



UESTC1008: Microelectronic Systems

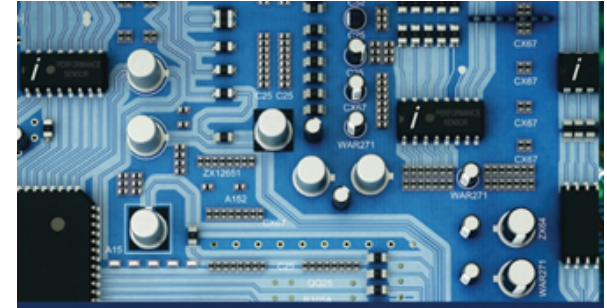
Academic year 2019/2020 – Semester 2 –Lecture 4

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“A good student never steals or cheats”

Agenda

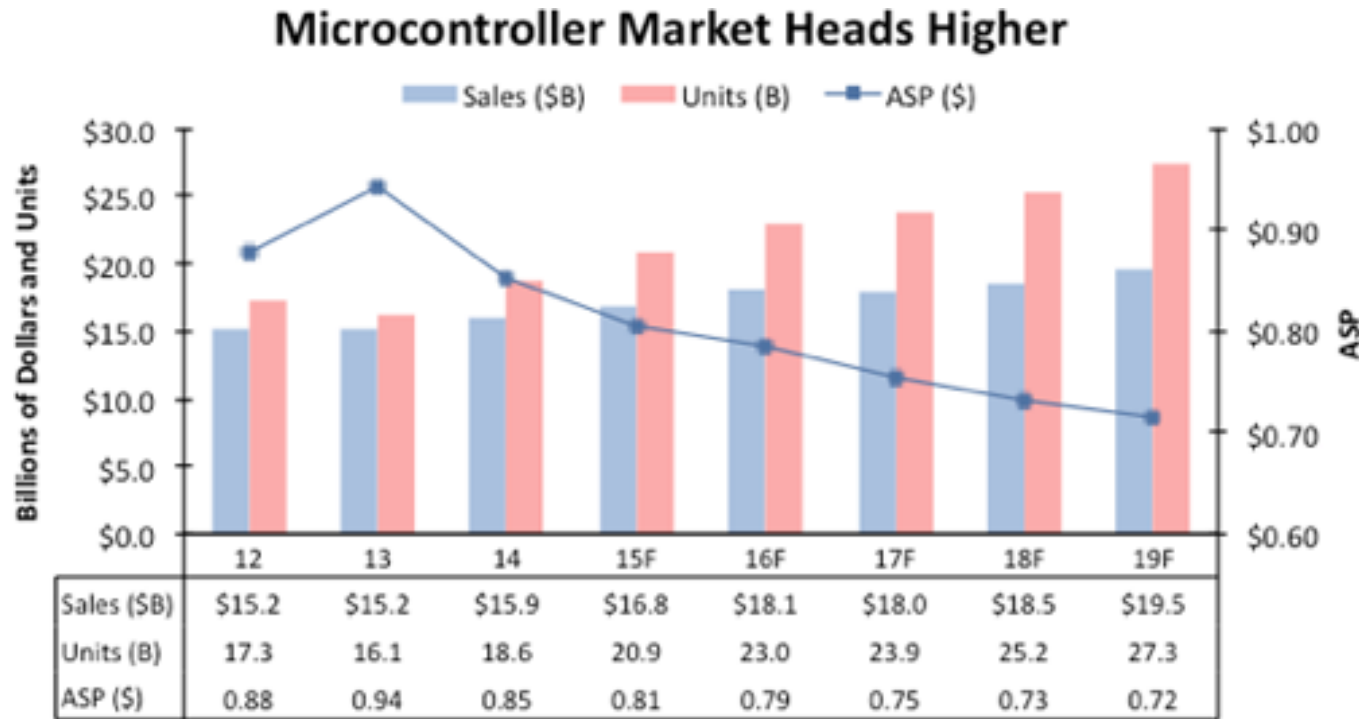
- Review of previous lecture
- Architecture
- Digital I/O
- Summary



