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Computer Systems / Rekenaarstelsels 245 - 2020

Lecture 1

Module Introduction

Module Inleiding

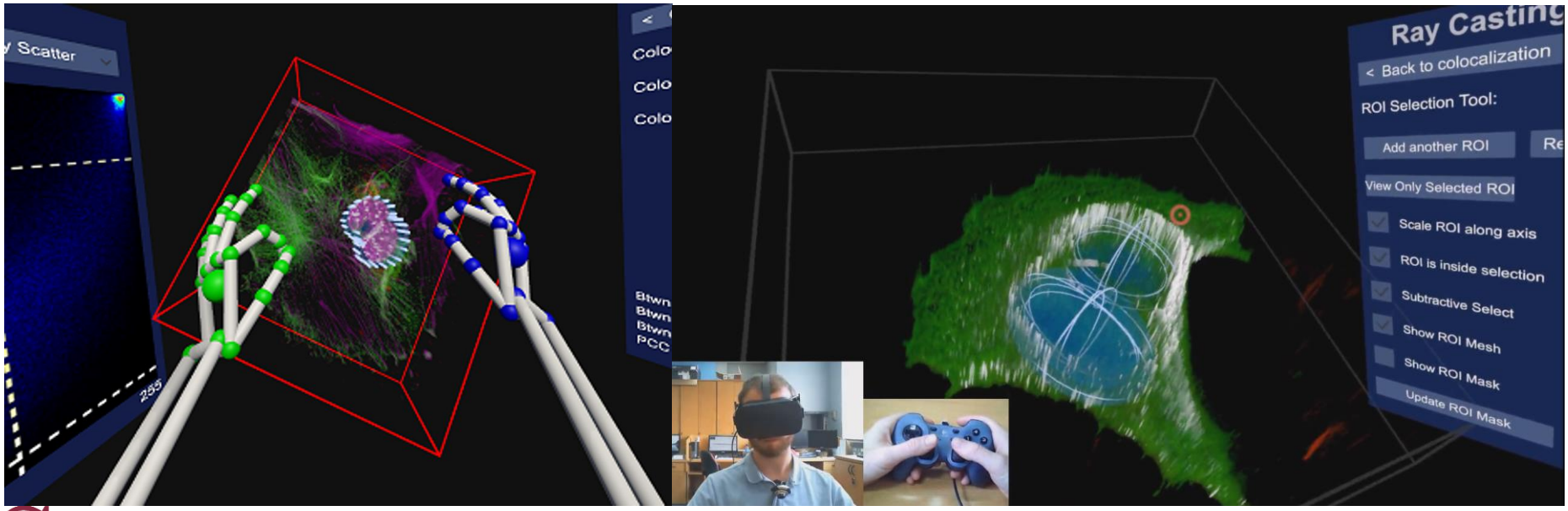
Dr Rensu Theart & Dr Lourens Visagie

Lecture Overview / Lesing Oorsig

- Who am I?
- Study guide
- History of computers
- Microcontrollers

Who am I? / Wie is ek?

- Rensu Theart
- Studied E&E at Stellenbosch
  - Specialized in computer systems, informatics and control systems
- Finished PhD in 2020
  - Virtual Reality visualisation and analysis of biological cells



Study guide / Studie Gids

- Computer Systems 245
  - Builds on Computer Programming 143 and Computer Systems 214
  - Language Policy – Tuition in English
  - SAQA Credits: 15
  - Workload: 12 hours per week
    - 3 hours Lectures
    - 3 hours Practicals and Tutorials
    - 6 hours Home Study

- Lecturers
  - Dr Rensu Theart & Dr Lourens Visagie
    - Email: rptheart@sun.ac.za, lvisagie@sun.ac.za
    - **Please post non-personal questions on the Online Forum**
- Teaching assistant
  - Mr Robert Waller
    - Email: 201592393@sun.ac.za
    - He will be taking main responsibility for the Practicals

