Teaching London Computing

CAS London CPD Day 2016

Little Man Computer

Queen Mary University of London

King's College London

COMPUTING AT SCHOOL
EDUCATE · ENGAGE · ENCOURAGE

Department for Education

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NETWORK OF EXCELLENCE COMPUTER SCIENCE TEACHING
UNIVERSITY PARTNER

William Marsh
School of Electronic Engineering and Computer Science
Queen Mary University of London

Overview and Aims

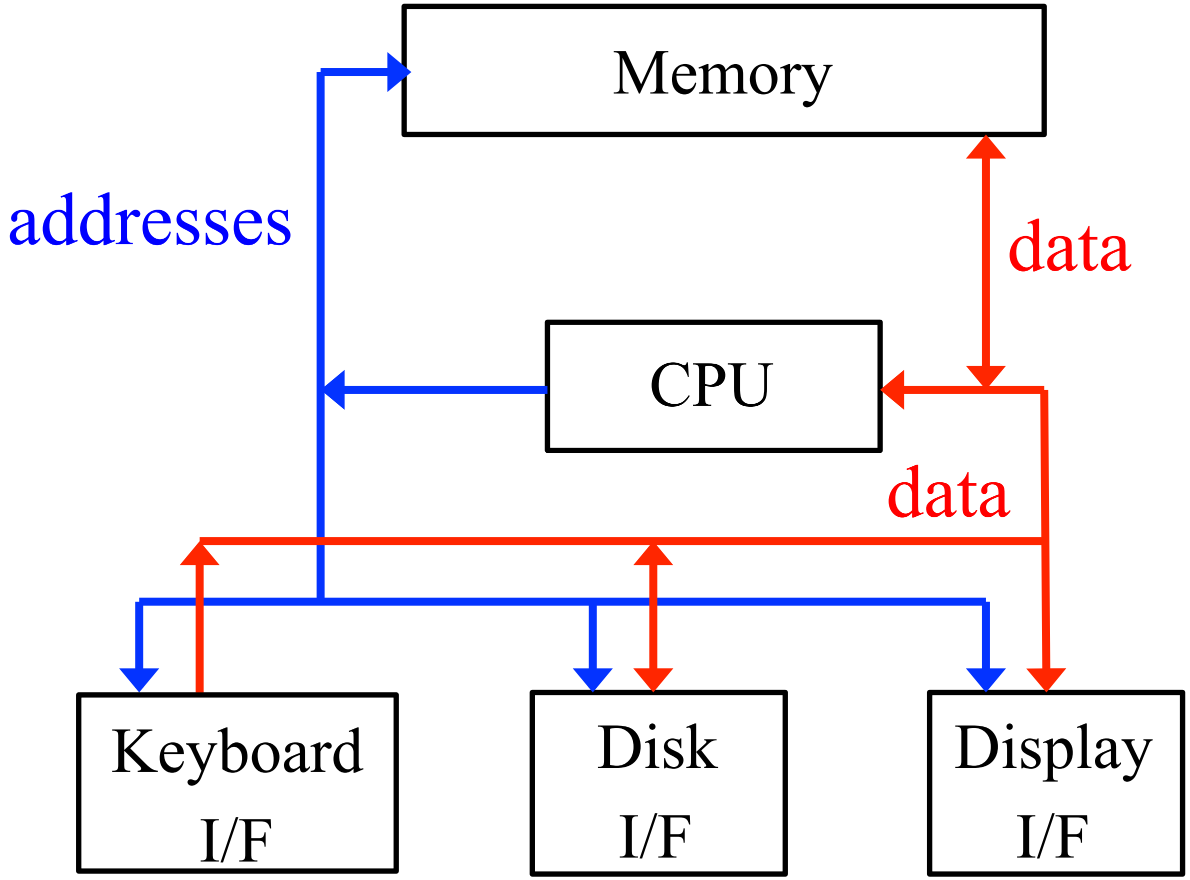
- LMC is a computer simulator
  - … understanding how a computer work
- To program the LMC, must understand:
  - Memory addresses
  - Instructions
  - Fetch-execute cycle
- *Practical exercises*
- What we can learn from LMC

What is in a Computer?

- Memory
- CPU
- I/O

Simple Computer

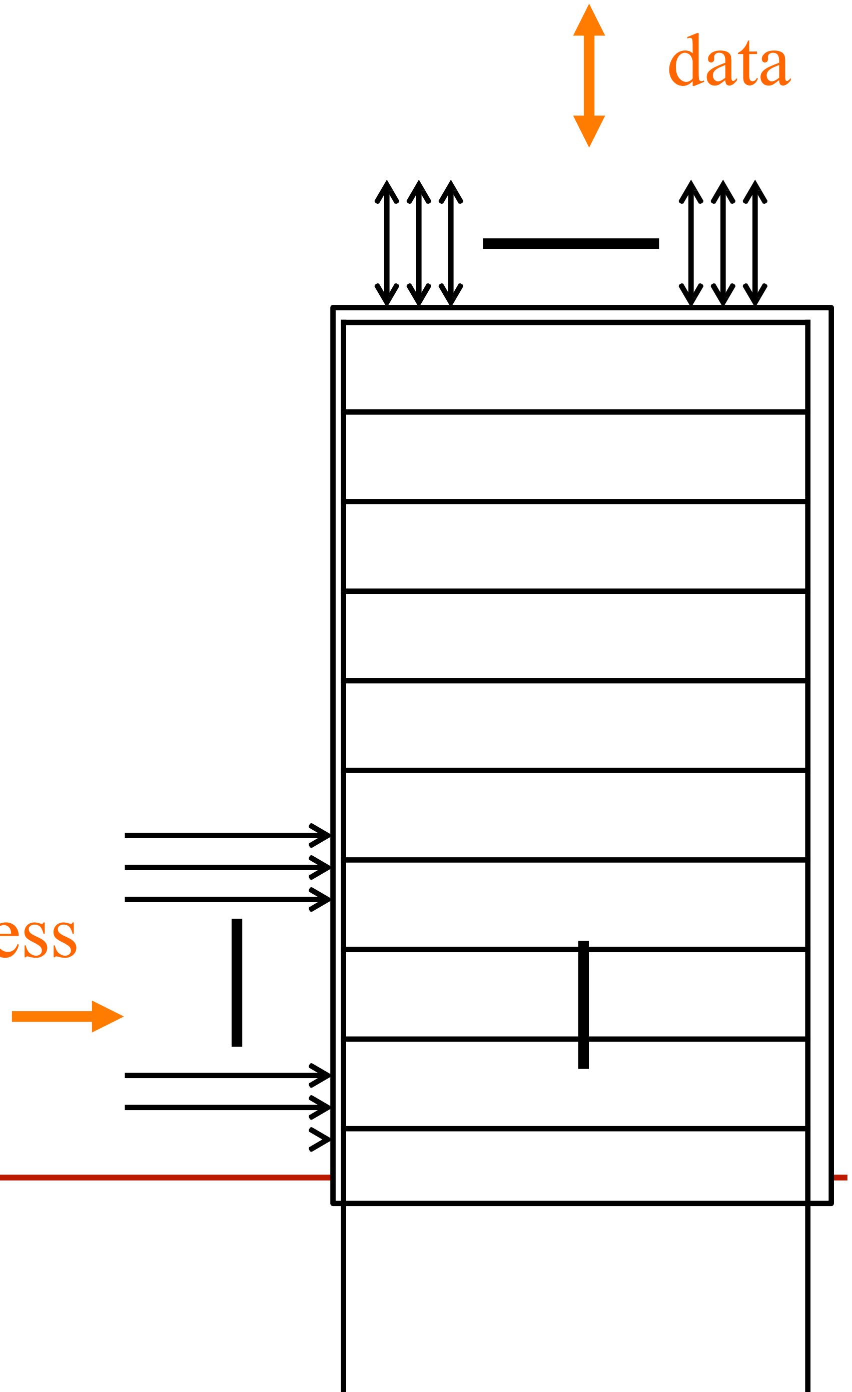
- Processor
  - CPU
- Memory
  - Data
  - Program instructions
- I/O
  - Keyboard
  - Display
  - Disk