Where to find microcontroller

- Personal information products: phone, pager, watch, pocket recorder, calculator
- Laptop components: mouse, keyboard, modem, fax card, sound card, battery charger
- Home appliances: door lock, alarm clock, thermostat, air conditioner, tv remote, hair dryer, VCR, small refrigerator, exercise equipment, washer/dryer, microwave oven
- Toys; video games, cars, dolls, etc.
- Usually anything with a keypad

Microcontroller market



Source: IC Insights

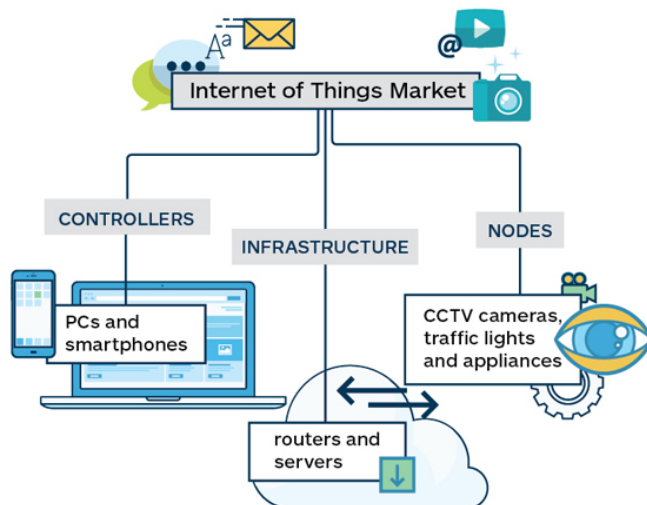
- \$15Bn to \$20Bn market
- Steady increase over time
- Drop in average selling price over time
- Market share (approx.)
 - 4 bit : 1%,
 - 8 bit 40%,
 - 16bit 20%,
 - 32bit 19%



Microcontroller Market Growth to Rise in Internet of Things Applications

What some still consider to be only a hype surrounding the emerging Internet of things (IoT) trends has already begun disrupting the microcontroller units (MCU) market

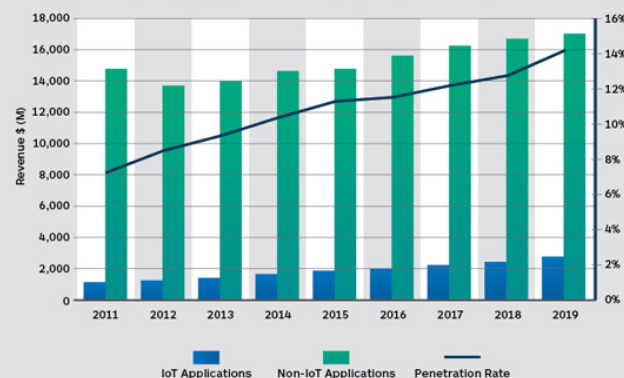
Tom Hackenberg
Senior analyst for IHS Technology



The IoT trend has a strong relationship with the MCU market, as the small nodes used for connectivity, and sensor hubs to collect and log data are primarily based on MCU platforms

The market for MCUs used in connected cars, wearable electronics, building automation and other IoT applications is expected to grow at an overall compound annual growth rate (CAGR) of 11%, from \$1.7 billion in 2014 to \$2.8 billion in 2019.