Study guide: Practicals / Studie Gids: Praktiese

- **Practical sessions:** Wednesday from 10:00 to 13:00.
- Presented as a SunLearn quiz.
- Submits results or program code for the assignments on SunLearn.
  - The answers will be graded automatically and feedback provided via SunLearn.
- Assignments will open from Wednesday 10:00 and are **due on the Sunday evening** of the same week (before the next week starts).
- Questions regarding the practical must be posted on the **SunLearn Q&A forum**
- **Lecturers will not answer questions about the practicals via email or MS Teams.**

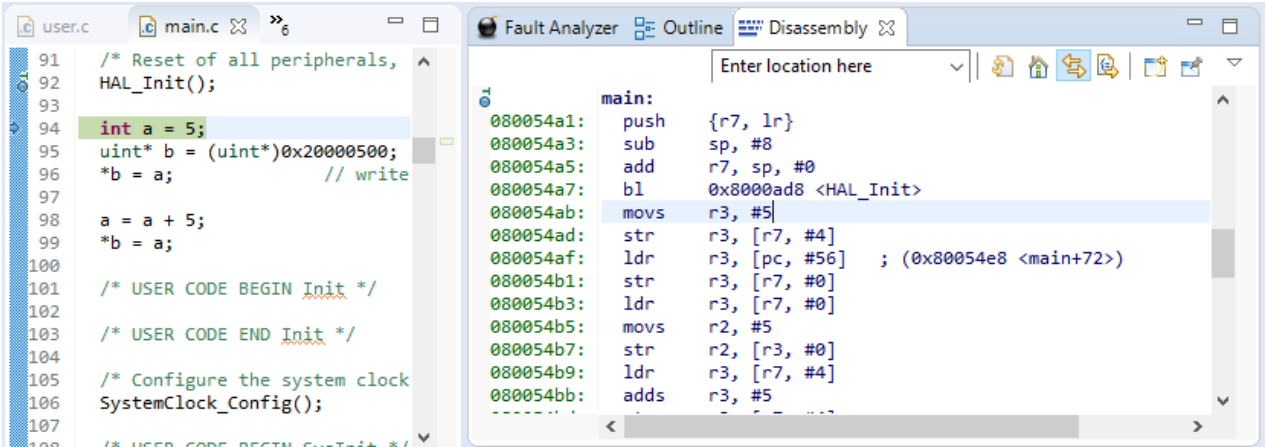
Mark Calculation / Punteberekening

- Final mark formula
  - FM = (20% × SM) + (30% × A1) + (50% × A2)
  - With SM = average(Tut/Prac)
  - Before SM is calculated lowest two marks are removed.
  - If you miss a practical submission for whatever reason, you will be awarded a mark of zero for that practical.
- Prescribed pocket calculators (or the Windows built-in calculator app) may be used during tests.
- Carefully read through the *Faculty of Engineering General Stipulations for Undergraduate Modules* and the *Faculty of Engineering Assessment Rules* on SUNLearn.

What you will learn in Computer Systems 245?

- **From Yearbook:** Microprocessor programming; basic microprocessor architecture; bus, memory and input-output systems.
- You will learn how to develop systems that has a microcontroller at its heart.
  - What the low-level implications are when writing programs.
  - Setting up GPIOs.
  - Responding to events – Interrupts.
  - Communication interfaces.
  - Working with peripherals.

