

برنامه نویسی سیستمی

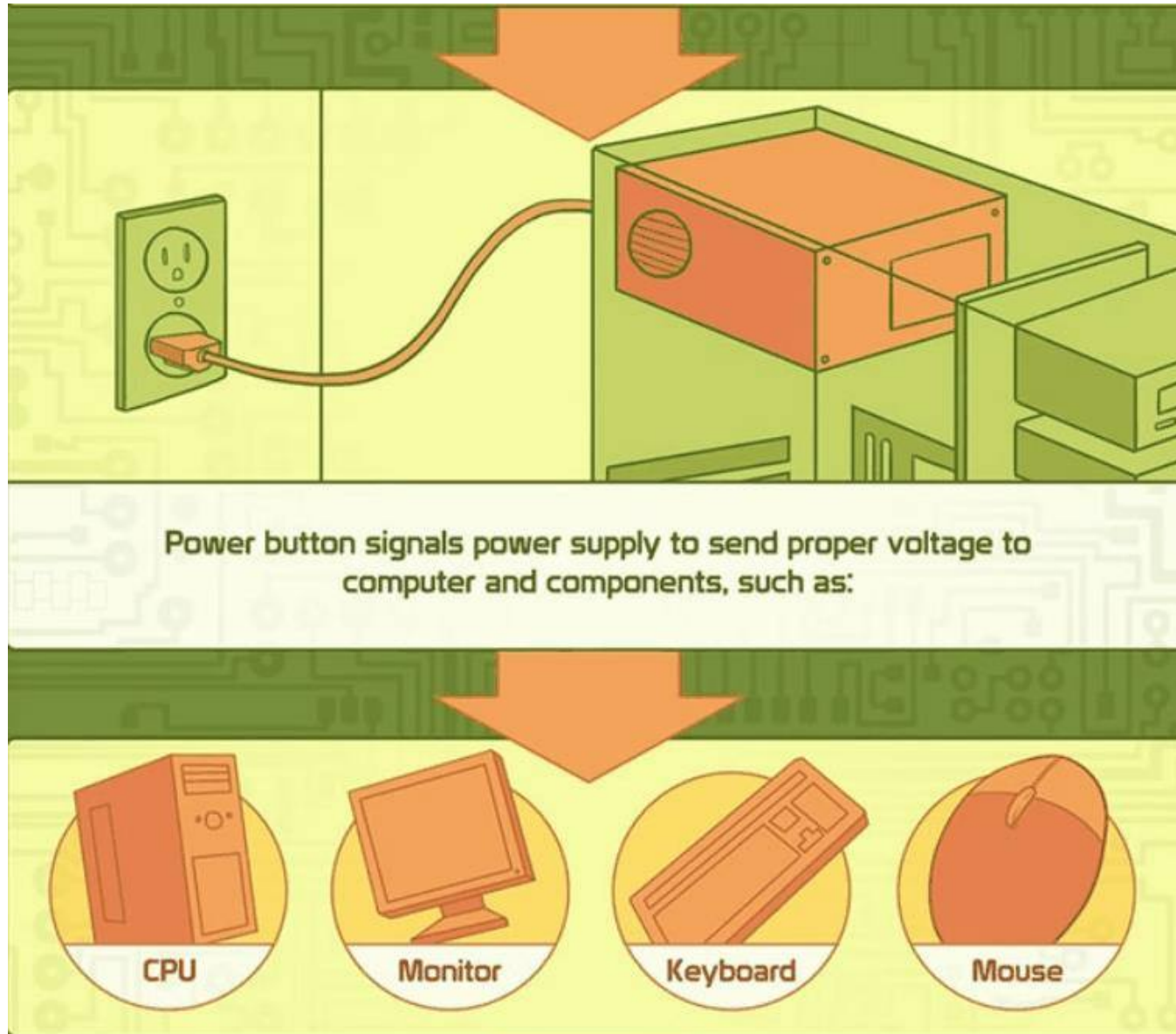


Windows Internals

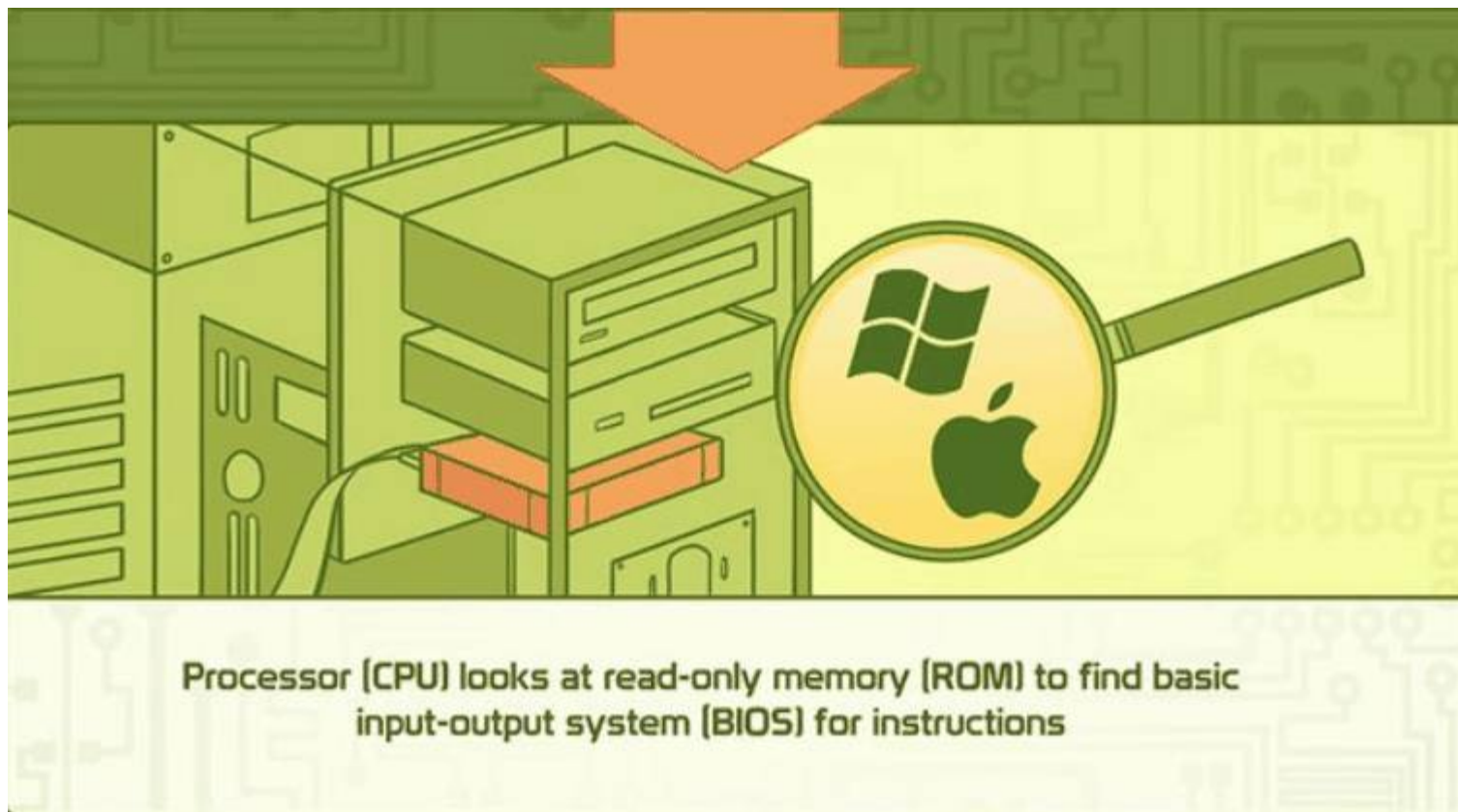
کاوه حقیقی

کامپیوتر چگونه کار می کند؟

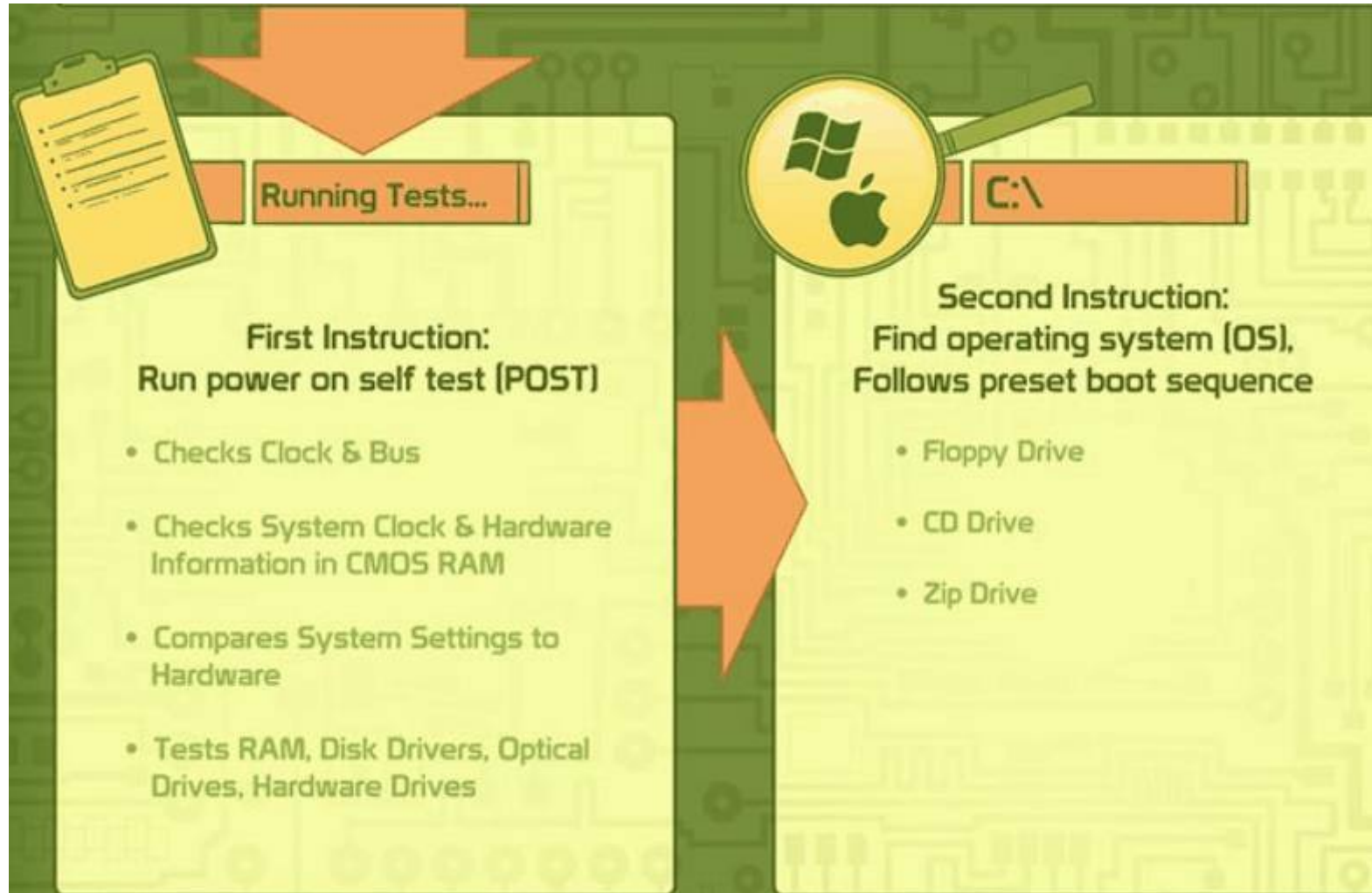