Memory

- Each location
  - has an address
  - hold a value

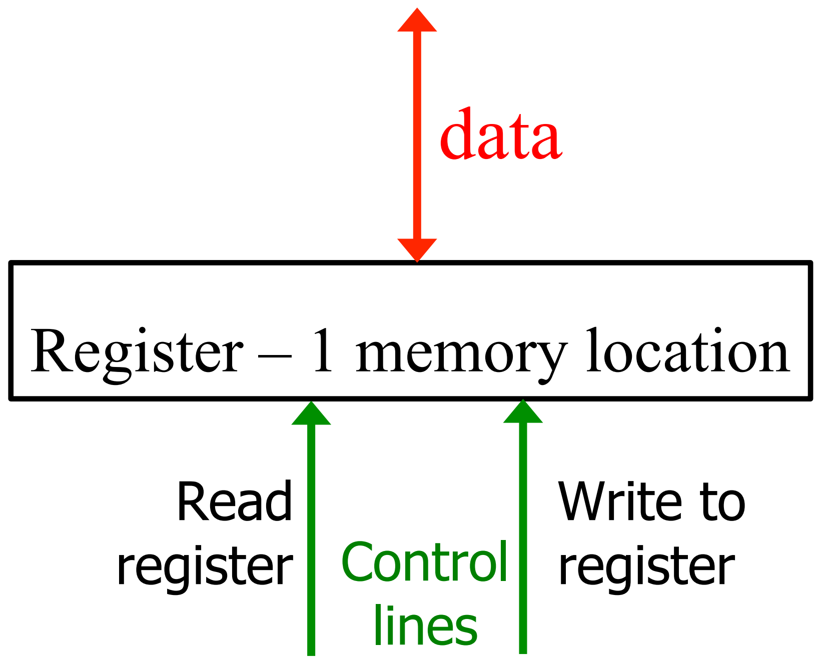
- Two interfaces
  - address – which location?
  - data – what value?

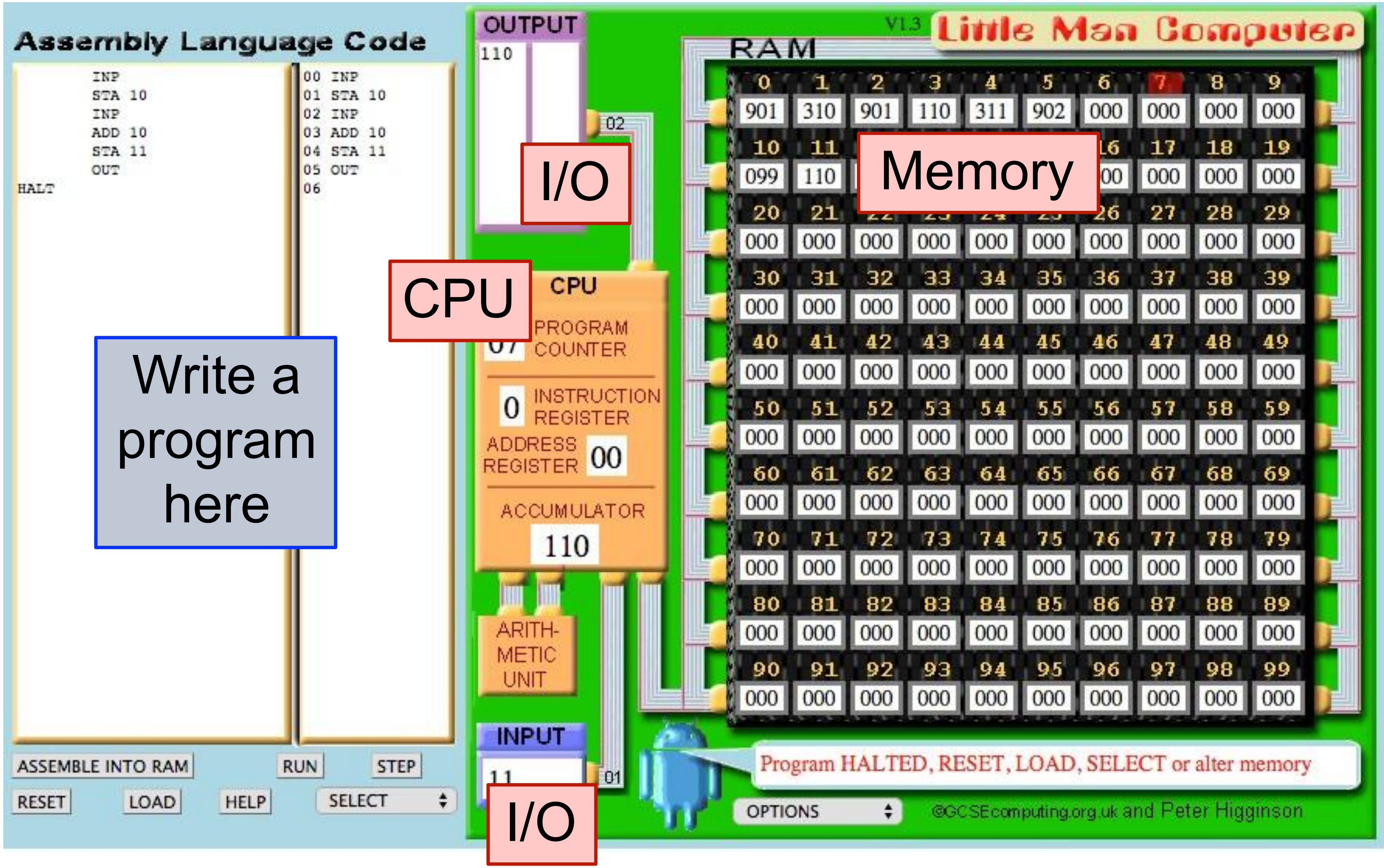


Quiz – What is the Memory?

