr
BUSHEHR
Zahedan
PAKISTAN
SISTAN AND BALUCHESTAN
SAUDI ARABIA
HORMOZGAN
Bandar-E Abbas
Strait of Hormuz
Persian Gulf
Al Manama
BAHRAIN
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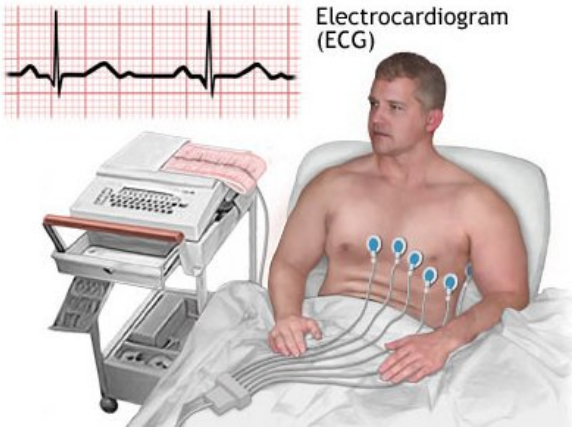
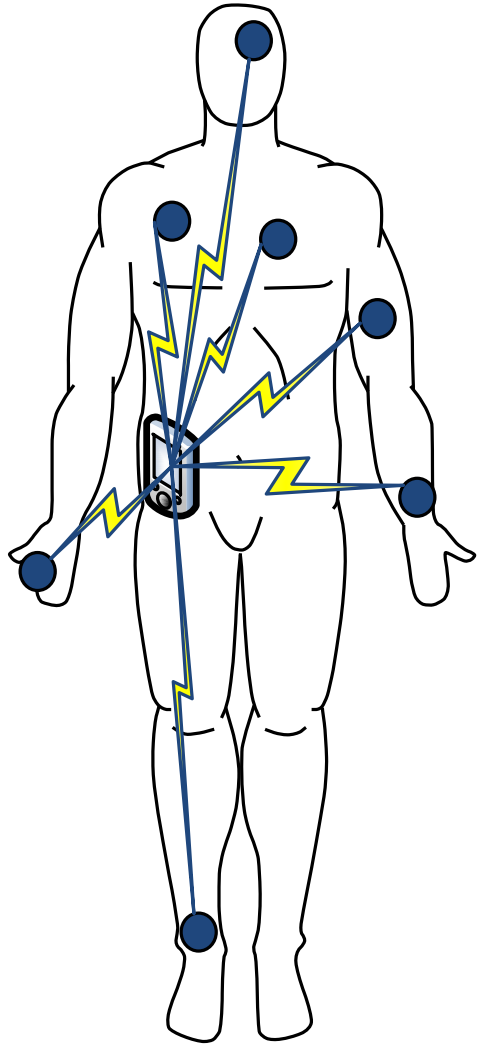
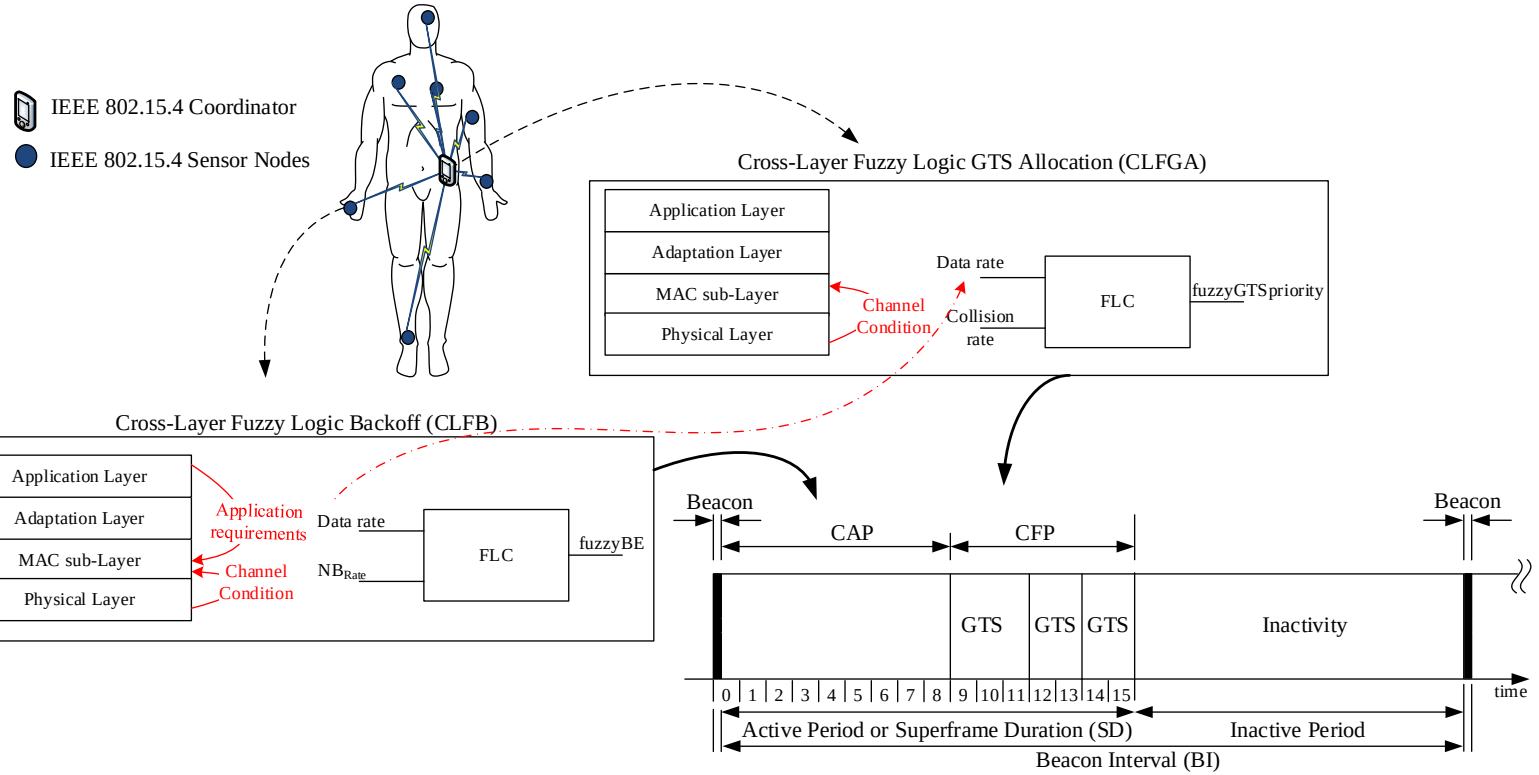
About Me