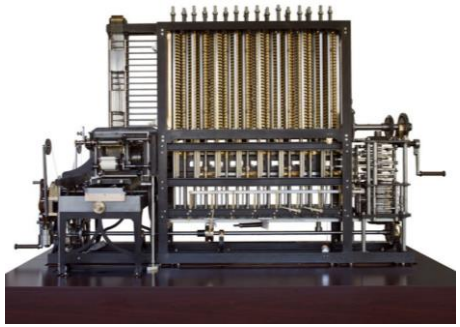
⇒ Learn how to program microcontrollers in C and ARM assembly



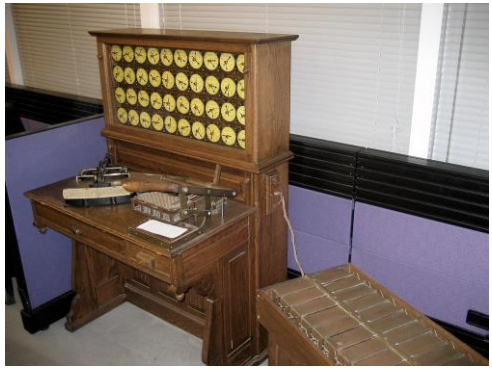
Brief history of computers – Mechanical

- Computers started off as mechanical calculators with the **Abacus** as early as 2400BC.
- In 1640s Pascal invented a mechanical calculator capable of adding six-digit numbers.
- In the early 1800s Charles Babbage invented the first mechanical computer, the **Difference Engine**, to tabulate polynomial functions.
- In 1833, Babbage invented the **Analytical Engine**, both a program and data can be provided via punched cards.
  - Incorporated an arithmetic logic unit, control flow in the form of conditional branching and loops, and integrated memory, making it the first design for a general-purpose computer.
- One of the first commercial uses of mechanical computers was by the US Census Bureau, which used punch-card equipment designed by Herman Hollerith to tabulate data for the 1890 census.
  - Accomplishing the task in just three years and saving the government $5 million.
  - Later formed IBM.

Pascal's Calculator



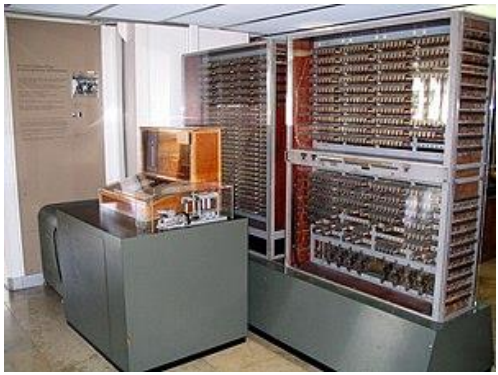
Difference Engine



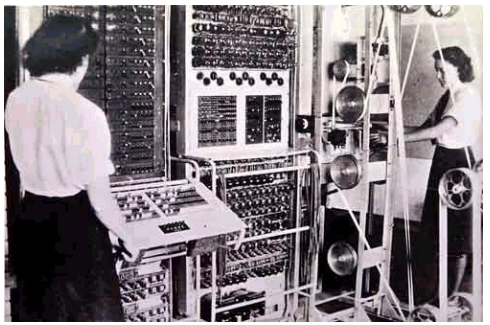
Tabulating machine

Brief history of computers – Electronic

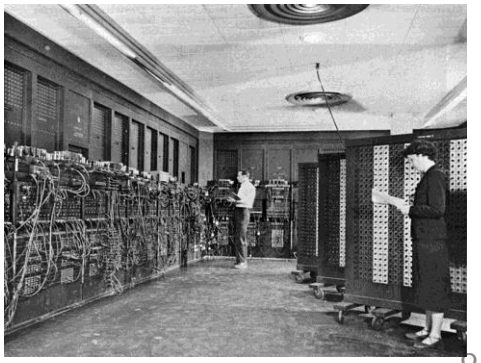
- First automatic electronic digital computer conceived in 1937 called the **Atanasoff–Berry computer.**
  - Not programmable
- In 1941, Konrad Zuse designed the **Z3**, an electromechanical computer, the first working programmable, fully automatic digital computer.
  - Built with 2,600 relays, implementing a 22-bit word length that operated at a clock frequency of about 4–5 Hz. Program code was stored on punched film. Used the binary number system.
- First vacuum tube computers were employed for military use
  - **Colossus** (1943 - Britain) – crack German secret codes
  - **ENIAC** (1946 – US) – calculate artillery firing tables
- ENIAC had to be reprogrammed by rewiring the computer! To map a problem on the machine usually took weeks.
- ENIAC could execute 5,000 additions, 357 multiplications, and 38 divisions in one second.