MCU market in IoT applications compared to markets outside of IoT

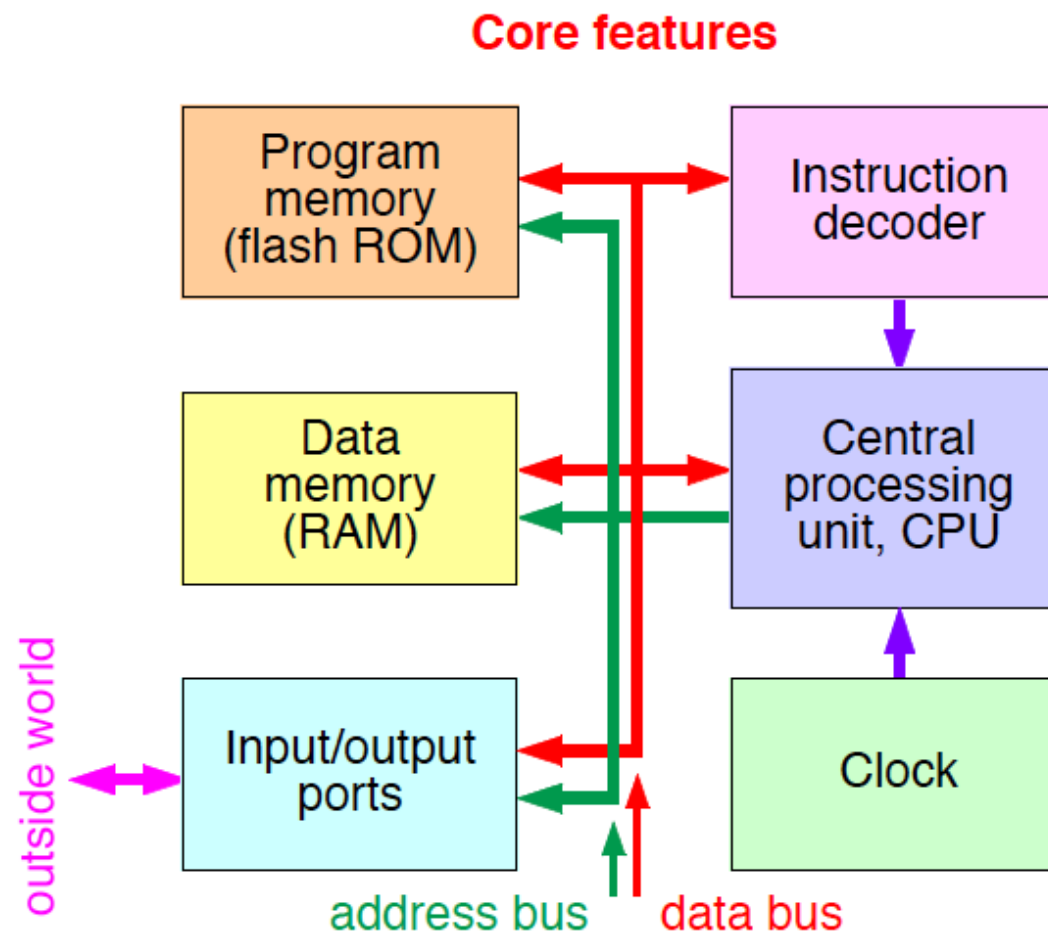


IoT connectivity demands a new consideration of semiconductor features. Many semiconductor companies have begun developing IoT platform solutions and among the semiconductor suppliers adopting IoT-focused strategies are: *Atmel Corporation, Broadcom, Cisco Systems Inc, Freescale Semiconductor, Infineon Technologies, Intel, Microchip Technologies, NXP, Qualcomm, Renesas Electronics Corporation and Texas Instruments.*

The microcontroller – a few more details

- **Clock** – keeps everything synchronised - 100 MHz for the mbed
- **CPU** – the heart of the micro – the ARM Cortex-M core in the mbed
- **Instruction decoder** – controls the chip, carries out actions for each instruction
- **Input/output ports** – serial, digital, analog, PWM etc
- **Memory** – program and data

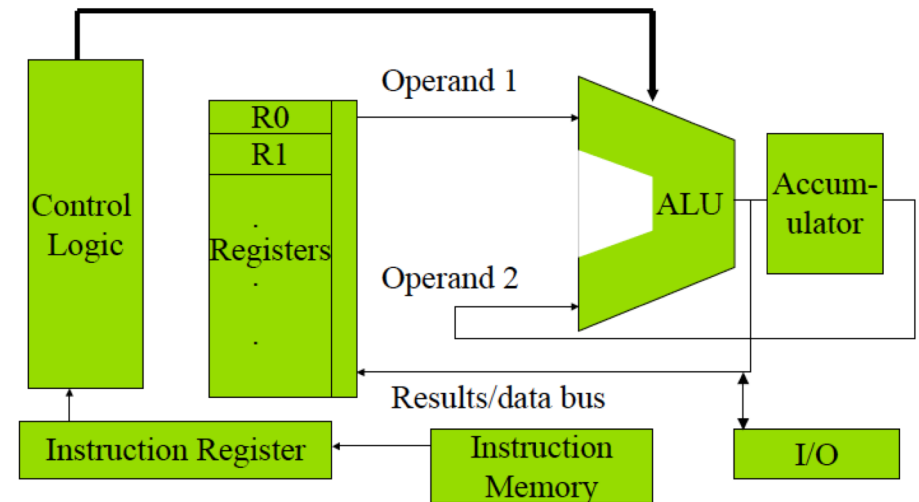
The microcontroller – a few more details



The **clock** keeps all parts synchronized.

