COMP 2401/2001 – day 3

Today's agenda

- Bits and bytes
  - bits...
  - nybbles and bytes...
  - data
-

Bits and Bytes

- What is a bit?
  - a **bi**nary digi**t**, or bit, is the basic unit of information in a computer
  - we generally think of 0s and 1s (abstraction)
- Physical bits...
  - voltage, electrical state of a flip-flop
  - polarization of light
  - direction of magnetic dipole
  - anything with two measurable "states"

Bits and Bytes

- a **bit** is our abstract basic (atomic) unit of information
- a **byte** is 8 bits
- a **nybble** is 4 bits
  - or ½ of a byte
- a **word** is a basic unit of data
  - more on this soon...

Data

- What does 10011100 mean?

Data

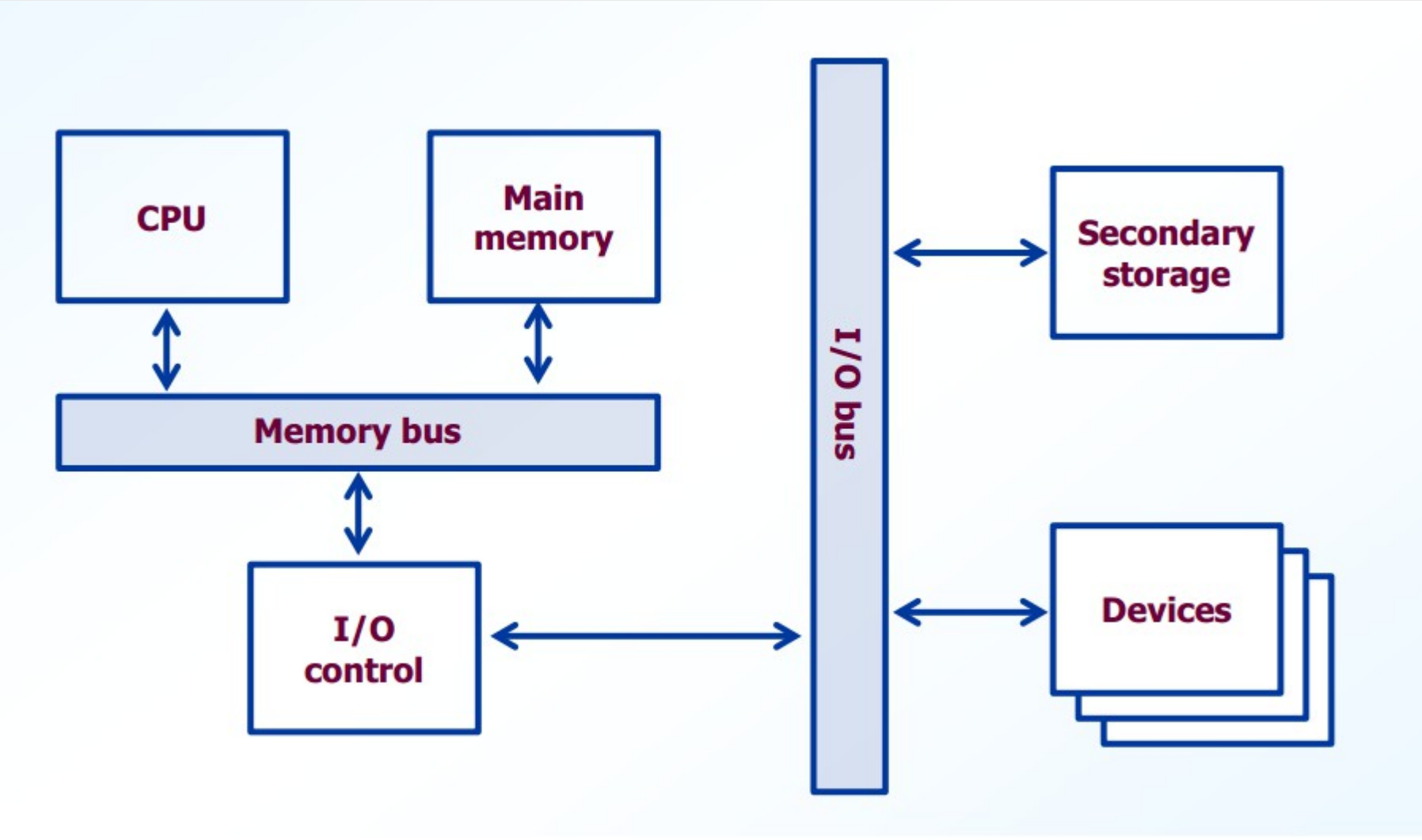
- What does 10011100 mean?
- Unfair question!