کاوه حقیقی - برنامه نویسی سیستمی



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American
Megatrends

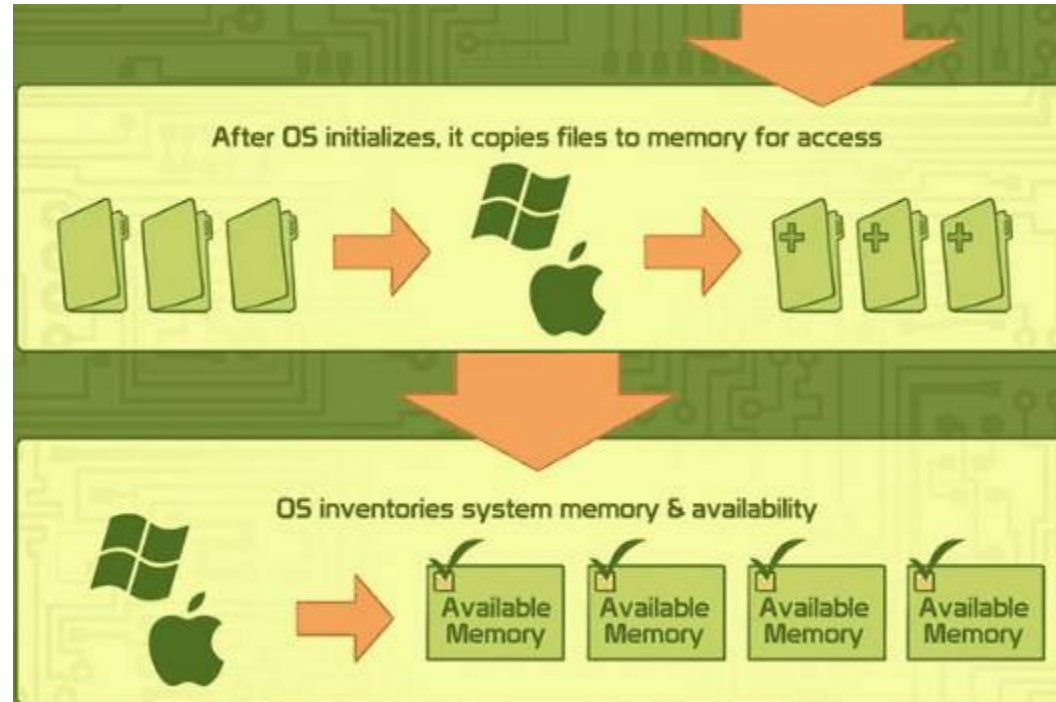
www.ami.com

