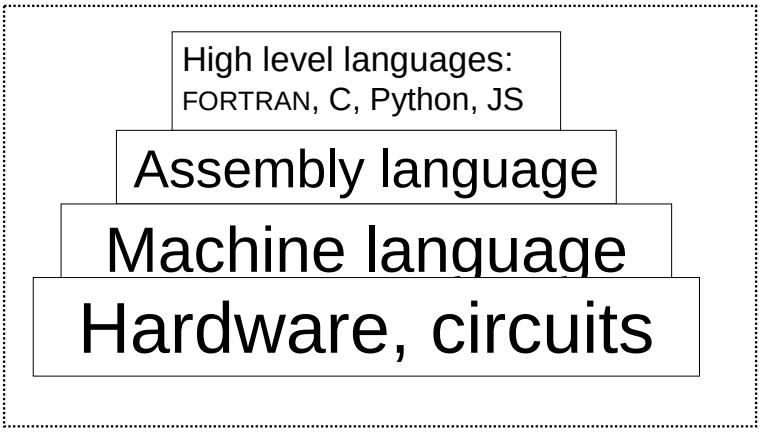
The CPU & Computer Architecture

CSC 103

September 26, 2007

Hierarchy of Languages

- The process for people (natural languages) to communicate with computers:



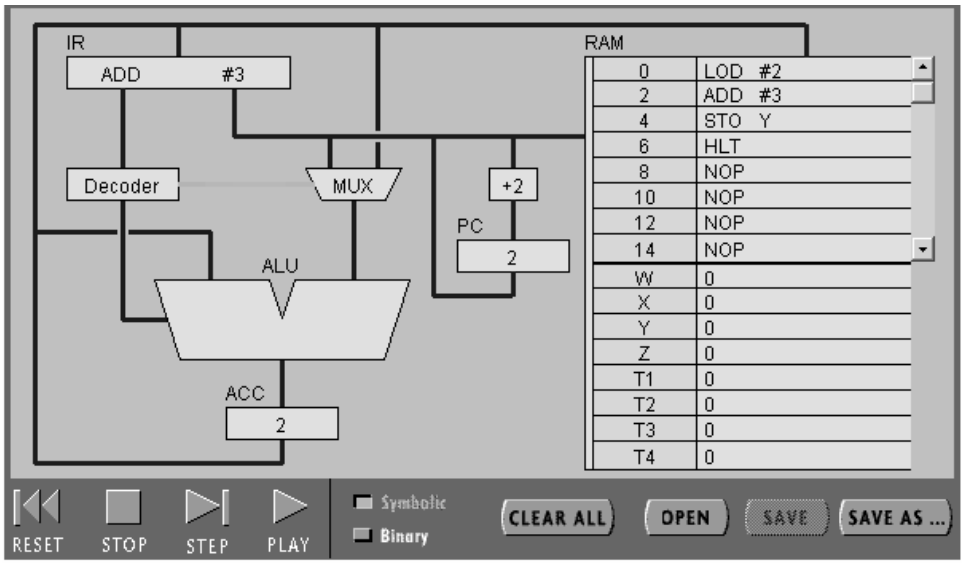
Overview for Today

- The CPU – central processing unit
  - Elements of the CPU
  - Fetch-execute cycle
- Decoder circuit
  - Interpreting instruction codes (opcode)
- Assembly Language
  - Types of instructions
  - Instruction structure
    - Opcode and operand

Assembly Language

- To perform 2 + 3 = 5 :
  - LOD #2 = load #2 into the CPU
  - ADD #3 = add #3 to whatever is there
  - STO Y = store the result to ‘Y’
  - HLT = stop!
- Fetch and then execute

Components of the CPU (Pippin)