The central processing unit

- ALU : Data manipulation
- Registers : Temporary storage of data to be manipulated
 - E.g. load number one in to register R0 from memory location yyy
 - Load number two into register R1 from memory location zzz
 - Add register R0 to R1 and put the result in R0
 - Output register R0 to memory



The program must break down your task into these simple operations

They can be calculated at GHz rates – so the system is powerful

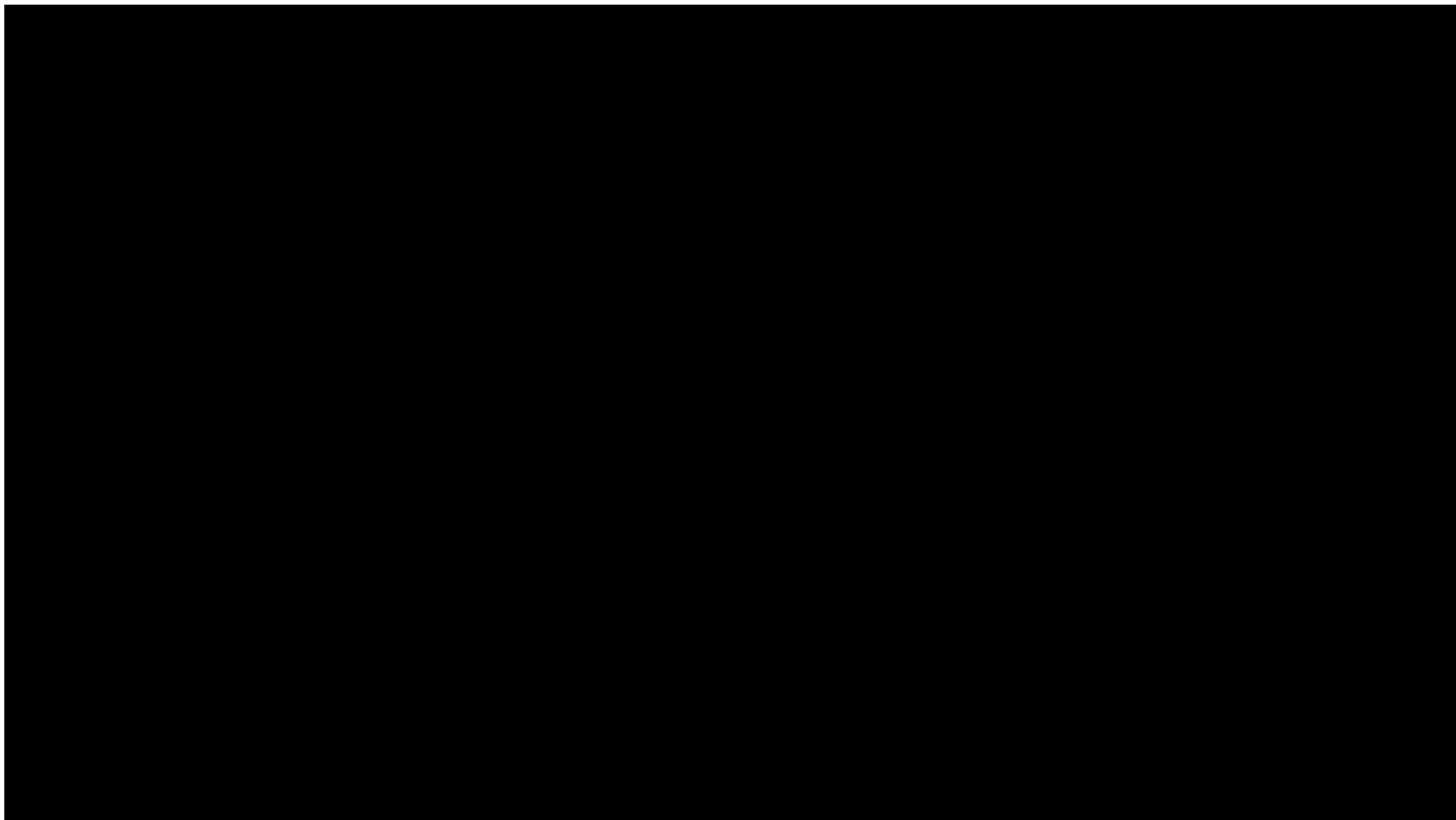
The instructions for the CPU

- Machine language
 - Fundamental basic instructions (instruction code)
 - 10000000 : Or 0x80 : Add register B to accumulator
 - Very easy to make mistakes, can be made optimum
- Assembly language
 - Mnemonics : ADD B
 - Machine specific instructions
- Programming language