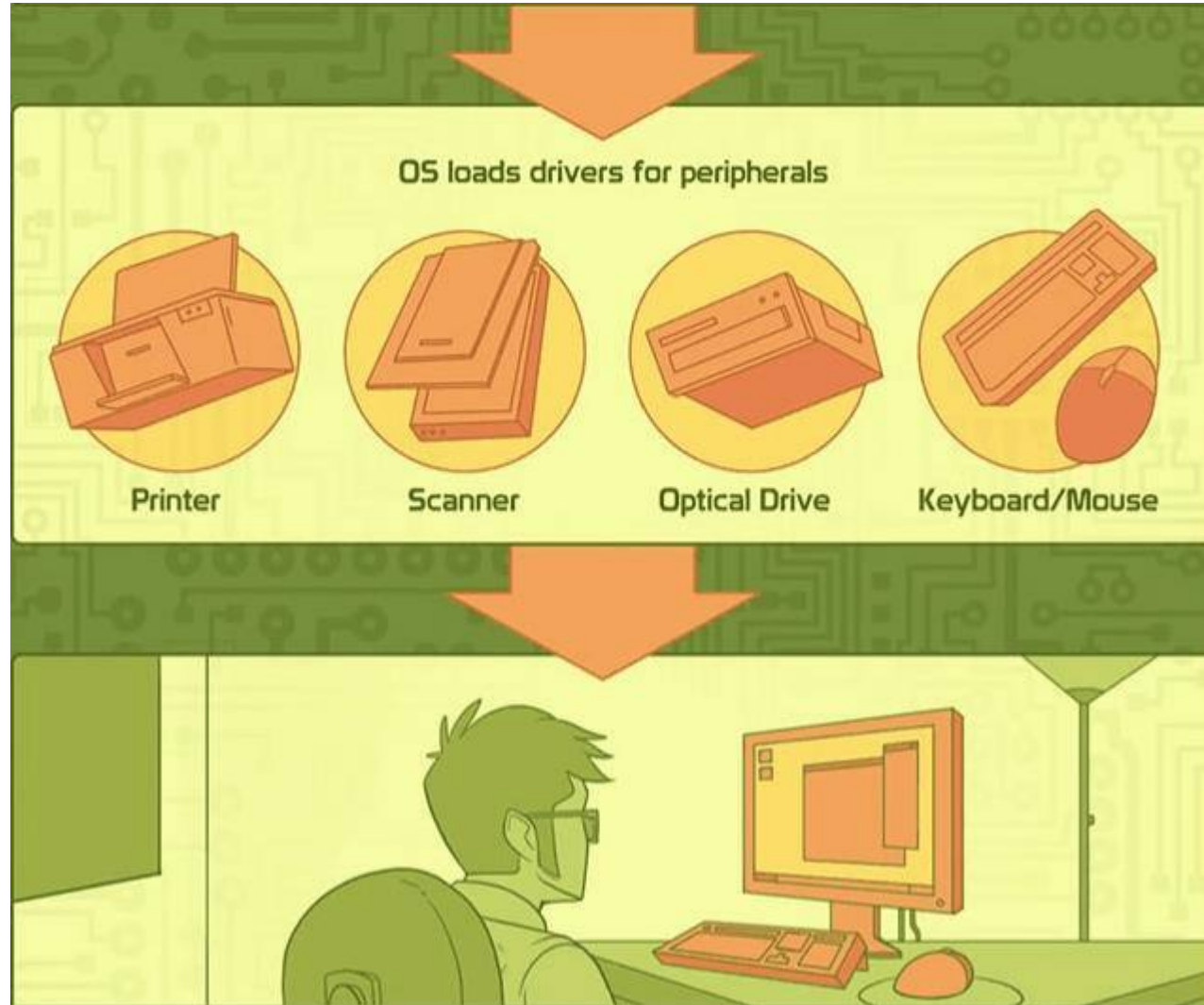
AMIBIOS (C) 2007 American Megatrends, Inc.
ASUS P5KPL ACPI BIOS Revision 0603
CPU : Intel(R) Pentium(R) Dual CPU E2180 @ 2.00GHz
Speed : 2.51 GHz Count : 2