Z3



Colossus

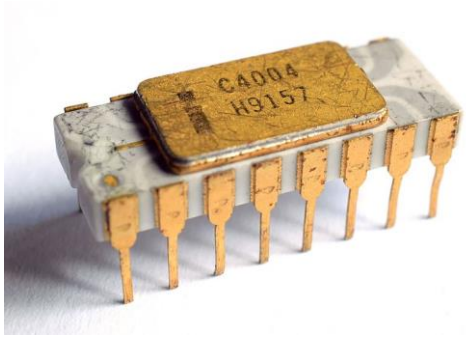


ENIAC

Rekenaars begin as meganiese toestelle en vorder tot groot elektriese rekenmasjiene in 1950 met spesifieke aanwending

Microprocessors / Mikroverwerkers

- Fast forward to today: invention of the transistor, integrated circuits and eventually microprocessors.
- The Intel 4004 is the first microprocessor in 1971
  - 740 kHz, 4-bit word length, 2250 transistors
- So what is a microprocessor?
  - The microprocessor is a multi-purpose, clock driven, register based, digital-integrated circuit…
  - which accepts binary data as inputs,
  - processes it according to instructions stored in its memory,
  - and provides results as output. (Wikipedia)
- Initial computers were conceived because people needed to
  - Count stuff (census, accounting)
  - Make war (especially during WWII)
- Now microprocessors are used and needed… *everywhere*

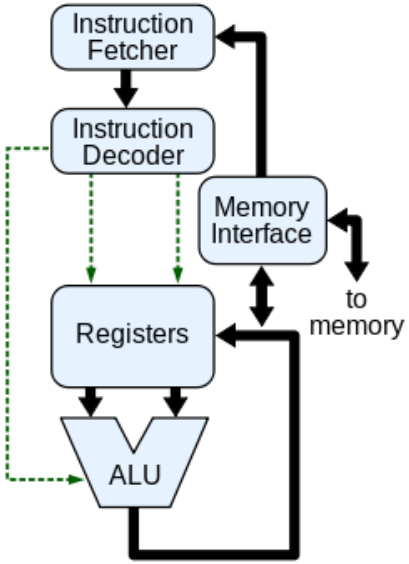


Intel 4004

- Mikroverwerkers kom deesdae in meeste elektriese toestelle voor.
- 'n Mikroverwerker is ‘n digitaal geintegreerde stroombaan met registers wat deur ‘n klok aangedryf word.

Microprocessors / Mikroverwerkers

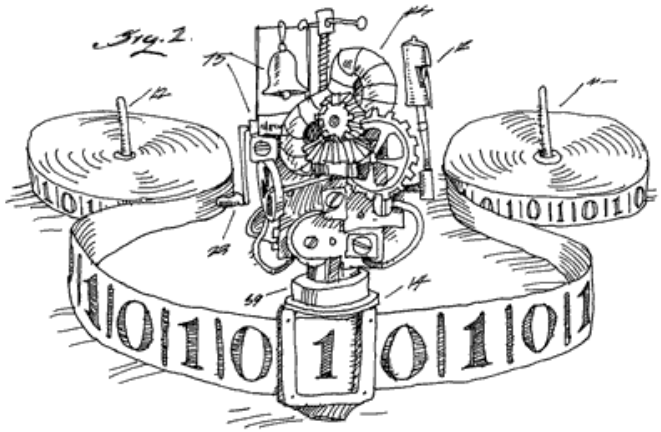
- Still… What is a microprocessor?
- Also called a CPU (Central Processing Unit)
- Performs operations described by a set of instructions (the program) stored in memory
- Stores state in a set of 'registers' (scratchpad)
- Instructions are primitive operations
  - Move data around (load from memory, store into memory)
  - Arithmetic (add stuff, multiply etc.)
  - Jump to different parts of the program
  - Conditional logic (jump only if some condition is true)
- The majority of (low level) instructions in a typical program involves moving data around! (https://www.strchr.com/x86_machine_code_statistics)



- Mikroverwerkers voer primitiewe instruksies uit op 'n stel registers.