Registers (or Accumulators)

- A storage area inside the CPU
- VERY FAST
- Used for arguments and results to one calculation step




Assembly Language Code
INP
STA 10
INP
ADD 10
STA 11
OUT
HALT
00 INP
01 STA 10
02 INP
03 ADD 10
04 STA 11
05 OUT
06
Write a program here
ASSEMBLE INTO RAM
RUN
STEP
RESET
LOAD
HELP
SELECT
OUTPUT
110
I/O
CPU
PROGRAM COUNTER
INSTRUCTION REGISTER
ADDRESS REGISTER
ACCUMULATOR
110
ARITH-METIC UNIT
INPUT
I/O
V1.3
Little Man Computer
RAM
Memory
Program HALTED, RESET, LOAD, SELECT or alter memory
OPTIONS
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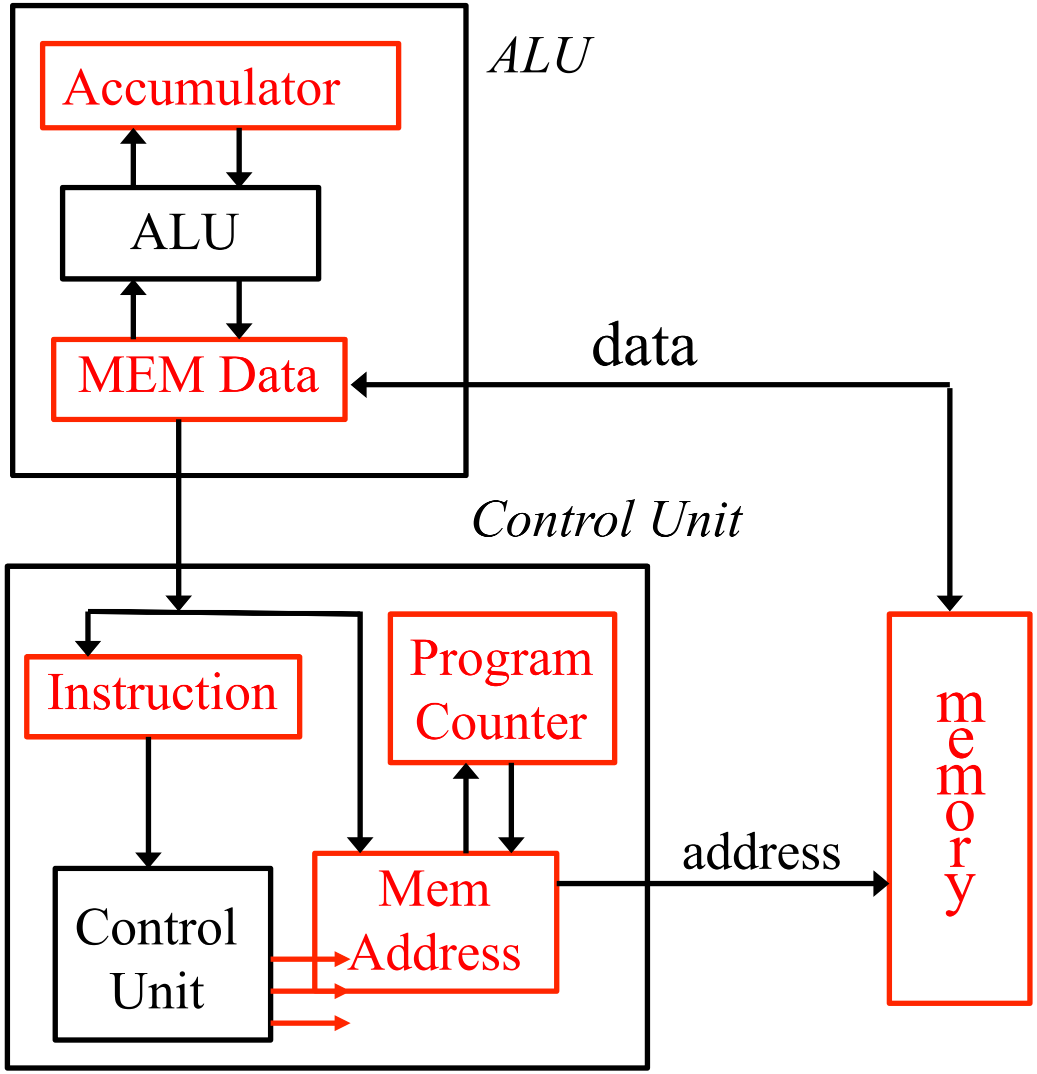
LMC CPU Structure



- Visible registers shown in red
- Accumulators
  - Data for calculation
- *Data*
  - *Word to/from memory*
- PC
  - Address of next instruction
- Instruction
- Address
  - For memory access

Instructions

The primitive language of a computer

Instructions

OpCode	Address

- Instruction
  - What to do: Opcode
  - Where: memory address
- Instructions for arithmetic
  - Add, Multiply, Subtract
- Memory instructions
  - LOAD value from memory
  - STORE value in memory

- The instructions are very simple
- Each make of computer has different instructions
- Programs in a high-level language can work on all computers

Instructions

OpCode	Address

- Opcode: 1 decimal digit
- Address: two decimal digits – xx
- Binary versus decimal

Code	Name	Description
000	HLT	Halt
1xx	ADD	Add: acc + memory à acc
2xx	SUB	Subtract: acc – memory à acc
3xx	STA	Store: acc à memory
5xx	LDA	Load: memory à acc
6xx	BR	Branch always
7xx	BRZ	Branch is acc zero
8xx	BRP	Branch if acc > 0
901	IN	Input
902	OUT	Output