Press DEL to run Setup
Press F8 for BBS POPUP
DDR2-667 in Dual-Channel Interleaved Mode
Initializing USB Controllers .. Done.
3584MB OK

(C) American Megatrends, Inc.
64-0603-000001-00101111-022908-Bearlake-A0820000-Y2KC

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اجزای پردازنده

کاوه حقیقی - برنامه نویسی سیستمی

The Central Presentation Unit

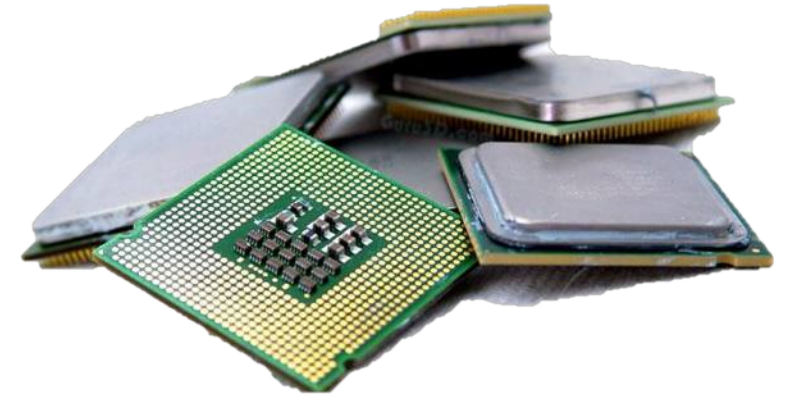
What is the CPU? •

The Microprocessor •

Structure of the CPU •

Parts of the CPU •

1. Buses
2. The Control Unit
3. The Arithmetic Logic Unit
4. Program counter
5. Instruction Register
6. Memory Data Register
7. Memory Address Register





What is the CPU?

- The CPU is short for the Central Processing Unit
- It is the main part of the computer where instructions are processed
- The central processing unit includes the main memory
- Now a day's most computers have more than one CPU to provide better speed

کاوه حقیقی - برنامه نویسی سیستمی

The Microprocessor

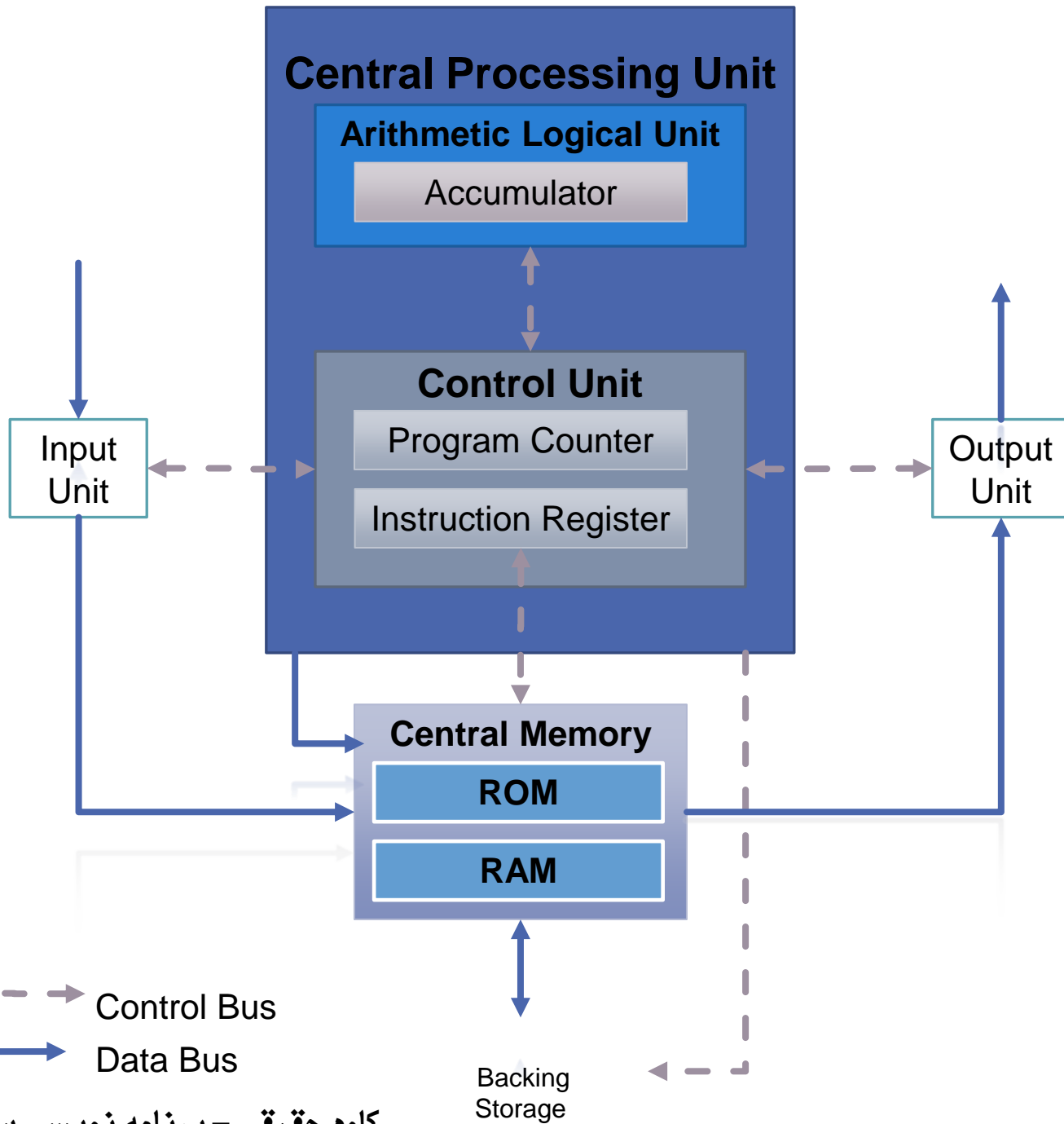
- Small computerised devices such as washing machines have small specialised CPUs known as microprocessors
- It is an integrated circuit as a single unit which includes all that the CPU needs excluding main memory