 - + : but this also contains a fetch from memory, load into register B, fetch from memory and load into accumulator, add and then output accumulator to memory instructions
 - General, 'easy' to write, inefficient

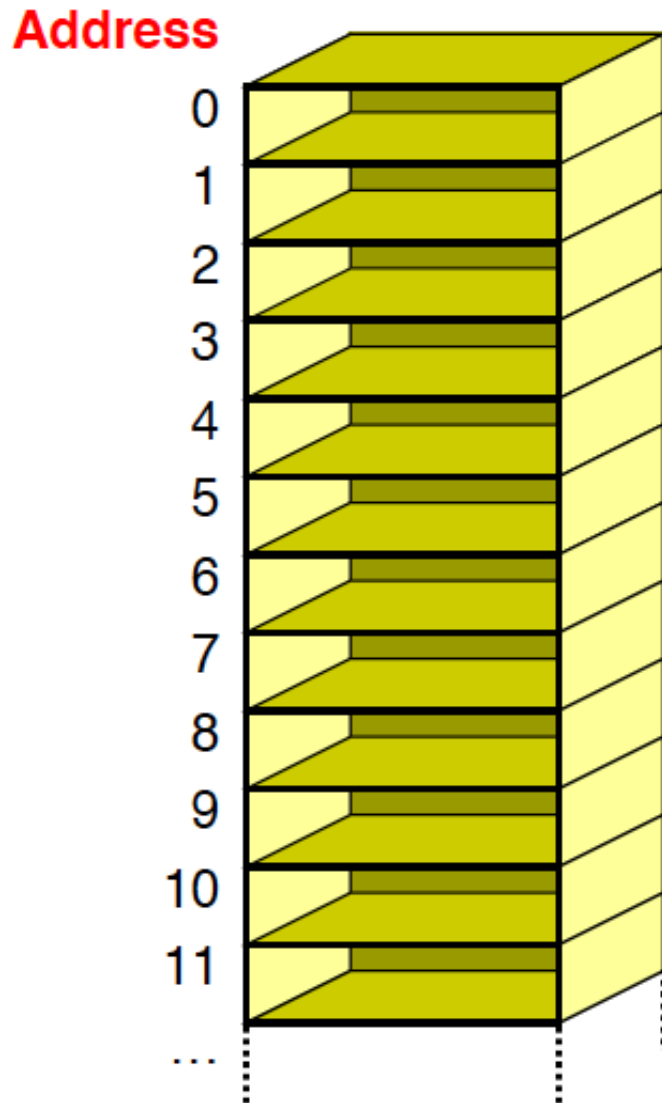
Numbers

- 8 bit unsigned integer number
 - 8 binary bits represent the number
 - E.g. 10011101 0x9D or 9DH
 - To deal with big numbers, simply break into blocks of 4 and convert to hex
- For I/O ports, hex has a bit more meaning than decimal
- Floating point numbers (float, etc.) more complex
 - $1.2345 = +12345 \times 10^{-4} = 12345E-4$
 - Stored as Sign bit, Exponent : 8 bits, Significand : 23bits= 32bit binary number (in IEEE 754 binary format)
 - Usually don't worry how they are stored, leave the compiler to do that for us
 - Be aware of the limitation i.e. the number of significant figures in the significand