Electrocardiogram
(ECG)




IEEE 802.15.4 Coordinator
IEEE 802.15.4 Sensor Nodes
Cross-Layer Fuzzy Logic GTS Allocation (CLFGA)
Application Layer
Adaptation Layer
MAC sub-Layer
Physical Layer
Data rate
Collision rate
Channel Condition
FLC
fuzzyGTSpriority
Cross-Layer Fuzzy Logic Backoff (CLFB)
Application Layer
Adaptation Layer
MAC sub-Layer
Physical Layer
Application requirements
Channel Condition
Data rate
NB_Rate
FLC
fuzzyBE
Beacon
CAP
CFP
Beacon
GTS
GTS
GTS
Inactivity
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
time
Active Period or Superframe Duration (SD)
Inactive Period
Beacon Interval (BI)

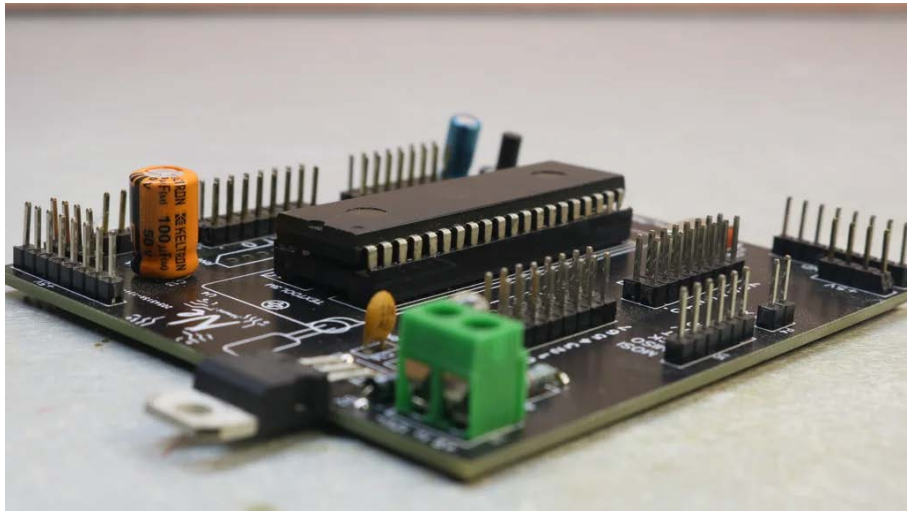
Today

- Goal 1: Understand what a microcontroller is and why they're used.
- Goal 2: Understand the basics of the 8051's architecture.
- This will prepare us to begin writing assembly language programs (starting Wednesday! 😨)

What is a microprocessor?