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Structure of the CPU

- The CPU is made up of many components such as
 1. Registers (Program counter and Instruction Register)
 2. Arithmetic logic unit
 3. Control unit
 4. Buses
- We will now see a block diagram of the components of the CPU



← - - - → Control Bus
 ↔ Data Bus



Buses

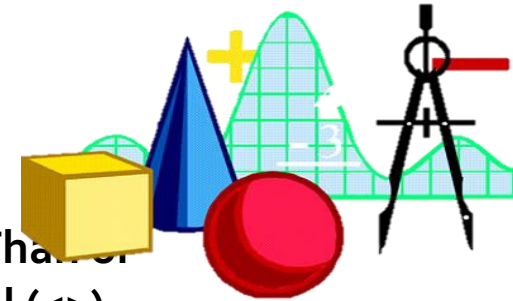
- All data traffic with the CPU takes place across the computer's bus
- A computer bus is a set of parallel electrical tracks connecting components within a computer
- The width of the data bus determines the word length
- The width of the address bus determines how many addresses the computer can send at a time

Control Unit (CU)

- The CU is considered the manager of the CPU
- The CU's jobs are to;
 1. decode instructions within a computer,
 2. Plan the reading and writing of data
 3. control the order in which instructions are executed
 4. control the operations performed by the ALU.
- In the CU you will find two registers;
 1. Instruction Register: stores a copy of the current instruction being performed
 2. Program Counter.

The Arithmetic Logic Unit (ALU)

- The ALU is that part in the CPU where arithmetic and logic operations are carried out in other words all mathematical calculations. The result of the calculations are sent to the main memory
- The ALU is capable of performing:
 1. Addition, Subtraction, Multiplication, Division
 2. Greater Than ($>$), Smaller Than ($<$), Equal ($=$), Greater Than or Equal To ($>=$), Smaller Than or Equal To ($<=$), Not Equal ($<>$)
 3. AND, NOT, OR
- Within the ALU we will find the register known as the Accumulator. The accumulator stores the result of the current calculation.



Program Counter (PC)



- The program counter is sometimes known as the instruction pointer
- The PC indicates where the computer is in its instruction set. If the instruction set has 5 steps the PC will point to which step the computer has arrived
- Depending on the device the PC could hold
 1. The address of the instruction being executed, or
 2. The address of the next instruction to be executed.
- The program counter is automatically incremented (increased by 1) after each step (instruction cycle)

Instruction Register (IR)

- The instruction register (IR) is also found with the control unit
- The IR is used to store a copy of the current instruction being performed
- This instruction is stored in the form of operator and operand (covered later on)
- Also known as CIR (Current Instruction Register)

Memory Data Register (MDR) Or Memory Buffer Register (MBR)

- The Memory Data Register in the central processor stores the data being transferred to and from the access store.
- It acts as a buffer allowing the central processor work independently without being affected by differences in operation.

Memory Address Register (MAR)

- The Memory Address Register in the central processor stores the address of the memory location currently in use.
- When the CPU is fetching data the MAR would store the address of the instruction being loaded
- When the instruction is being executed the address of the data being used is stored.

Main Memory

- The main memory is where most of the results are temporarily stored;
- Main memory is much faster than the hard disk this is why it is used
- Each result is stored in a location in the main memory and each location has an address, this way the CPU can store and retrieve information which is stored in the main memory easily and faster.
- When the CPU writes information to the main memory two things are supplied
 1. the address section: passes through the address bus
 2. the data section: passes through the data bus

کاوه حقیقی - برنامه نویسی سیستمی



زبان سطح بالا
(C++, Python, Java)

```
temp = v[k];  
v[k] = v[k+ 1];  
v[k+ 1] = temp;
```

کامپایلر

زبان اسمبلی
(ARM, MIPS, x86)