Video for number conversion



Memory



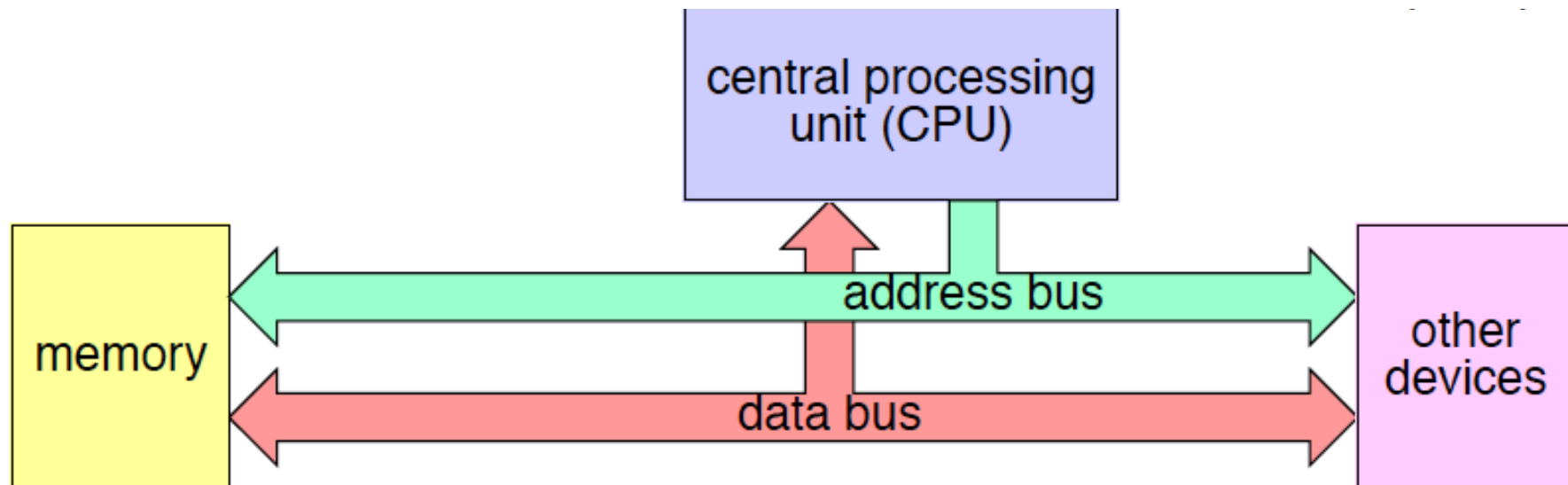
- **Memory** is just like a very tall stack.
- In the case of the mbed, each holds 32 bits.
- Each location is identified by its **address**, a serial number starting from 0. The address is said to **point to** a memory location.
- When a communication is made with memory to read or write a value, both the address and the data stored in the address must be handled.
- There may be distinct “stacks” for different types of memory.
- A memory location may be called a register, and is just like a set of 32 D-type flip-flops.

Communication with memory

Data is transferred between memory and the rest of the system on buses. These are shared sets of wires that join the components, like a multi-lane highway. In the case of the 32 bit μ C on the mbed, there are 32 parallel wires.

Several sets of these parallel wires are required :

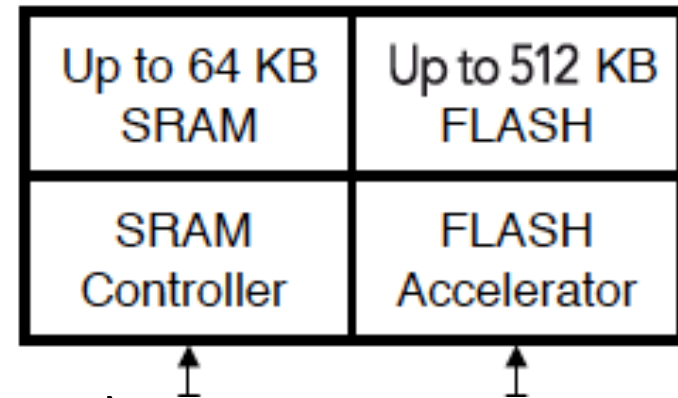
- Address bus – carries address (serial number) of the “mailtray”
- Data bus – carries the 32 bits either from the memory (read) or to the memory (write)
- Control lines are also needed to synchronise timing, select read/write, ensure that only one device tries to use the bus at once.