Add and Subtract Instruction

	ADD Address

	SUB Address

- One address and accumulator (ACC)
  - Value at address combined with accumulator value
  - Accumulator changed

- Add: ACC ß ACC + Memory[Address]
- Subtract: ACC ß ACC – Memory[Address]

Load and Store Instruction

	LDA Address
	STA Address

- Move data between memory and accumulator (ACC)

- Load: ACC ß Memory[Address]
- Store: Memory[Address] ß ACC

Input and Output

INP	1 *(Address)*
OUT	2 *(Address)*

- **Input**: ACC ß *input value*
- **output**: output area ß ACC

- It is more usual for I/O to use special memory addresses

Branch Instructions

BR	Address

- Changes program counter
- May depend on accumulator (ACC) value

- BR: PC ß Address
- BRZ: if ACC == 0 then PC ß Address
- BRP: if ACC > 0 then PC ß Address

Assembly Code

- Instructions in text
- Instruction name: STA, LDA
- Address: name using DAT

Numbers

- Memory holds numbers
- Opcode: 0 to 9
- Address: 00 to 99

Line		
1		INP
2		STA x
3		INP
4		STA y
5		HLT
6	x	DAT
7	y	DAT

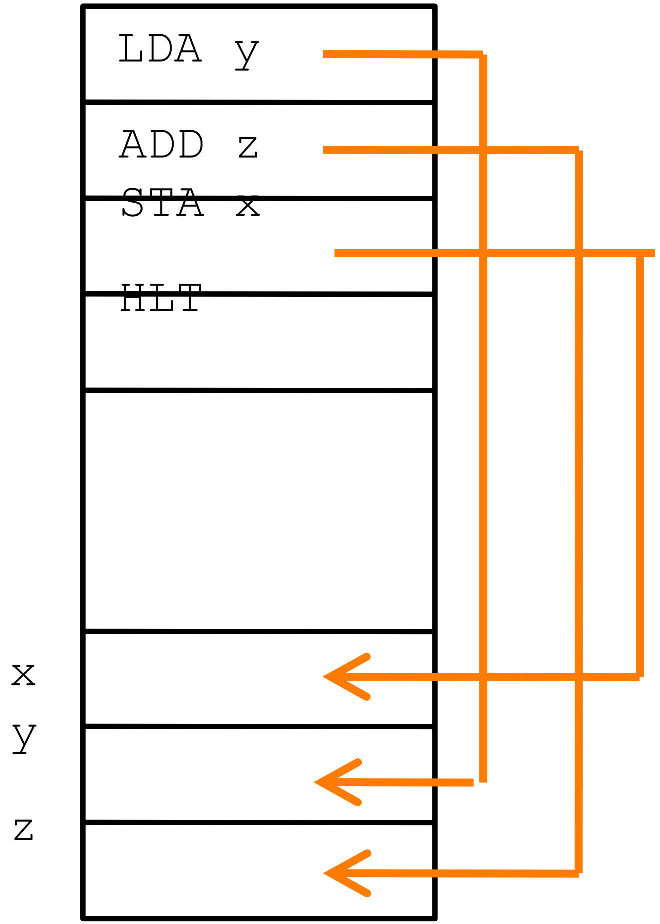
ASSEMBLE →

Location	
00	9 01
01	3 05
02	9 01
03	3 06
04	0 00
05	*(used for x)*
06	*(used for y)*