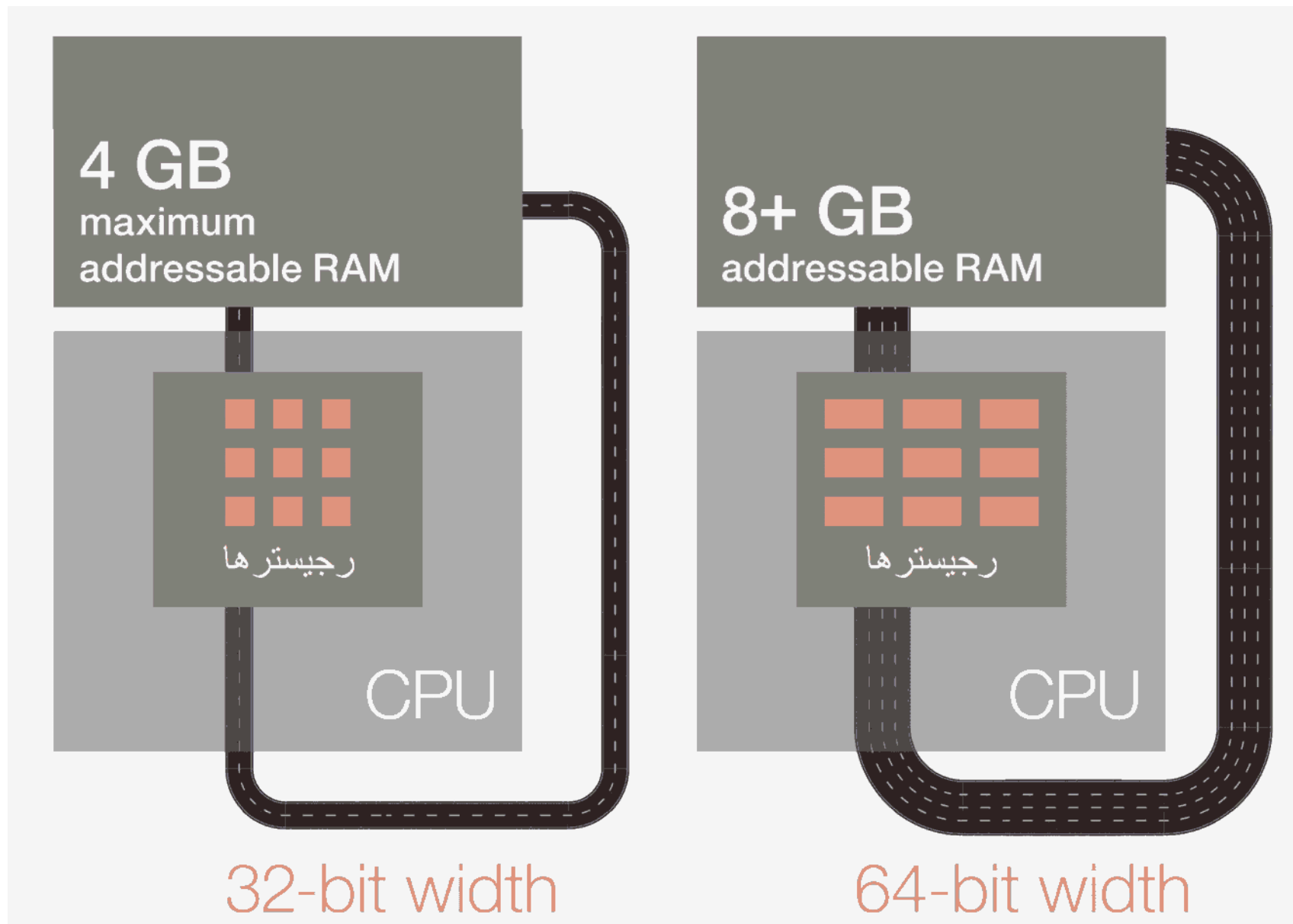
```
lw $t0, 0($2)  
lw $t1, 4($2)  
sw $t1, 0($2)  
sw $t0, 4($2)
```

اسمبلر

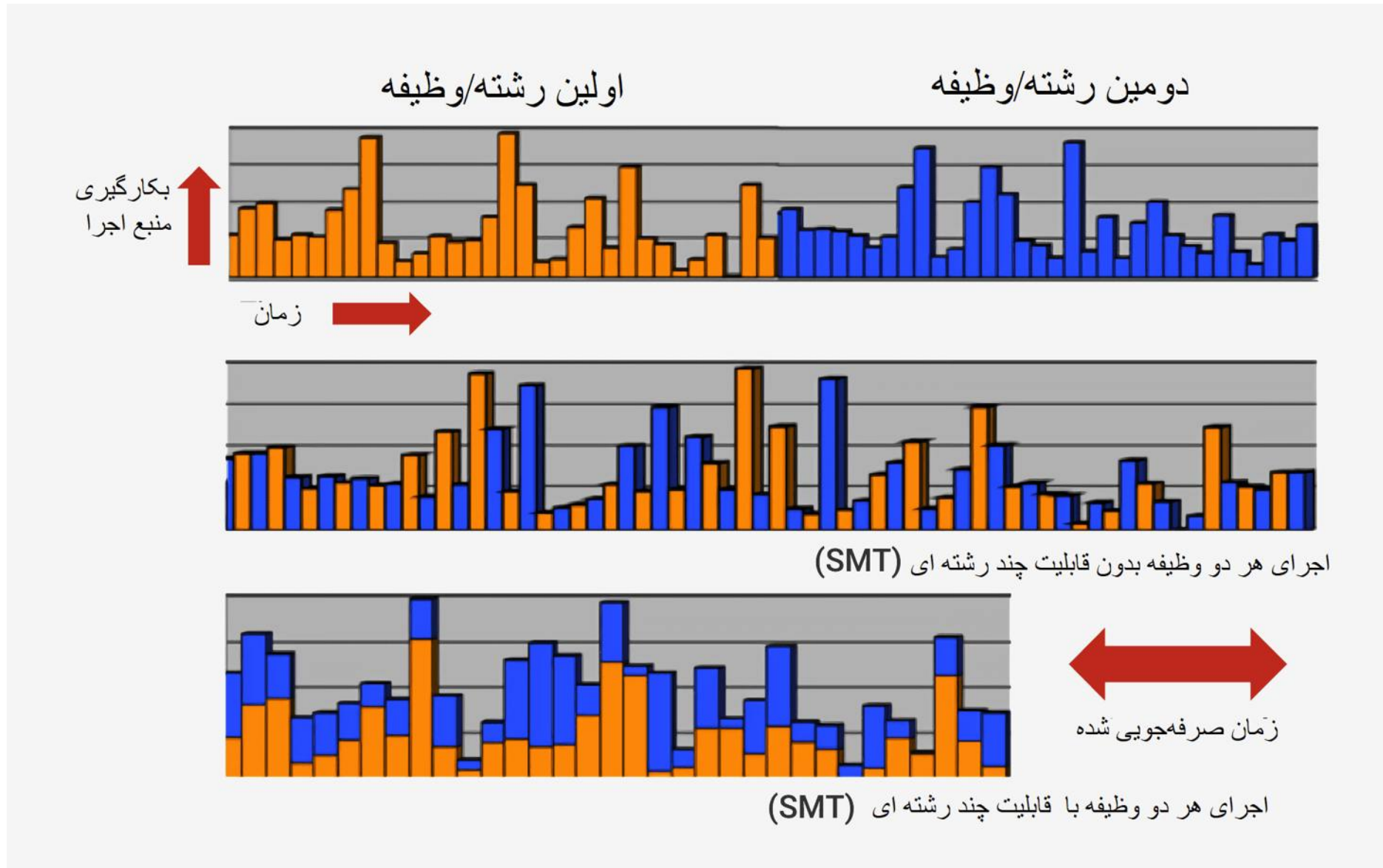
زبان ماشین

```
0000 1001 1100 0110 1010 1111 0101 1000  
1010 1111 0101 1000 0000 1001 1100 0110  
1100 0110 1010 1111 0101 1000 0000 1001  
0101 1000 0000 1001 1100 0110 1010 1111
```