Memory Types

Microcontrollers have 2 types of memory

RAM – random access memory
- volatile – i.e., contents are lost when the power is removed
e.g., SRAM (static RAM – 6 transistors)



ROM - read only memory. Non-volatile – contents are retained even when power is removed. Modern ROM is flash memory.

Almost all memory in a PC is RAM. Each program must be read into RAM from non-volatile memory (hard disk) whenever it is needed. Similarly, the operating system is loaded into RAM when the system, is booted.

In contrast, microcontrollers execute only one program, which can be stored in ROM and is therefore available instantly.

Memory Architectures

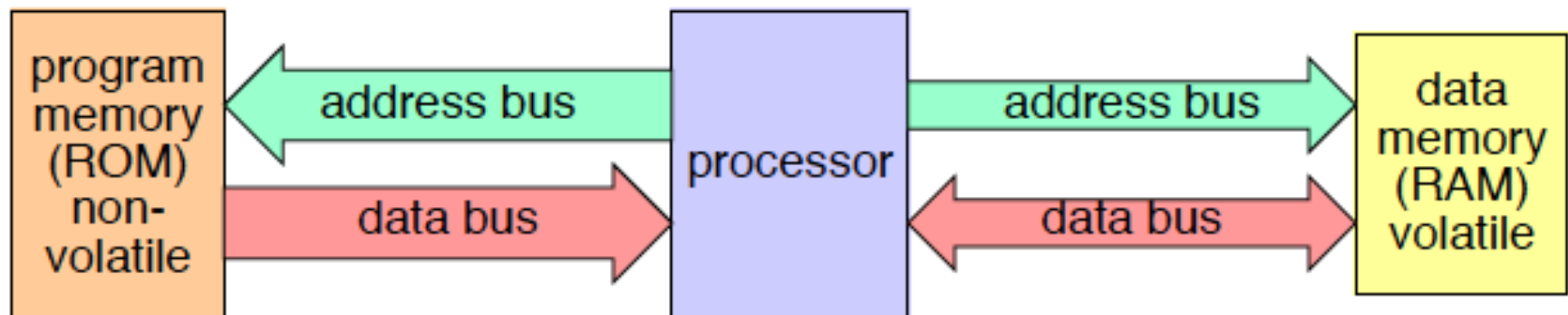
The two types of memory

- non-volatile ROM for program

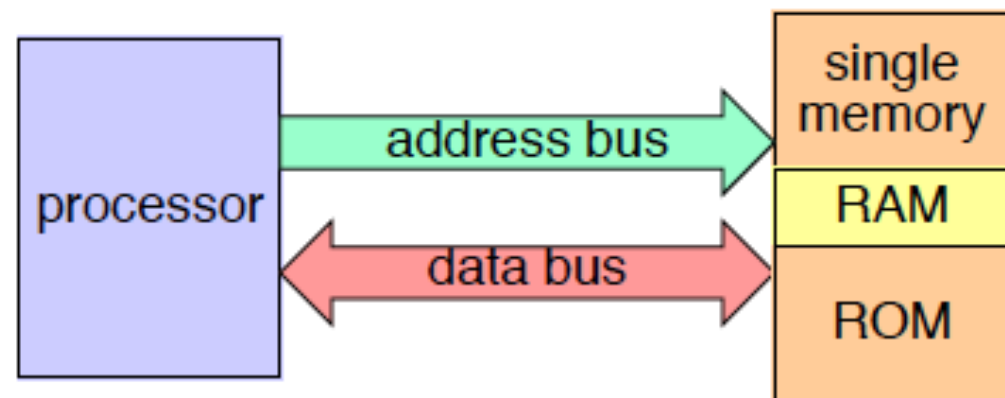
- volatile RAM for variables

Can be treated in two general ways

- two completely separate memory systems, each has its own data and address bus – this is the **Harvard** Architecture