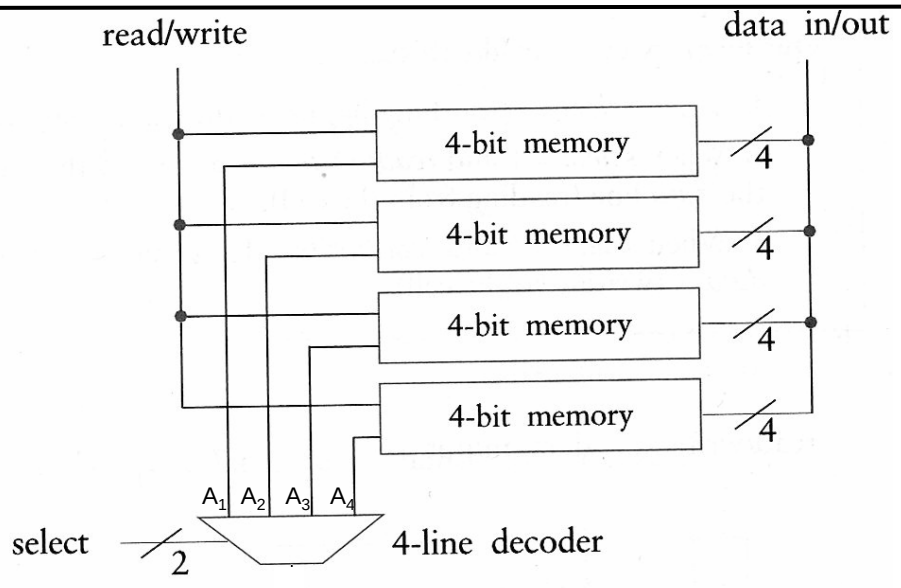


Assembly Language

- Our example must be written in simple steps
  - LOD #2 = 0001 0100 0000 0010
  - ADD #3 = 0001 0000 0000 0011
  - STO Y = 0000 0101 1000 0010
  - HLT = 0000 1111 0000 0000
- How are these instructions decoded by the CPU?

Understanding How Opcodes Work → Decoder Circuits

Memory: RAM & Registers

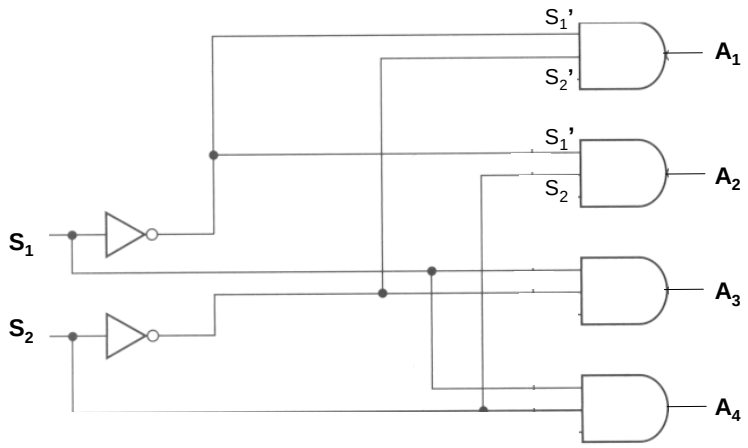


Control Circuit: Decoder

- RAM Address; Decode instruction
- Truth Table of a 2-to-4-Line Decoder

Inputs		Outputs			
S_1	S_2	A_1	A_2	A_3	A_4
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1

Inputs		Outputs			
S_1	S_2	A_1	A_2	A_3	A_4
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1