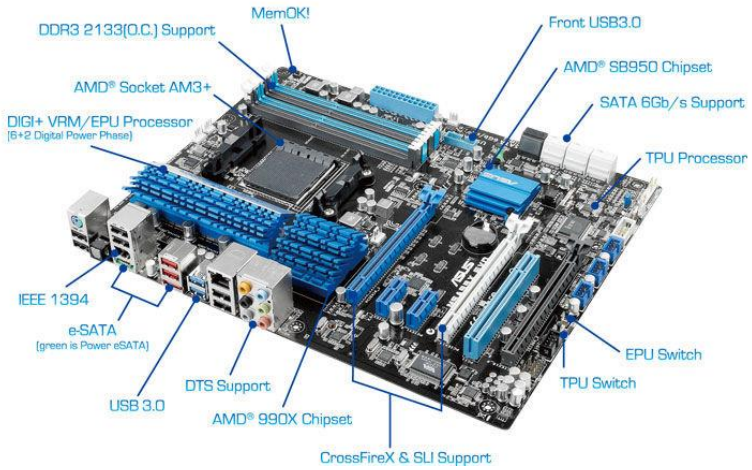
Turing Machine

- Slightly off-topic… What's a Turing Machine?
- Abstract machine that manipulates symbols on a strip of tape according to a table of rules
- More precisely – a mathematical model of computation that defines the above device
- Useful to mathematically prove what algorithms can be executed on a computer
- Not exactly identical to the CPU model, but parallels exist (tape == memory, table of rules == program)



Microcontrollers / Mikrobeheerders

- So… What is a micro**controller**?
- A CPU by itself does not have much (any?) use. We need
  - Memory
  - Timers
  - Peripherals
- Traditional PC architecture: CPU mounted on a ‘mainboard’, Memory ‘daughter boards’. Additional peripherals either soldered onto the mainboard (separate from CPU) or plugged in via some interface,
- With a microcontroller the CPU, memory and IO peripherals are integrated into the same device.
- Why?
  - Size! (smaller is better)
  - Power! (less is more)



ASUS M5A99X EVO mainboard

Mikrobeheerder sluit geheue en radapparaat in

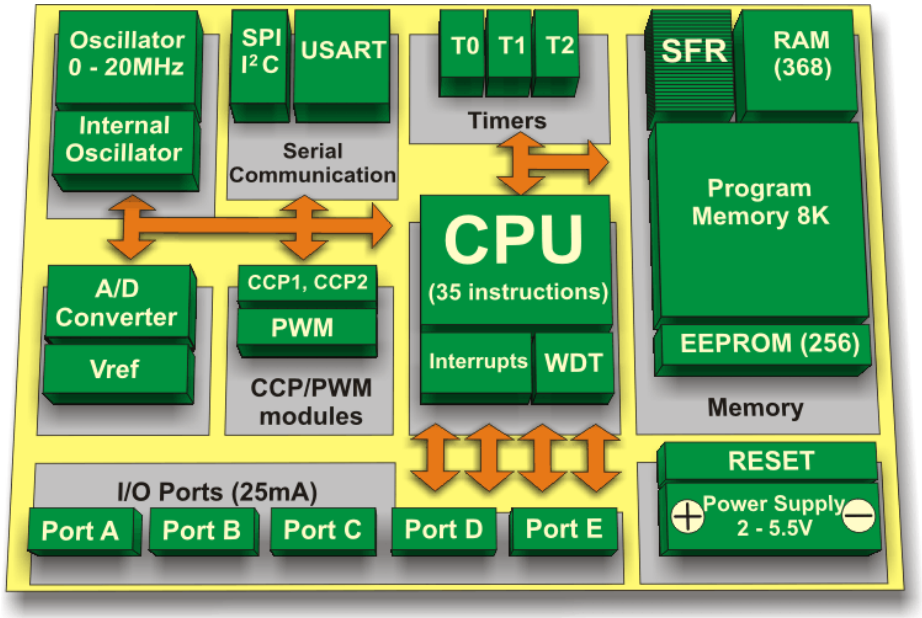
	CPU	RAM	Non-Volatile	Power	Size/Mass	Cost
Computer	Dual, 3 GHz	4GB	500GB	100W	Large	R3000
SMT32Ff411VEt6	100 MHz	128kB	512kB	<50mW	Small	R137