The heart of any computer is a microprocessor. It can be considered a sophisticated state machine.

We can think of a microprocessor as a general-purpose digital logic device that can perform many digital logic operations.



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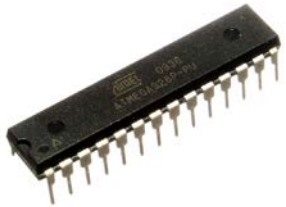
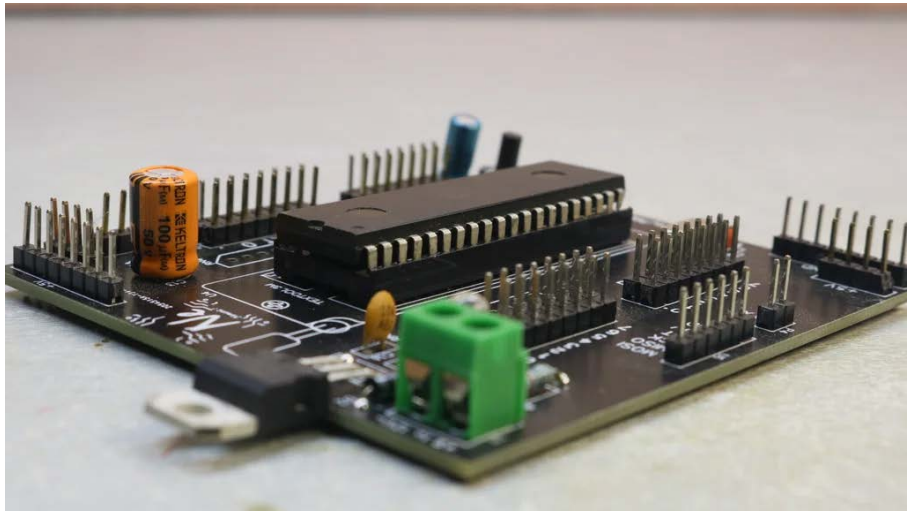
What is a microprocessor?

- The microprocessor is a programmable device; therefore, one microprocessor can replace a whole range of discrete logic components.
- The operations are performed in a sequence based on the program written for the microprocessor.
- It can be considered as a sophisticated “state machine”.





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Microprocessors vs. Microcontrollers

- Microprocessors are single-chip CPUs used in microcomputers.
- How do microcontrollers differ from microprocessors?
- Three perspectives: hardware architecture, applications, and instruction set features.

Microcontrollers

- **Performance > robustness**
- **Multiple discrete peripherals**
- **Power efficiency = relatively low priority**
- **Often designed with multitasking operating systems in mind**
- **Relatively expensive**
- **Often programmed on the device**

Conventional computing systems

- **Robustness > performance**
- **Monolithic: integrated peripherals**
- **Power efficiency = high priority**
- **Designed to use simple operating systems (or none at all)**
- **Relatively cheap**
- **Programmed via cross-compiled code**

Microcontrollers

But… mobile devices, high-performance microcontrollers, and systems-on-chips (e.g., RPI) are really blurring the lines in recent years

Why study microprocessors and microcontrollers?

