COMP310: Legacy Game Systems

1: Assembly language

Learning outcomes

- **Explain** the historical significance of the 6502 CPU
- **Identify** the key components of the 6502 architecture
- **Read** and **write** simple programs in 6502 assembly language

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Module introduction

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  - Requires creative **problem solving**
  - Makes you a **better programmer**

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- Your de-make must run on the **NES** and be written in **6502 assembly**
- **In week 3**: present a **proposal** and **Trello board**
- **Tip**: scope carefully! Assembly programming is hard — keep it simple

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Assignment 2: Research Journal

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- Deadline is in just over **2 weeks**!

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The 6502 CPU architecture

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- Still in production **today**

Uses of the 6502

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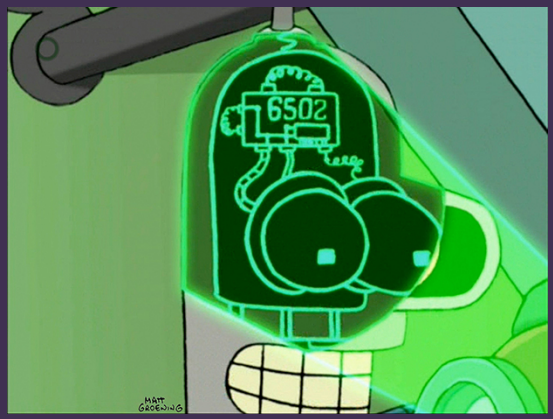

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Hex	Dec	Hex	Dec	Hex	Dec
00	0	10	16	F0	240
01	1	11	17	F1	241
⋮	⋮	⋮	⋮	⋮	⋮
09	9	19	25	F9	249
0A	10	1A	26	FA	250
0B	11	1B	27	FB	251
0C	12	1C	28	FC	252
0D	13	1D	29	FD	253
0E	14	1E	30	FE	254
0F	15	1F	31	FF	255

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- The **program counter (PC)** register stores the address of the next instruction to execute

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- PC = **program counter** register (16 bits)
- **Status** register, composed of seven 1-bit **flags**

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- Translates **directly** to machine code
- I.e. 1 line of assembly = 1 CPU instruction
- An **assembler** translates assembly to machine code
  - I.e. an assembler is a "compiler" for assembly language
- Each CPU architecture has its own instruction set therefore its own assembly language

Our first assembly program

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```
LDA #$01
STA $0200
LDA #$05
STA $0201
LDA #$08
STA $0202
```

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Try it out! `http://skilldrick.github.io/easy6502/`

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- Store the value `01` (hexadecimal) into register A
- **`LDA`** ("load accumulator") stores a value in register A
- `#` denotes a literal number (as opposed to a memory address)
- `$` denotes hexadecimal notation

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- Note that address is a **16-bit** number (2 bytes, 4 hex digits)

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STA $0200
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- Write the value of register A into memory address `0200` (hex)
- `STA` ("store accumulator") copies the value of register A into main memory
- Note that address is a **16-bit** number (2 bytes, 4 hex digits)
- In this emulator the display is "memory mapped", with 1 byte per pixel, starting from address `0200`
  - This may **not** be the case on other 6502-based systems!

Assembly to machine code

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A9 01
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A9 05
8D 01 02
A9 08
8D 02 02
```

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Note that the 6502 is **little endian**

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Note that the 6502 is **little endian**

- In 16-bit values, the "high" byte comes before the "low" byte
- Intel x86 is also little endian

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- Some instructions **modify** the PC
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```
INC $0200 ; add 1 to the value at address 0200
JMP $0600 ; jump back to beginning of program
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- In this emulator the program always starts at address `0600`
  - This may **not** be the case on other 6502-based systems!

Labels

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start:
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```
start:
    INC $0200
    JMP start
```

- `start` is essentially a constant with value `$0600`
- The assembled code is exactly the same as for the previous slide

Conditional branching

Conditional branching

```
  LDX #$08        ; set X=8
decrement:
  DEX             ; subtract 1 from X
  STX $0200       ; store X in top left pixel
  CPX #$03        ; compare X to 3
  BNE decrement   ; if not equal, jump
  STX $0201       ; store X in next pixel
  BRK             ; halt execution
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```

$X = 8$
do
    $X = X - 1$
    memory[0200] $= X$
while $X \neq 3$
memory[0201] $= X$

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- Assembly language does not have **structured programming** constructs such as if/else, switch/case, for, while, etc.
- However all of these can be implemented using branch instructions
- ... which is exactly how compilers implement them

Subroutines

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- `RTS` (return from subroutine) jumps back to the instruction after the `JSR`
- These are used to implement **function calls**

Addressing modes

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- That `#` makes a big difference!

Addressing modes

- Immediate: `LDA #$42`
  - Load the literal value 42 (hex) into register A
- Absolute: `LDA $42`
  - Load the value stored at memory address 42 (hex) into register A
- That `#` makes a big difference!
- Note that these actually assemble to **different** CPU instructions

Indexed addressing

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LDA $0200,X
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- Look up the value stored at memory address

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Indexed addressing

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LDA $0200,X
```

- Look up the value stored at memory address

  $0200 + (\text{value of X register})$

  and store it in A
- Can also do `LDA $0200,Y`
- ... but **only** `X` and `Y` registers can be used for indexed addressing

Indexed addressing

```
  LDX #0        ; X=0
loop:
  TXA           ; A=X
  STA $0200,X   ; store A to 0200+X
  INX           ; X++
  JMP loop      ; loop forever
```

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- Why does it stop $\frac{1}{4}$ of the way down?

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- Why does it stop $\frac{1}{4}$ of the way down?
- Hint: it stops after filling 256 pixels...

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- **Understand** and try to **modify** the Snake game code