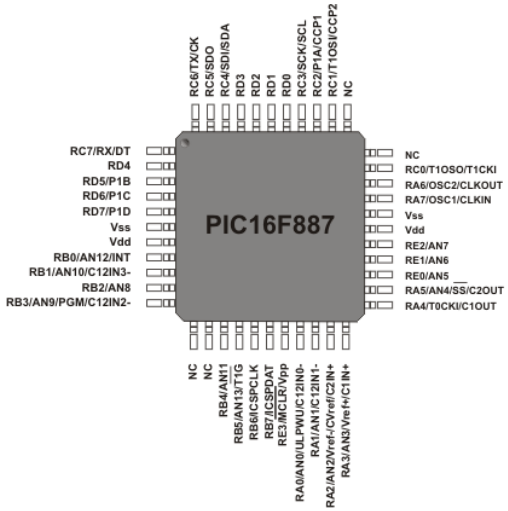
Microcontrollers / Mikrobeheerders

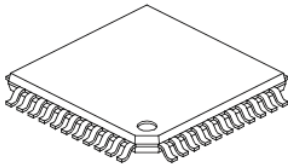
- A microcontroller is similar to but less sophisticated than a system on a chip (SoC).
- A SoC may include a microcontroller as one of its components.

Apple A13 SoC – contains CPU, GPU and Neural Engine

Microcontrollers / Mikrobeheerders



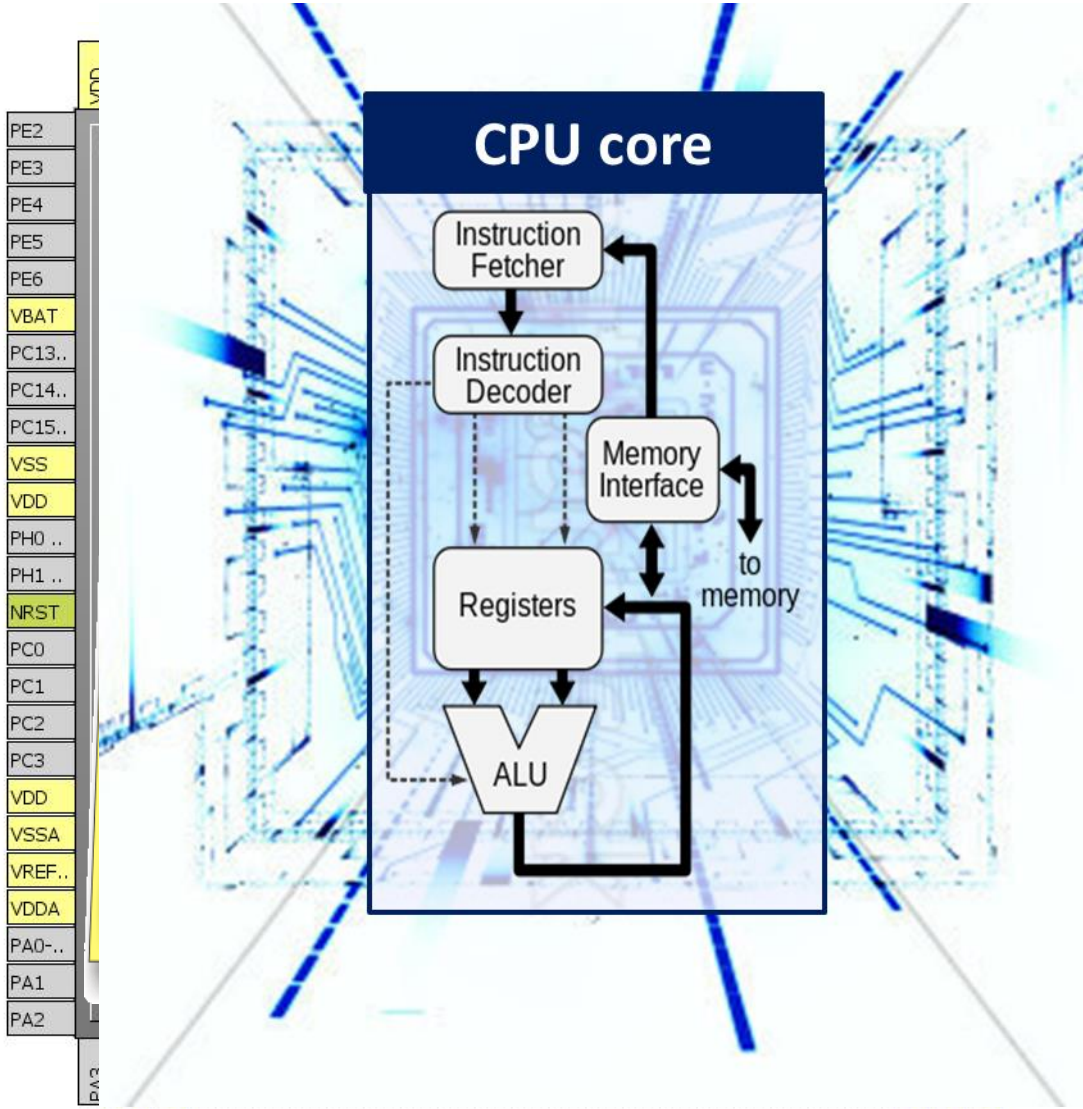




PIC 16F9887 Microcontroller (Microchip)