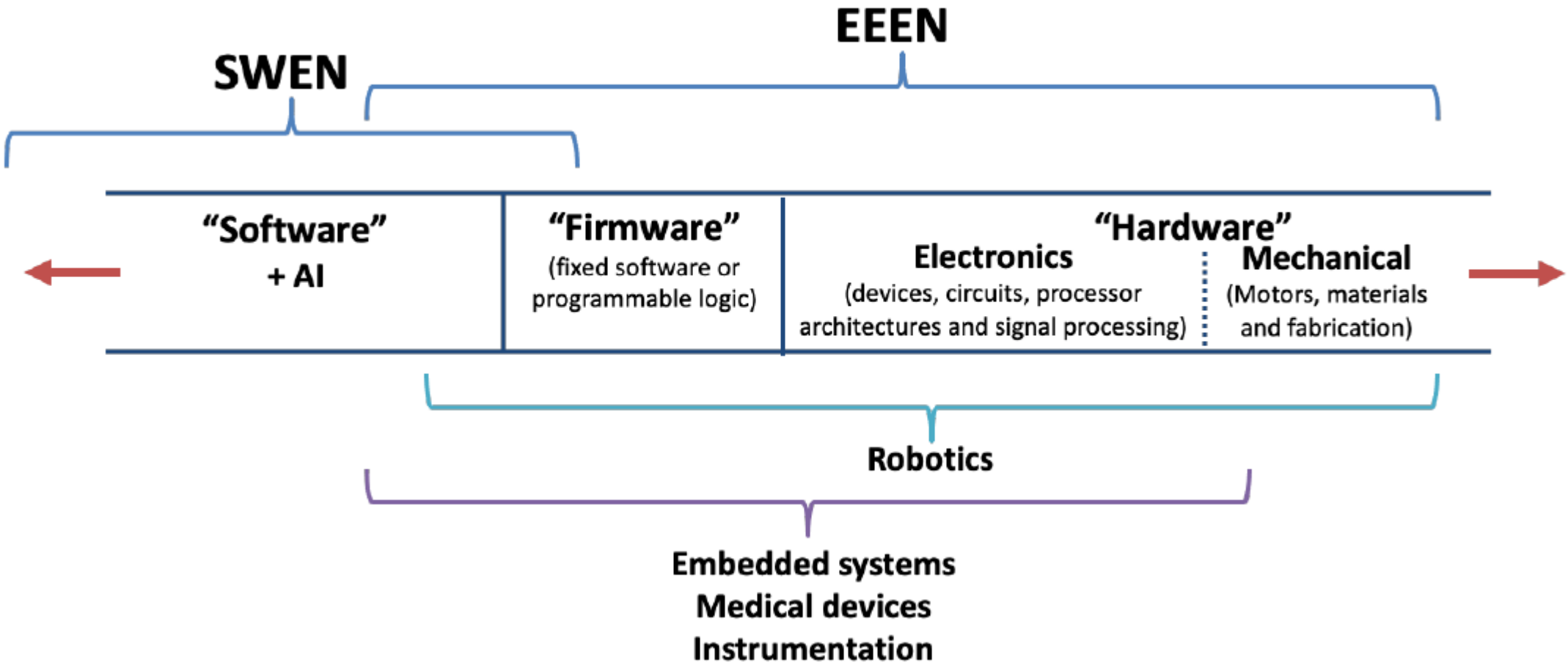
- Learn what happens inside the devices you program.
- Learn how to build and code embedded devices.
- Learn about new developments in high performance and energy efficient computing.

“Moore’s Law is over.” –

David Patterson, (ret) Prof. U.C. Berkeley.

https://spectrum.ieee.org/david-patterson-says-its-time-for-new-computer-architectures-and-software-languages