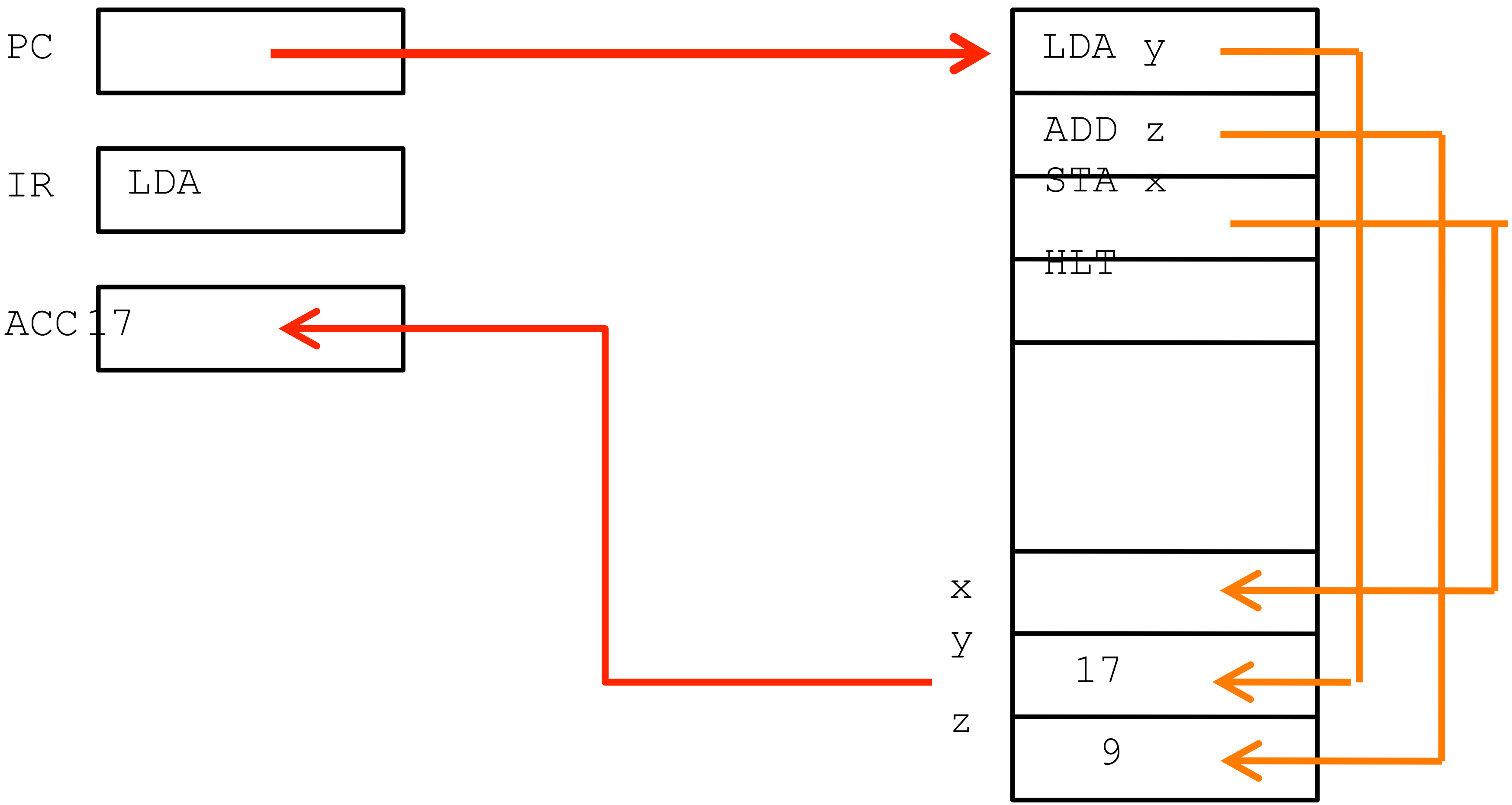
LMC Example

Simple Program

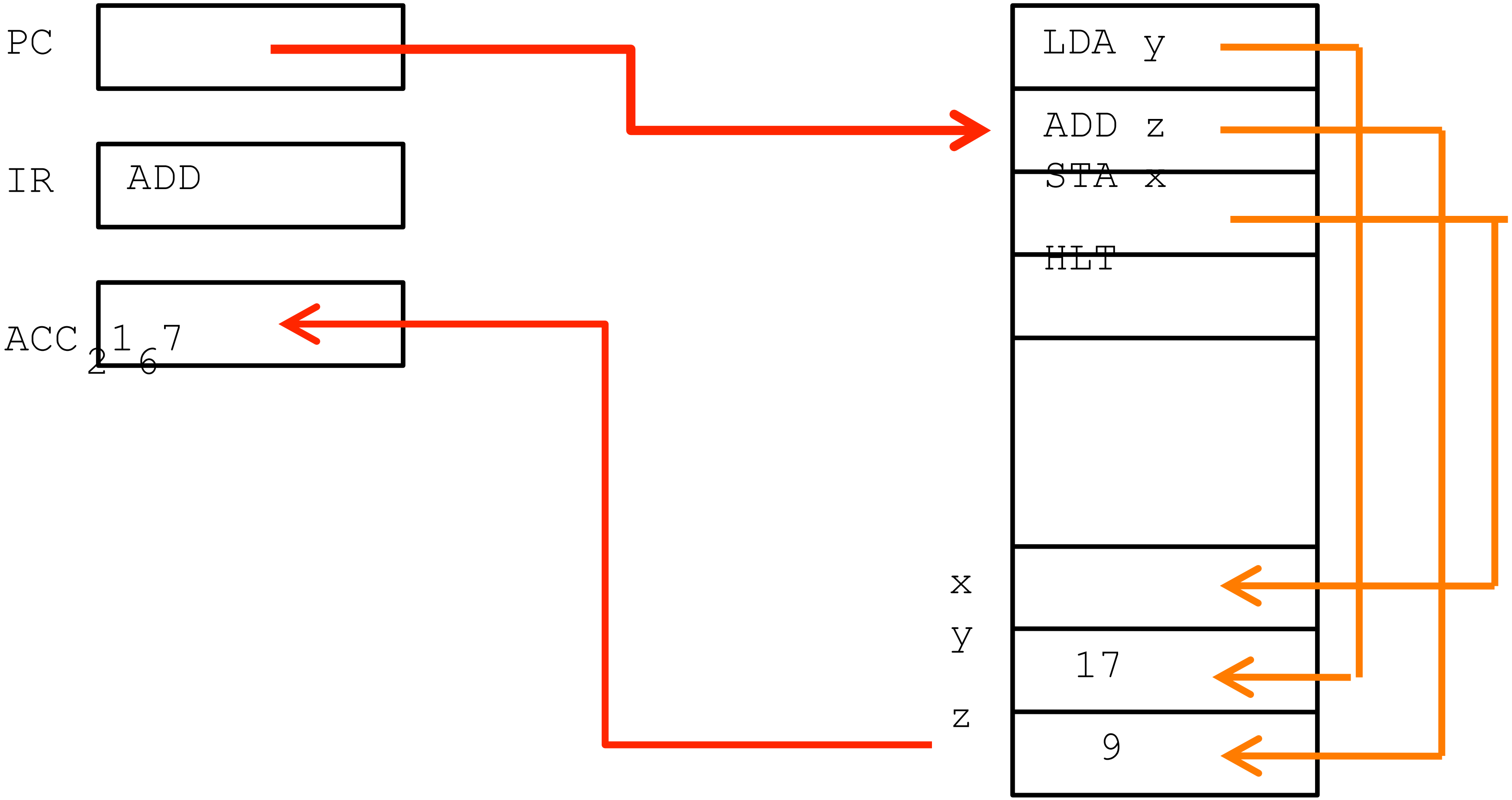
- $x = y + z$



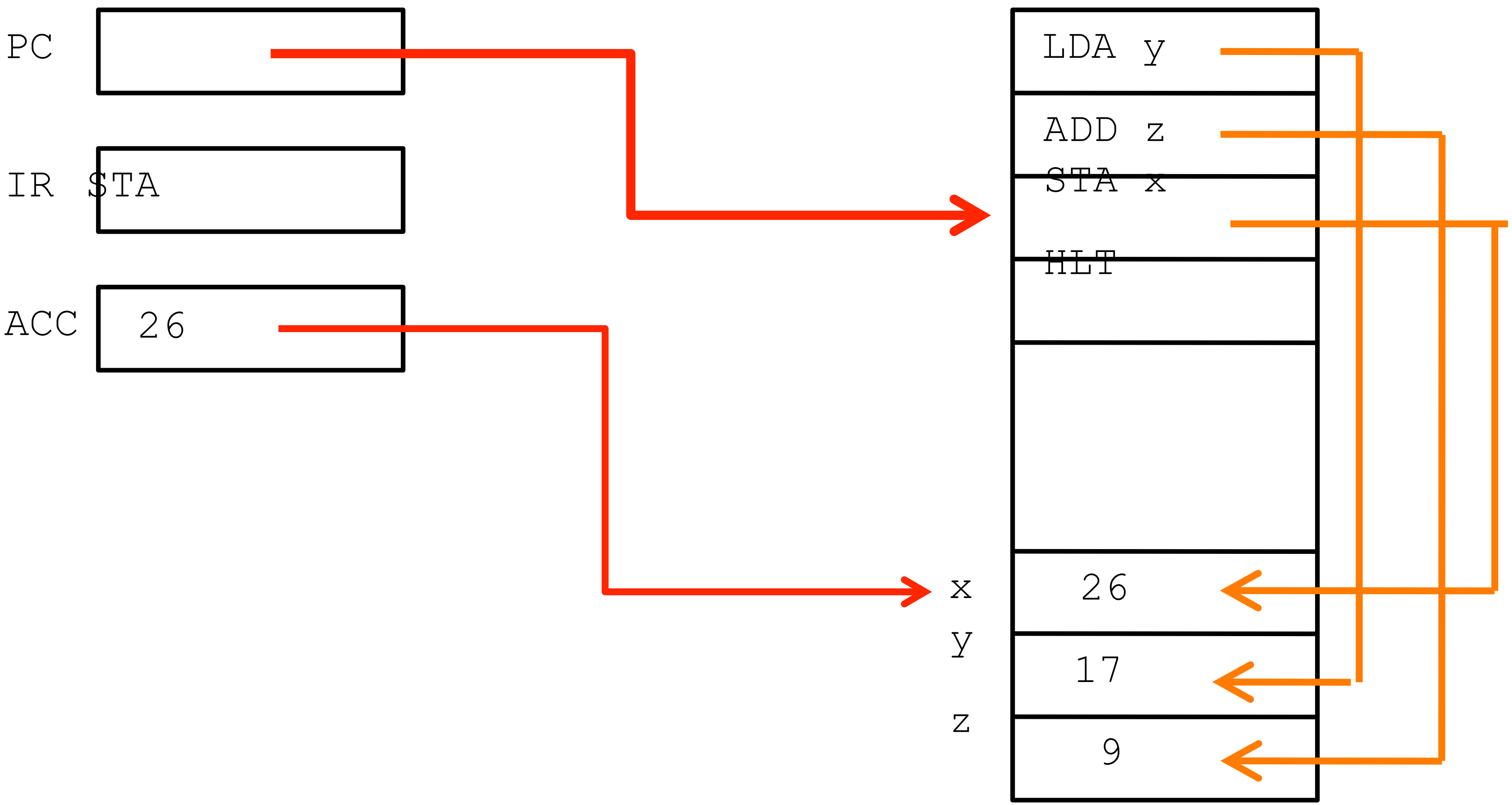
Running the Simple Program



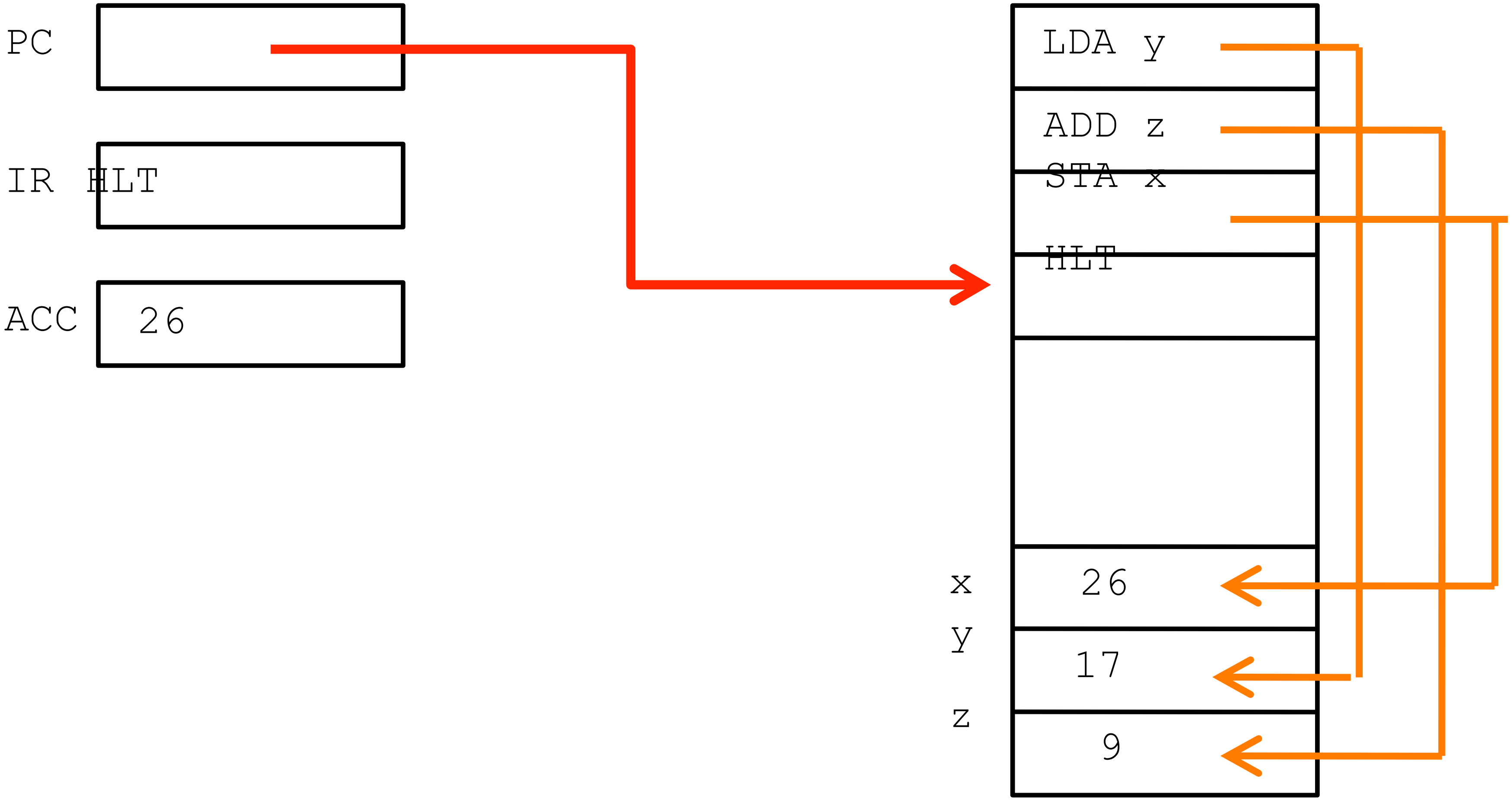
Running the Simple Program