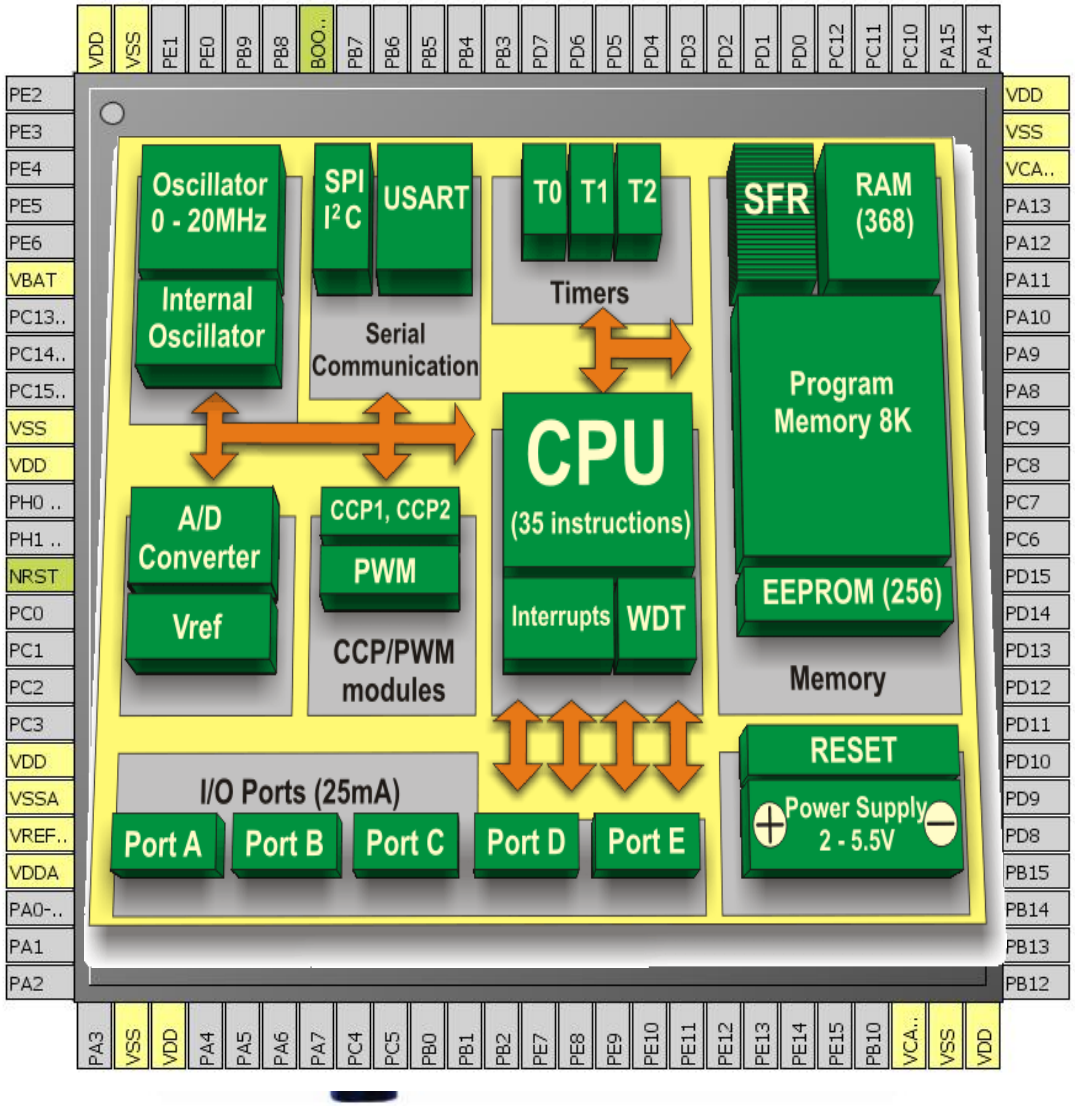
Microcontroller in perspective

- Inside the **processor core**
  - Registers (r0 to r15, status register etc)
  - ALU (Arithmetic Logic Unit)
  - Logic to fetch and decode instructions
  - Memory interface



Microcontroller in perspective

- Inside the **microcontroller**
  - The processor core
  - Memory (flash memory for program, SRAM for data)
  - Peripherals (Timers, GPIO ports, Serial ports, A/D)



Microcontroller in perspective

- On the **PCB** (printed circuit board)
  - Whatever the design calls for
  - External oscillator
  - External memory
  - Switches
  - Sensors
  - Connectors
  - User input (buttons, touchpad)
  - User display (LCD)
  - External A/D
  - FPGA
  - Other microcontrollers

Microcontrollers

- Microcontrollers come in all shapes and sizes
  - Tiny devices with basic, dedicated functions (remote control, temperature controller)
  - Larger devices with same computing capability as desktop PCs (Raspberry PI, multiple cores, integrated GPU)
- Choice of which microcontroller to use for a project is part of the design process
  - Trade-off requirements and constraints
- To OS or not to OS…

- What is an 'embedded system'?
  - a combination of a computer processor, computer memory, and input/output peripheral devices—**that has a dedicated function within a larger mechanical or electrical system**

- Daar is tans verskeie mikrobeheerders beskikbaar met variërende funksies en vermoëns

Start tinkering…

"If you're in college now, instead of going out and getting drunk with your friends, maybe take one night a week just to see if there's anything you want to work on personally."

- Marcin Kleczynski (founder of MalwareBytes antivirus software)