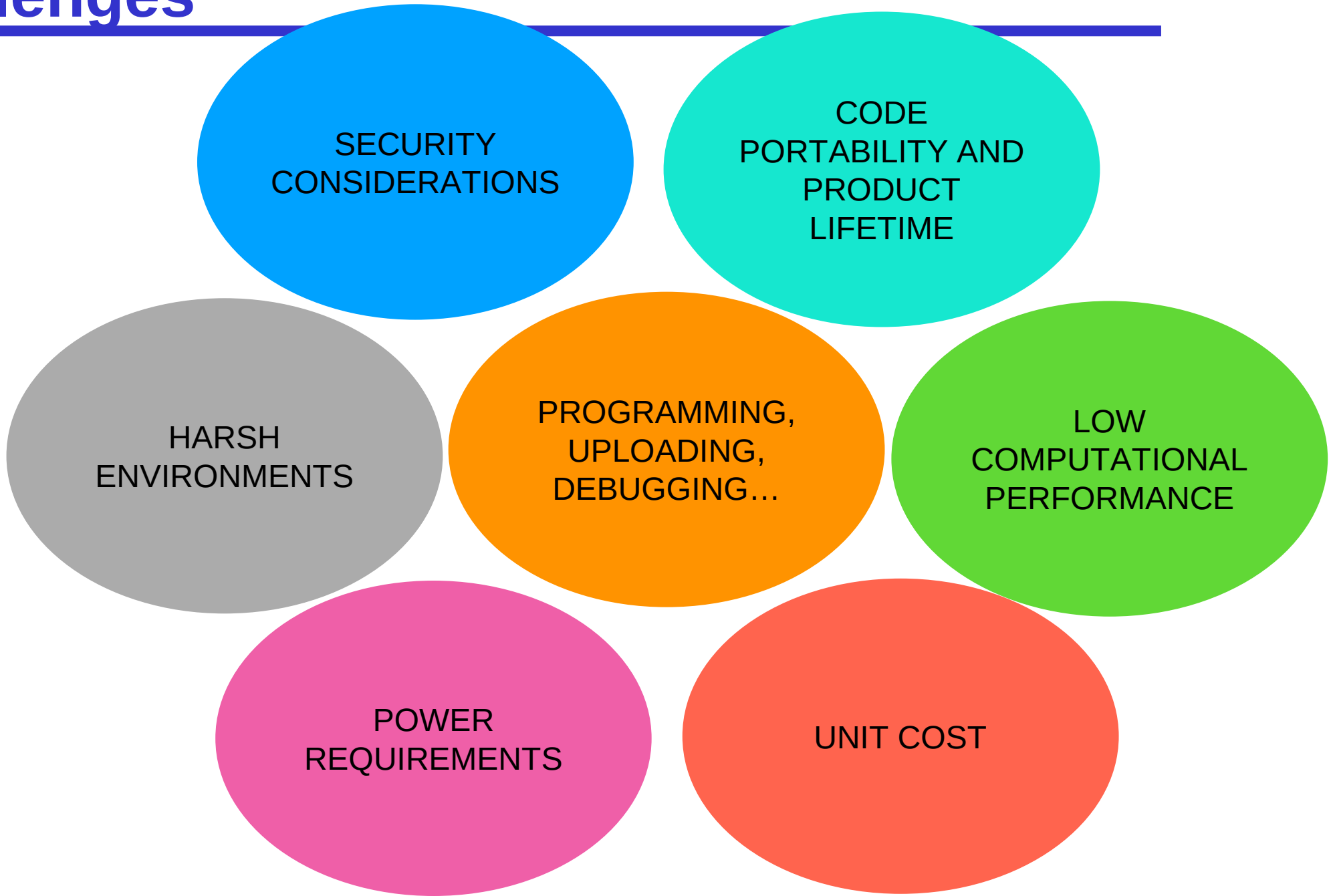
Software – Firmware - Hardware



Where are embedded systems used?

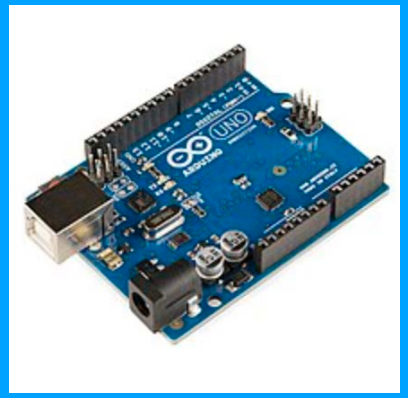
- Where aren't they used?

Challenges

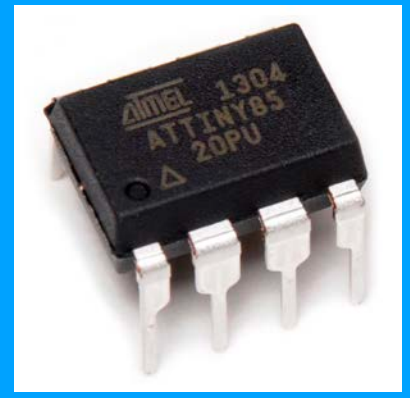

SECURITY CONSIDERATIONS
CODE PORTABILITY AND PRODUCT LIFETIME
HARSH ENVIRONMENTS
PROGRAMMING, UPLOADING, DEBUGGING…
LOW COMPUTATIONAL PERFORMANCE
POWER REQUIREMENTS
UNIT COST