Running the Simple Program



Running the Simple Program



Practice Exercises

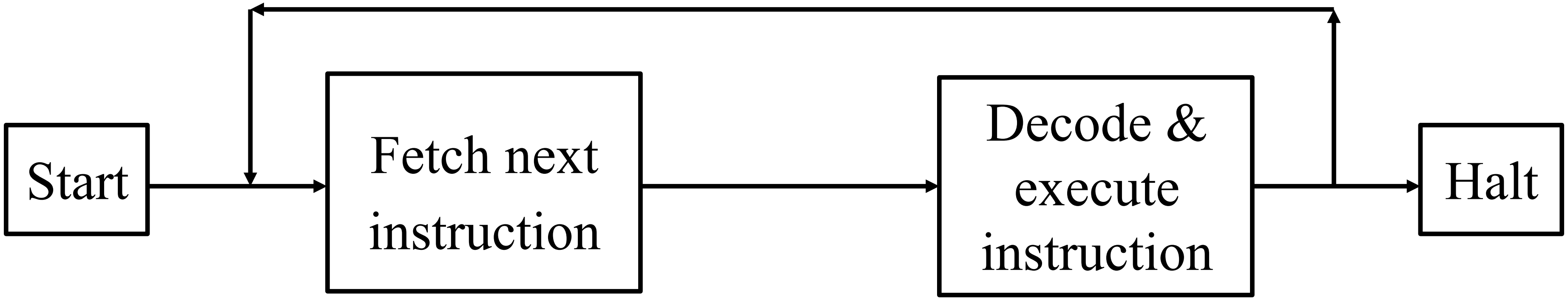
- Try the first three exercises on the practical sheet

Fetch-Execute Cycle

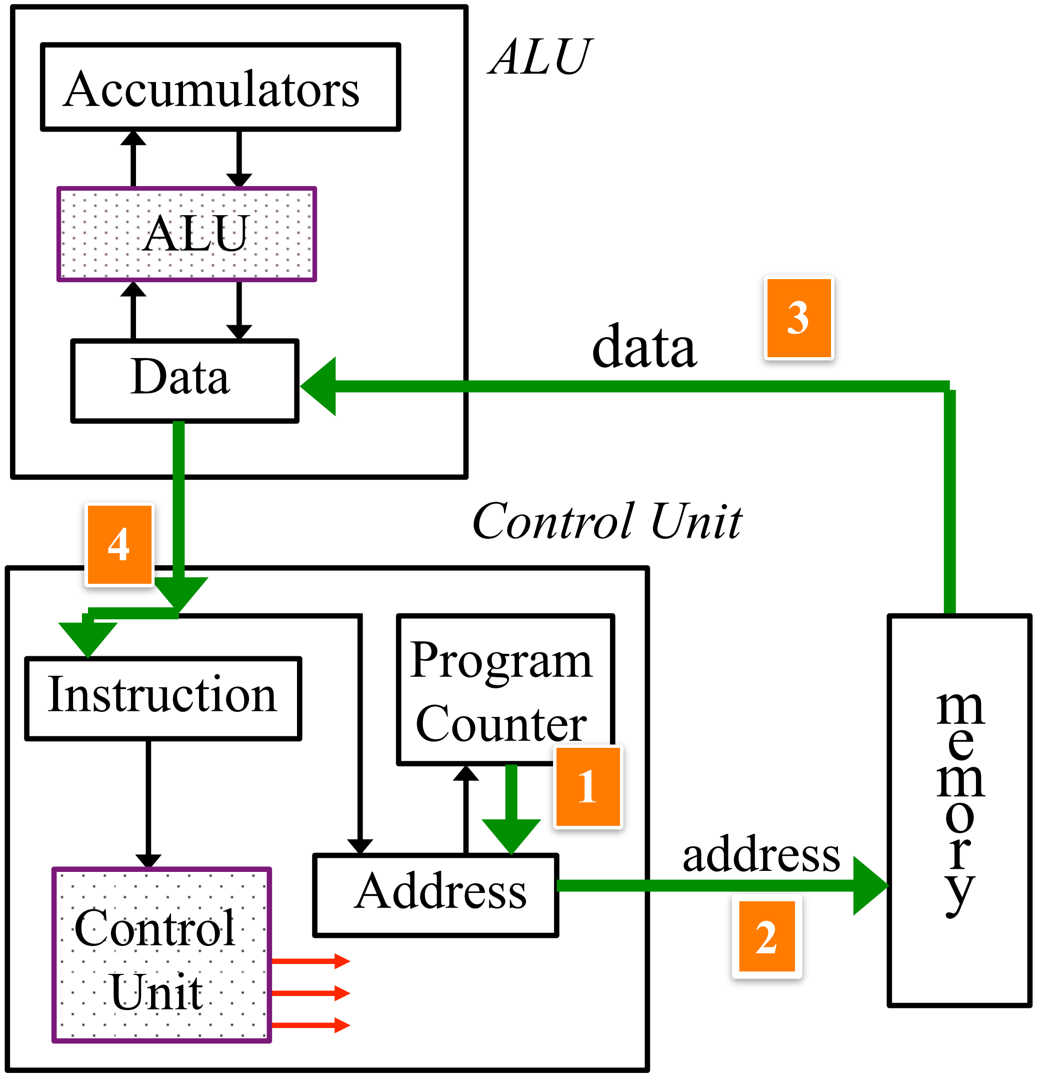
How the Computer Processes Instructions

Fetch-Execute

- Each instruction cycle consists on two subcycles
- Fetch cycle
  - Load the next instruction (Opcode + address)
  - Use Program Counter
- Execute cycle
  - Control unit interprets the opcode
  - ... an operation to be executed on the data by the ALU