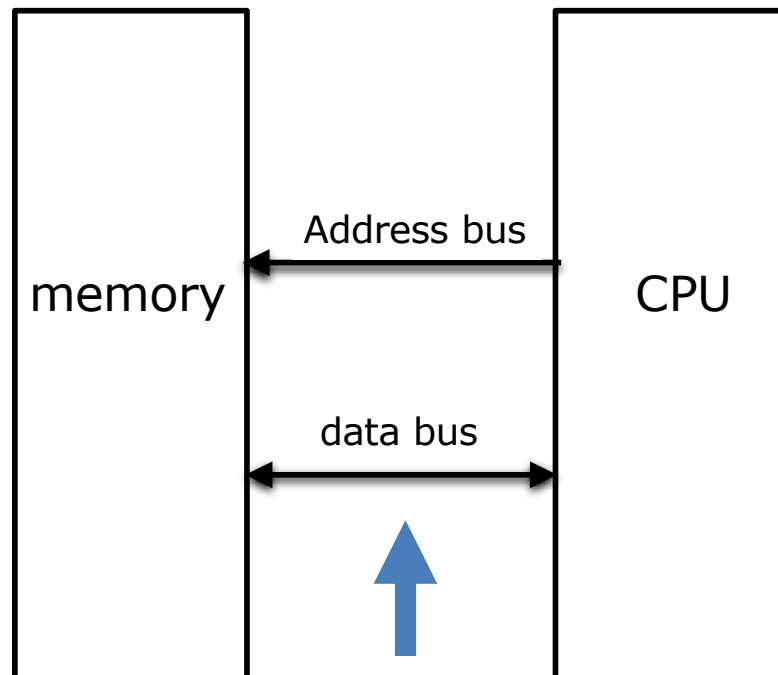


single memory system
– **von Neumann** (Princeton)
architecture



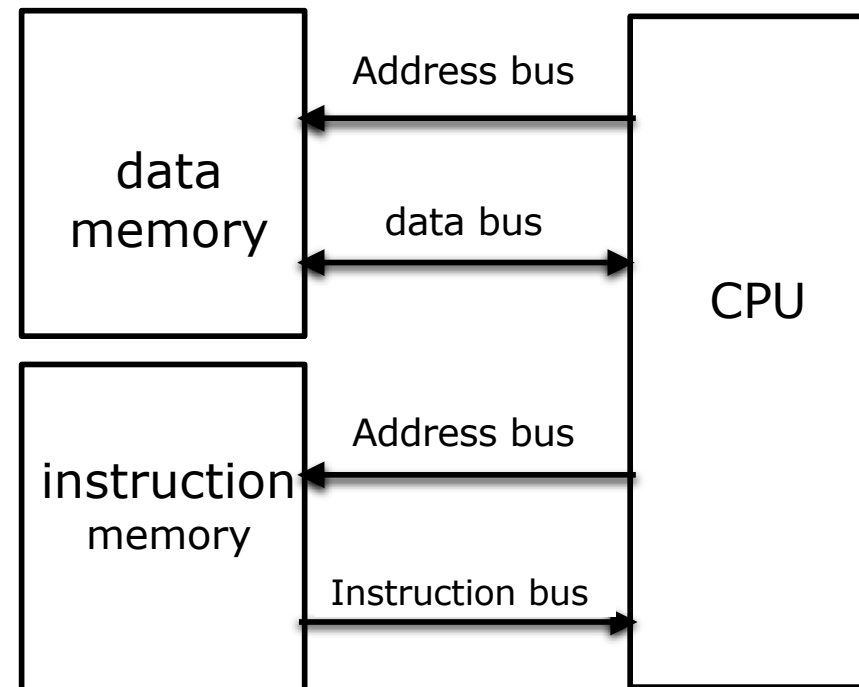
Von Neumann and Harvard Architecture

- Represent two different ways of exchanging data between CPU and memory



both instructions and data
go through here

Von Neumann Architecture



Harvard Architecture

Microcontroller vs Computer

Microcontroller is a computer but ...

Microcontroller

- Primary purpose is to control a system
- Input = analog/digital signals
- Output = analog/digital signals
- Event or Command driven
 - Response is due to either a change in the input or data entered by person, autonomous systems rely on only sensors
- Reactive
 - physical world in the loop
- As fast as needed

General Purpose Computer

- Primary purpose is to perform calculations and run programs
- Input = keyboard, game console, etc.
- Output = display, monitor
- Command driven
 - Response is due to data entered by someone
- Reactive
 - human-in-the-loop
- As fast as possible

Summary

- Architecture
- What will we study in next lecture.
- Digital I/O