State of the art

HIGH PERFORMANCE

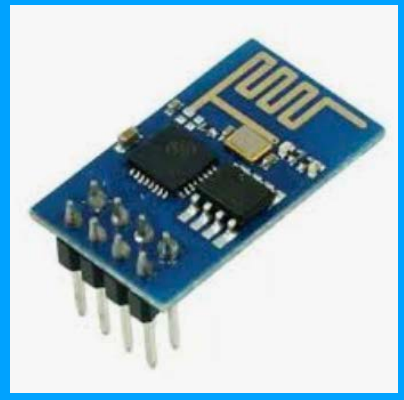


EASE-OF-USE



EXTREME LOW COST

LOW-POWER



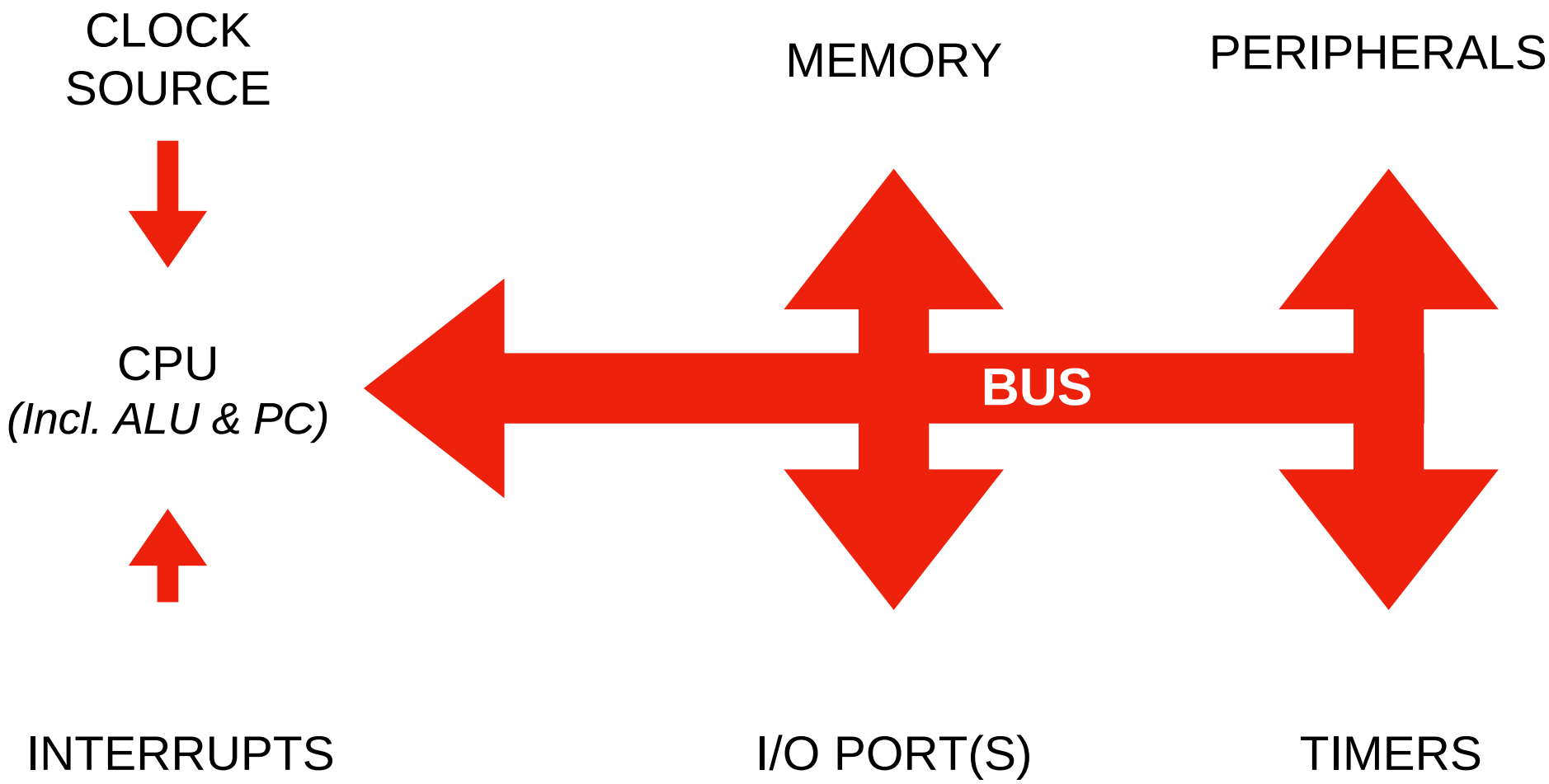
INTEGRATION

FLEXIBILITY

Popular microcontroller families

FAMILY	(TYPICAL) DATA BUS WIDTH	EXAMPLE DEVICE	EXAMPLE APPLICATION
ARM CORTEX	32 bit	STM32F103	Rapidly replacing others: ‘the future’
AVR	8 bit	ATMEGA328	Arduino Uno
PIC	8 bit (among others)	PIC16F18875	Smaller-run items (good toolchain)
MSP430	16 bit	MSP430F5529	Low-power applications
8051	8 bit	AT89C51AC3	Ubiquitous - automotive, etc.