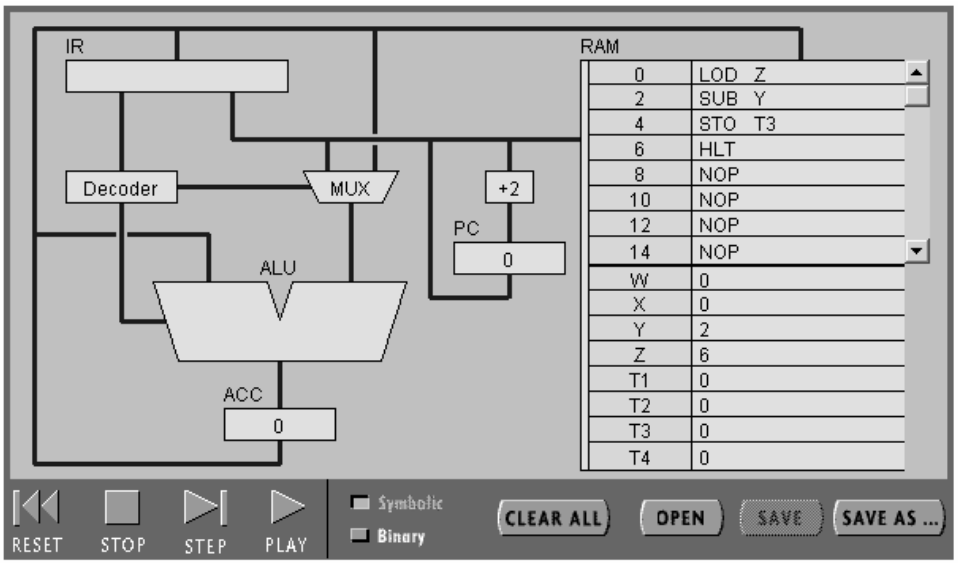
Control Circuit: Decoder

- To decode Pippin instructions

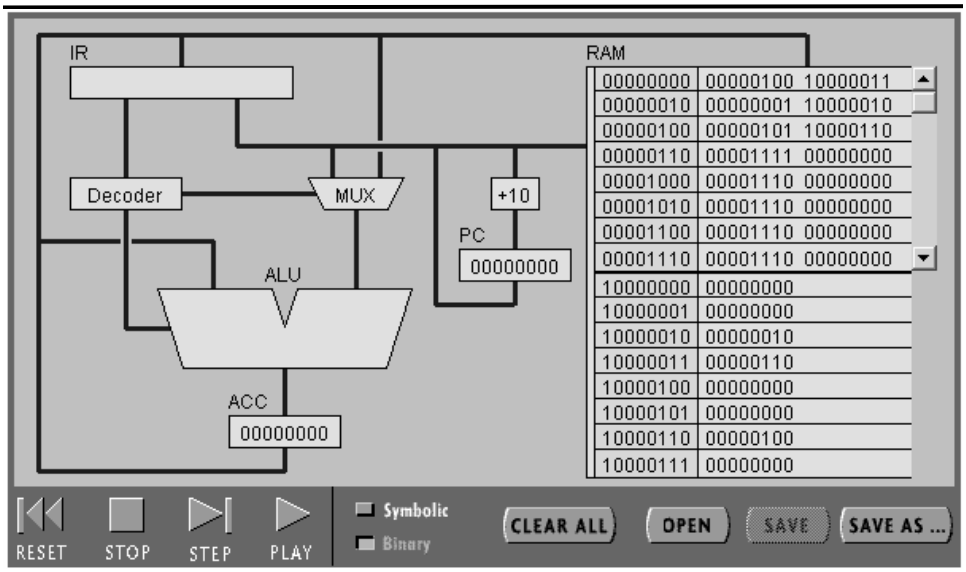
	Inputs	Instruction Line High
	$C_1\ C_2\ C_3\ C_4$	$I_1\ I_2\ I_3\ I_4\ I_5\ I_6\ I_7\ I_8\ I_9 \ldots$
– ADD:	0 0 0 0	1 0 0 0 0 0 0 0 0
– SUB:	0 0 0 1	0 1 0 0 0 0 0 0 0
– MUL:	0 0 1 0	0 0 1 0 0 0 0 0 0
– DIV:	0 0 1 1	0 0 0 1 0 0 0 0 0
– LOD:	0 1 0 0	0 0 0 0 1 0 0 0 0
– STO:	0 1 0 1	0 0 0 0 0 1 0 0 0

http://maven.smith.edu/~jcardell/courses/CSC103/PIPPINGuide.html

The CPU (Pippin)



The CPU (Pippin)



What a Computer Does:
The CPU &
‘Fetch-Execute’

Assembly Language

- To perform 2 + 3 = 5 :