کاوه حقیقی - برنامه نویسی سیستمی



کاوه حقیقی - برنامه نویسی سیستمی



کاوه حقیقی - برنامه نویسی سیستمی

پردازنده چگونه دستورات را اجرا می کند؟

- واکنشی (Fetch)
- کدگشایی (Decode)
- اجرا (Execute)

PC

MAR

MBR

CIR	
Op-Code	Operand

ALU

ACC

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

1

PC
2000

FETCH

MAR

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

1

FETCH

PC
2000

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

MBR

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

1

PC
2002

FETCH

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

1

PC
2002

FETCH

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

MBR

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

1

PC
2002

FETCH

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
100A

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

1

PC
2002

DECODE

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

MBR
100A

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 1010

ALU

ACC

1

PC
2002

DECODE

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
100A

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

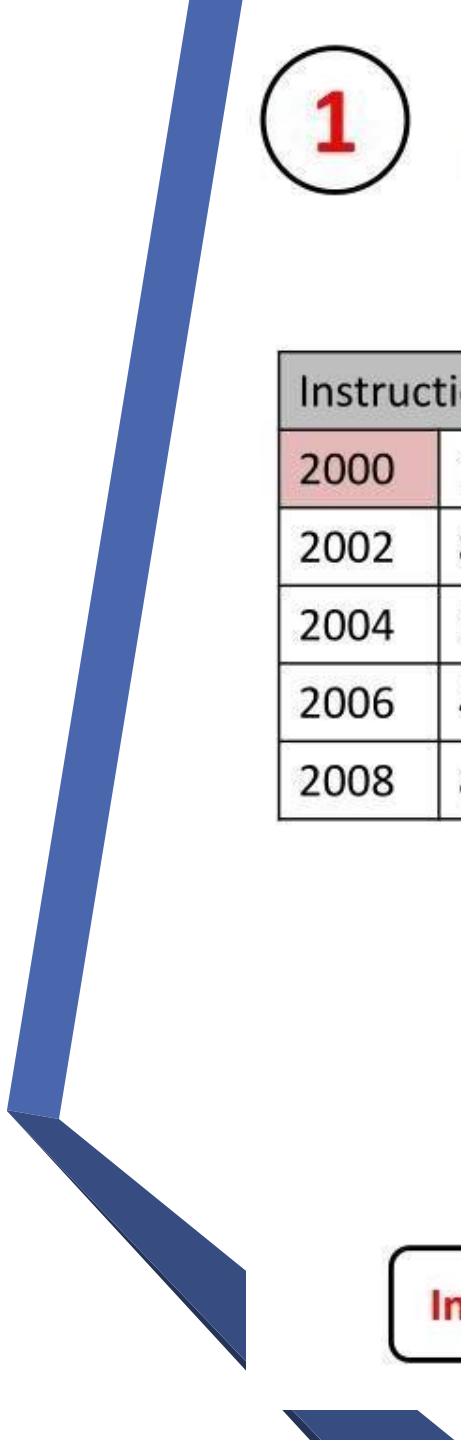
Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 1010