A (very) general microcontroller



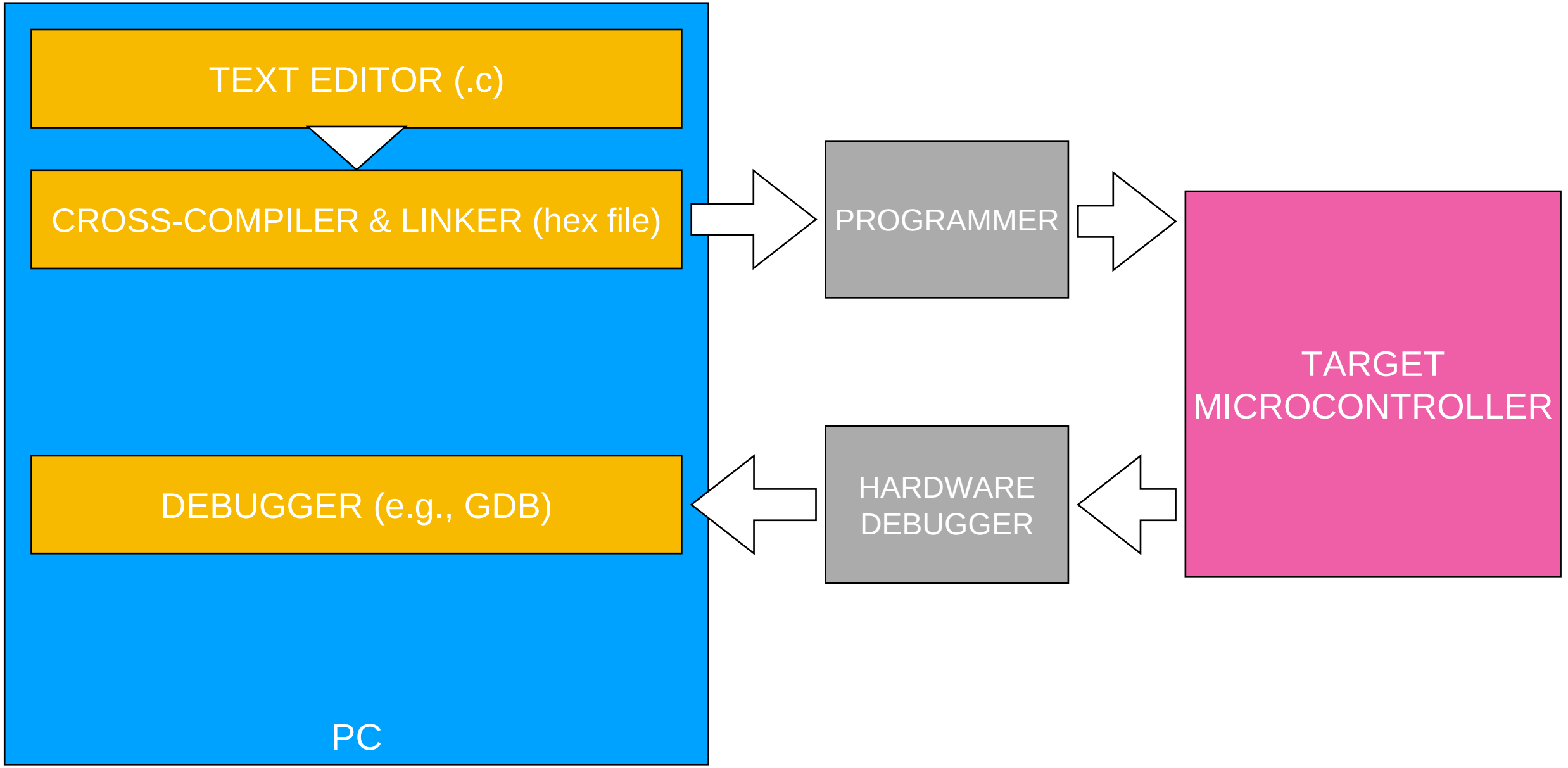
Terminology

- CPU: Central Processing Unit:
  - Fetches and executes instructions
  - Instructions are typically arithmetic (add, subtract, etc.) or logic (AND, OR, NOT, etc.) operations

- Bus:
  - A collection of wires carrying information with a common purpose.
  - Address bus contains fetch/store locations
  - Data bus contains the data
  - Control bus stops everything happening at the same time.