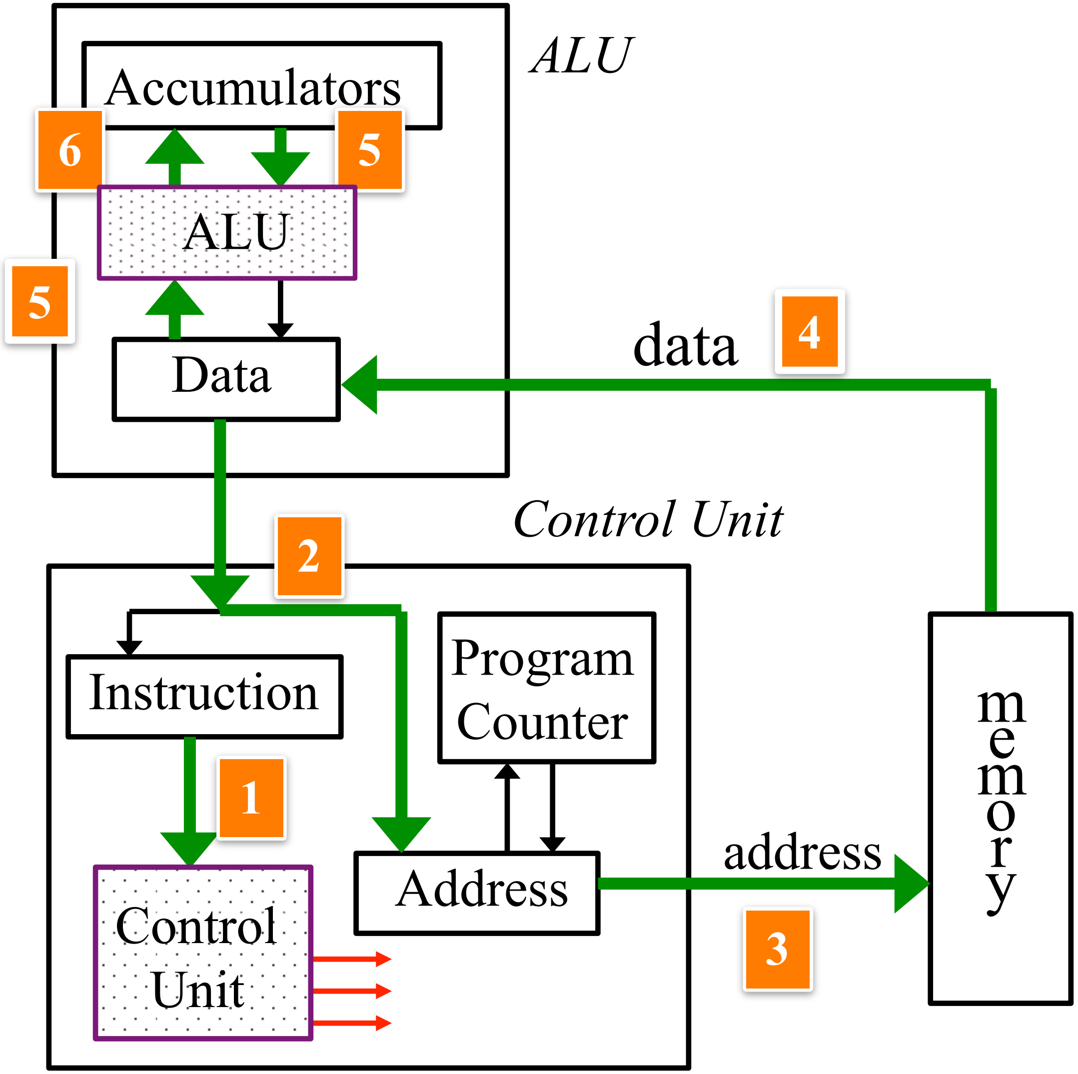


Fetch Instruction



1. Program counter to address register
2. Read memory at address
3. Memory data to ‘Data’
4. ‘Data’ to instruction register
5. Advance program counter

Execute Instruction



1. Decode instruction
2. Address from instruction to 'address register'
3. Access memory
4. Data from memory to 'data register'
5. Add (e.g.) data and accumulator value
6. Update accumulator

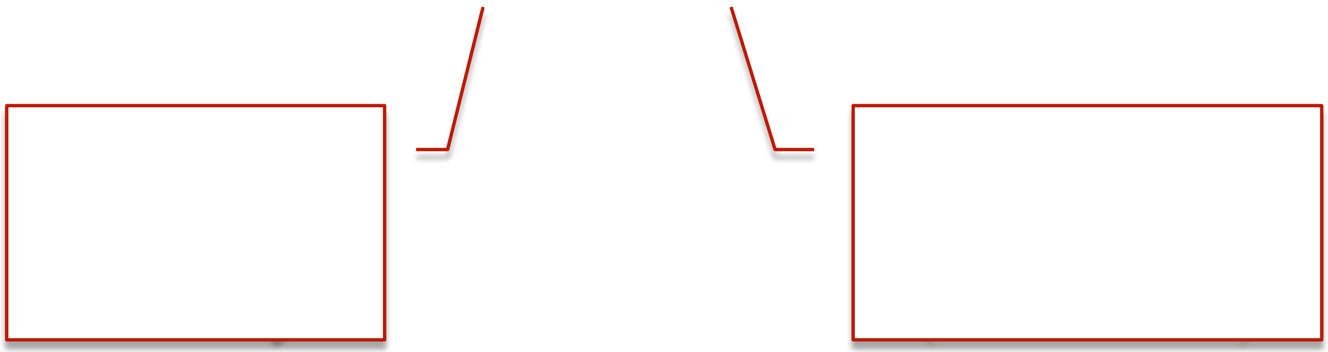
What We Can Learn from LMC

1. How programming language work
2. What a compiler does
3. Why we need an OS

Understanding Variables and Assignment

- What is a variable?
- What is on the left hand side of:

```
x = x + 1
```



Understanding Variables and Assignment

- What is a variable?
- What is on the left hand side of:

```
A[x+1] =42
```

Understanding If and Loops

- Calculate the address of the next instruction

```
if x > 42:
    large = large +
1   else:
    small = small +
    1
```

Compiler

- Compiler **translates** high level program to low level

source code

```
x = y + z
```

assembly code

```
LDA y
ADD z
STA x
HLT
```

object code

```
11010101
10010111
01110100
10000000
```

- Compiled languages
  - Statically typed
  - Close to machine
  - Examples: C, C++, (Java)
  - Compiler for each CPU

Why We Need An OS

LMC

- Only one program
- Program at fixed place in memory
- No
  - Disk
  - Screen
  - …

Real Computer

- Many programs at once
- Program goes anywhere in memory
- Complex I/O

Summary of CPU Architecture

- Memory contains data and program
  - Program counter: address of next instruction
  - Instructions represented in binary
  - Each instruction has an ‘opcode’
- Instructions contain addresses
  - Addresses used to access data
- Computer does ‘fetch-execute’
  - ‘Execute’ depends on opcode
- Computer can be built from < 10,000 electronic switches (transistors)

Project: Writing an LMC Interpreter

Write a Simple LMC Emulator

```
def
    readMem(memory):
    global mdr
    mdr  =  memory[mar]
```

```
acc =
0
mar =  0
mdr =
0
pc =   0
memory =  [504,105,306, 0,
    11, 17,...]
```

```
def execute(memory, opcode,  arg):
  global acc,  mar, mdr,
  pc  if opcode == ADD:
    mar =  arg
    readMem(memory)
    acc =  acc +
    mdr
  elif  opcode == SUB:
    mar =  arg
    readMem(memory)
    acc =  acc -
    mdr
```

```
def
    fetch(memory):
    global pc, mar
    mar = pc
    pc =  pc +  1
    readMem(memory)
```