  (…fetch and then execute)

  – LOD #2 = 0001 0100 0000 0010
  – ADD #3 = 0001 0000 0000 0011
  – STO Y = 0000 0101 1000 0010
  – HLT = 0000 1111 0000 0000

- The ‘operands’
  – Immediate mode, data follows: #2, #3
  – Direct addressing, data in RAM: Y

Binary Code Assignments for PIPPIN

- Load = LOD = 0001 0100 (data follows)
  = 0000 0100 (data in RAM)
- Add = ADD = 0001 0000 (data follows)
  = 0000 0000 (data in RAM)
- Store = STO = 0000 0101 (location follows)
- Halt = HLT = 0000 1111 (no data)

- Punch cards/Binary ⇨ Assembly ⇨ High level language
- See the handout and webpage link for full PIPPIN ‘instruction set’

Program Control

Computer Programs

- A computer computes: it manipulates symbols
  - The symbols are always binary data
- We must tell the computer everything
  - Where the data is
  - What the data is (instructions vs. operand)
  - What to do with the data

Computer Programs

- Sequential – start at the beginning and methodically execute instructions until done

  (Our examples so far are sequential)

or

- Repeat sections; jump over parts... ⇨ ***Program control***

Program Control

- *Decisions*: If-else
- *Repeat*: Loops

- On-line shopping
  - Repeat: "Continue shopping?"
  - Decision: "Or proceed to checkout?"
- Setting preferences
  - No beeping sounds? Many sounds?
  - Left- or right-handed mouse

Instruction Categories

- **Three categories** of instructions
  - Data flow – load and store
  - Arithmetic-logic – math, logic including compare
  - **Control – jump, halt, nop**
- New instructions
  - JMP n – go to instruction number ***n***
  - JMZ n – If Acc=0, goto instruction ***n***, else to go instruction immediately following
  - CPZ X – (compare zero) If X=0, set Acc to 1; else set Acc to 0
  - CPL X – (compare less) If X<0, set Acc to 1; else set Acc to 0

If-Else in Assembly

- Let 'X' represent the result from pulling the handle of a slot machine
  - X = 0 means you did not get 4-of-kind...
  - X ≠ 0 means you got a winning hand

```
if (X = 0)
        W = 0        // your winnings=0
else
        W = 100   // you win!!!
```

If-Else: If (X = 0)

```
0   LOD X     Useful to write out below:
2   CPZ X         if X=0, Acc=1, else Acc=0
4   JMZ ?         if Acc=0, goto 12
```

Note: Line numbers – we need to keep track of them to know what line to jump to with the 'JMZ' instruction

If-Else: Then W = 0

```
6   LOD #0
8   STO W
10  HLT
```

Don't forget to 'HLT' at the end of this branch (we do not want to execute both branches, only one)

If-Else: Else W = 100

```
12   LOD #100
14   STO W
16   HLT
```

Note: The ‘then’ *branch went to line* 10, *so we start the* ‘else’ *branch at line 12* ⇨
This is the line we jump (JMZ) *to*

Don’t forget to ‘HLT’

Complete If-Else Program

```
0   LOD X      Useful to write out below:
2   CPZ X          if X=0, Acc=1, else Acc=0
4   JMZ 12         if Acc=0, goto 12
6   LOD #0
8   STO W
10  HLT
12  LOD #100
14  STO W
16  HLT
```

The Pippin Simulator

http://www.science.smith.edu/~jcardell/Courses/CSC103/CPUsim/cpusim.html

Things to Remember

- The role of the accumulator
  - The result of the compare is stored in the accumulator
  - The jump occurs based on the accumulator
- Line numbers
  - Write out program FIRST to work out line numbers
- HLT
  - Do not forget the 'HLT' after the '*if*' branch and after the '*else*' branch

Summary

- The CPU
  - The fetch-execute cycle
  - The Pippin CPU simulator
- Programming Control
  - If-then statements
    - Using ‘compare’ and ‘jump’ for computer decision making