- Interrupts:
  - Special inputs to the CPU which interrupt normal instruction execution to execute pre-defined interrupt code.
  - Allows the rapid handling of special events or exceptions.

Toolchain, Tools, Hardware

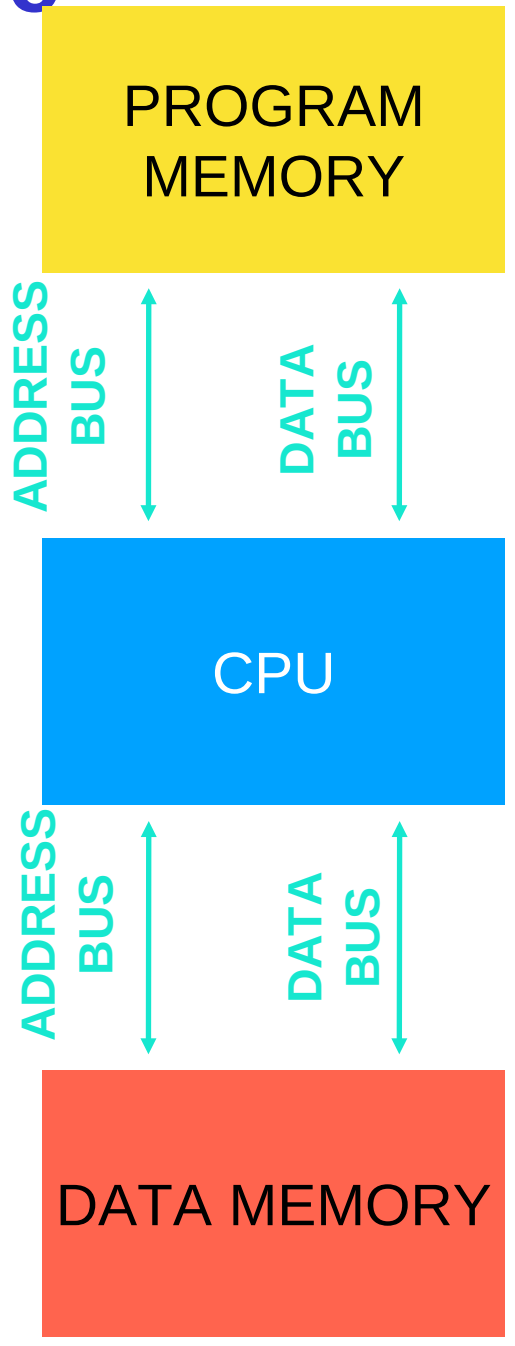


Computer Organisation: Von Neumann Architecture

- Memory is organised as a single block.
  - The program and the data are stored alongside each other: simplifies addressing.
  - Allows for data to be executed as the program
    - Interesting… security issues though (esp. on simple devices)!
- The CPU cannot read instructions and data at the same time (without caching)
  - Caching is less deterministic; if highly deterministic performance is required (e.g., DSP's), Von Neumann architecture isn't preferred.
- Program and data access must be sequential; this forms a bottleneck.
  - Pipelining, caching, etc. can deal with these issues.
    - These increase complexity past what cheap microcontrollers warrant.
- Pentium, ARM Cortex M0 (and most modern processors) are Von Neumann at the macro level, with separate caches for program and data

Computer Organisation: Harvard Architecture

- 8051: Harvard architecture.
- Rare in many modern computers: challenges related to memory mapping, advanced caching, etc. have made this obsolete.
  - Inexpensive and high-performance computers still use this.
- Can fetch program instruction and data in parallel.
- Good for situations where program memory might be on one memory type (e.g., Flash) and data memory on another.
  - This is common on microcontrollers.
    - Historically, microcontroller program memory was on a separate removable PROM
- Can be made highly deterministic
  - Strict Harvard architectures are used in many DSP's
- Harvard architecture allows for easy implementation of different bus widths for program and data.
  - This can lead to some confusion as to whether a microcontroller is really fully 8-bit, for example!



8051: CONTEXT

- 8051: Released by Intel in 1980. 40 years old (!)
- Released as the MCS-51
- Known now as the 8051
- Chief architect: John Wharton

- Originally Intel-only, but many ‘binary compatible’ devices by other manufacturers appeared.
  - These variants often feature additional peripherals, built-in memory, etc.
  - In ECEN202, we’ll be working with the AT89C51 binary compatible device.