  it can mean whatever I want it to mean
- Need to have a proper context
  - need a bit model [Hoover, 2.1]

Data

- What does 10011100 mean?
- 15th episode of season one of Star Trek TNG

Basic Machine Architecture



Basic Machine Architecture

- CPU ~ Central Processing Unit
- Main memory ~ RAM
- Bus ~ data is moved around via buses
  - modern computers use typically have
    - 32-bit width
    - 64-bit width
- word size, register size, memory limits are typically related to bus width

Basic Machine Architecture

Basic Machine Architecture

- ALU ~ arithmetic logic unit (brains/calculator)
  - performs computations
- control unit ~ (boss)
  - reads instructions
  - directs everything
- registers ~ **FAST** memory
  - computations use register memory only
  - typically 32 or 64 registers

Bit models

- back to 10011100...
- unsigned integers
  - magnitude only
- signed integers
  - sign-magnitude
  - one's complement (skip this)
  - two's complement

Unsigned integers

- non-negative integer types
- express numbers as a sum of powers of 2
  - $17 = \mathbf{1}*2^4 + \mathbf{0}*2^3 + \mathbf{0}*2^2 + \mathbf{0}*2^1 + \mathbf{1}*2^0$.
  - bits are placeholders for binary digits in base 2
  - $17 \rightarrow 10001$

  - $10011100 \rightarrow 1*2^7 + 1*2^4 + 1*2^3 + 1*2^2$
    $= 128 + 16 + 8 + 4$
    $= 156$

Unsigned integers

- express numbers as a sum of powers of 2
  - $17 = \mathbf{1}*2^4 + \mathbf{0}*2^3 + \mathbf{0}*2^2 + \mathbf{0}*2^1 + \mathbf{1}*2^0$.
  - $\longrightarrow$ 10001
- Order matters
  - rightmost bit is least significant bits (LSB)
  - leftmost bit is most significant bits (MSB)
  - read right-to-left $\longrightarrow$ increasing significance of bit

Unsigned integers

- Decimal to binary
  - find biggest power of 2 that is <= number (say 2^k)
    k-th bit is a 1
    subtract 2^k from number and repeat
- Binary to decimal
  - write out the sum of powers of two
  - do the addition

Unsigned integers

- Binary addition
  - same as decimal addition
  - add digits from right to left
  - carry to next bit when needed
    - decimal: 9 + 2 = 11
    - binary: 01 + 01 = 10

Unsigned integers

- range of numbers
- how many numbers can 1 nybble represent?
- how many numbers can 1 byte represent?
- how many numbers can 4 bytes represent?

Unsigned integers

- range of numbers
- how many numbers can 1 nybble represent?
- how many numbers can 1 byte represent?
- how many numbers can 4 bytes represent?
  - from 0 to $\Sigma\ 2^k$ (k=0..31) $= 2^{32} - 1 = 4{,}294{,}967{,}295$

    (4 gigabits)

Unsigned integers

- range of numbers
- what if we want/need bigger numbers?
  - unsigned
  - short int <= int <= long int <= long long int
  - software libraries for multiprecision integers

Unsigned integers

- C data types that use magnitude only bit model:
  - unsigned char
  - unsigned int
  - unsigned short int
  - unsigned long int
  - etc.

Signed integers

- How do we handle sign?
- Different bit models
  - sign-magnitude
  - one's complement
  - two's complement

Signed integers

- sign-magnitude
  - MSB is used for the sign of the number
    - 0 ~ positive
    - 1 ~ negative
  - any problems with this?