Instruction Decoded

ALU

ACC



1

PC
2002

EXECUTE

MAR
2000

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
100A

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 1010

ALU



ACC
0A

2

FETCH

PC
2002

MAR
2002

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

CIR	
Op-Code	Operand

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

ALU

ACC
0A

2

PC
2004

FETCH

MAR
2002

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

ALU

ACC
0A

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

2

PC
2004

FETCH

MAR
2002

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

ALU

ACC
0A

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

2

PC
2004

FETCH

MAR
2002

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
8019

CIR	
Op-Code	Operand

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

ALU

ACC
0A

2

PC
2004

DECODE

MAR
2002

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
8019

CIR	
Op-Code	Operand
1000	0000 0001 1001

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

ALU

ACC
0A

2

PC
2004

DECODE

MAR
2000

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
8019

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

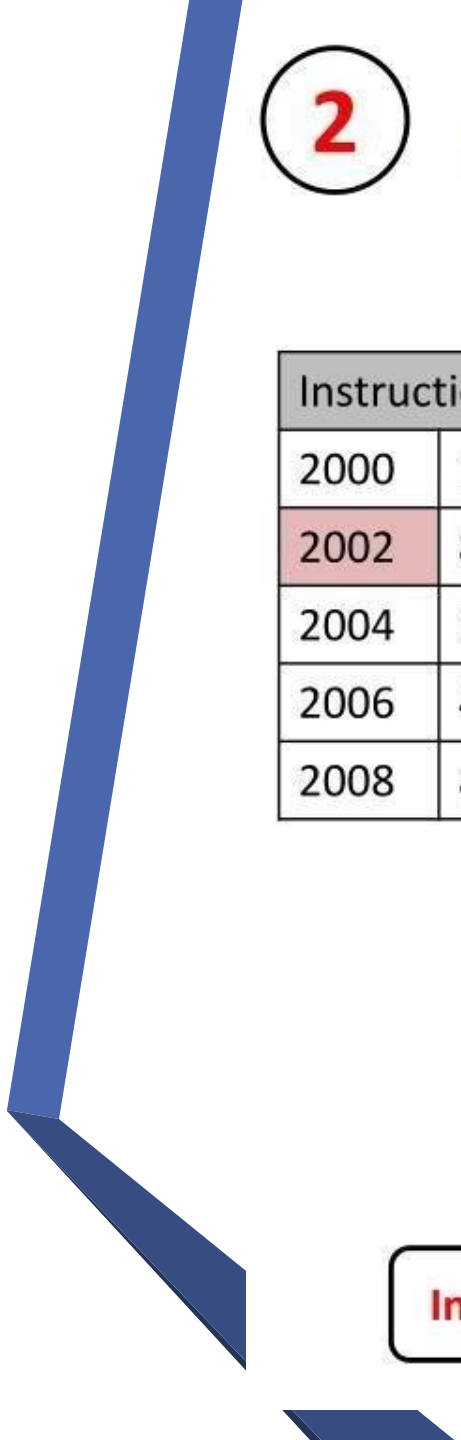
Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
1000	0000 0001 1001

Instruction Decoded

ALU

ACC
0A



2

PC
2004

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

CIR	
Op-Code	Operand
1000	0000 0001 1001

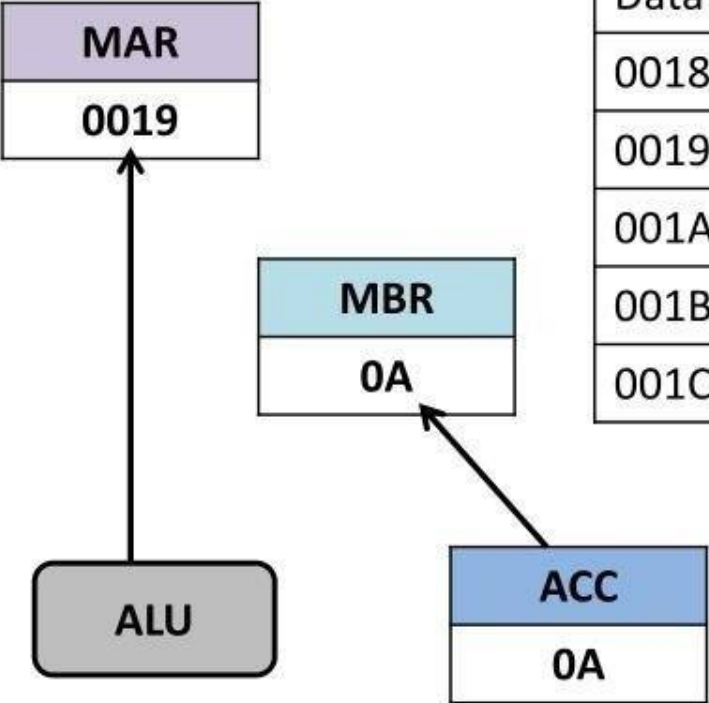
Data Memory	
0018	00
0019	00
001A	00
001B	00
001C	00

MAR
0019

MBR
0A

ALU

ACC
0A



2

PC
2004

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

CIR	
Op-Code	Operand
1000	0000 0001 1001

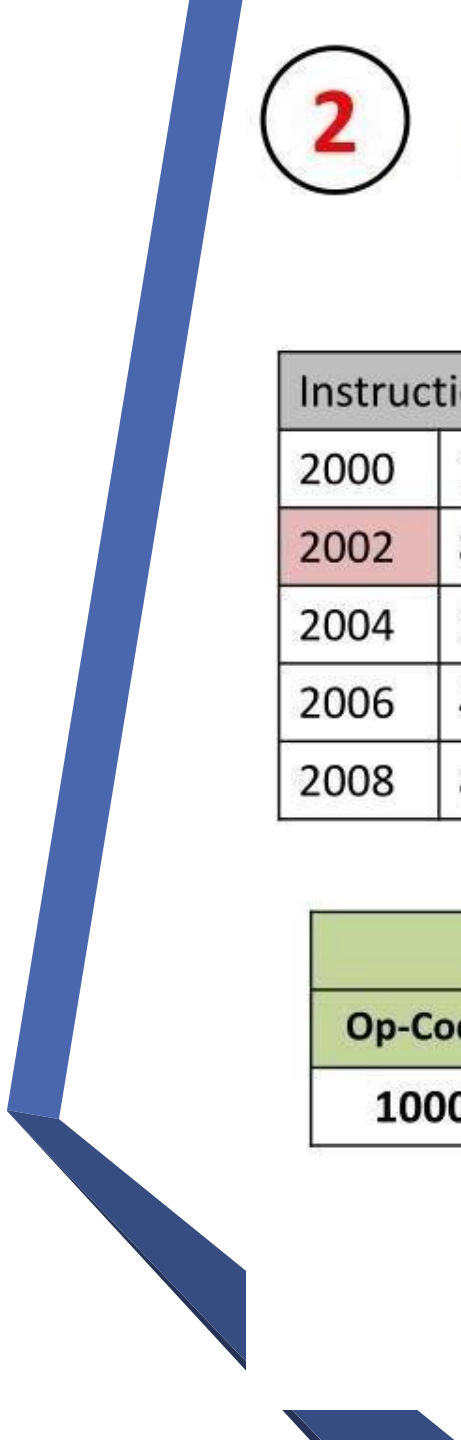
MAR
0019

MBR
0A

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC
0A



3

FETCH

PC
2004

MAR
2004

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
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MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

3

FETCH

PC
2006

MAR
2004

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC

3

PC
2006

FETCH

MAR
2004

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

3

PC
2006

FETCH

MAR
2004

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
1005

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC

3

PC
2006

DECODE

MAR
2004

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
1005

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 0101

ALU

ACC

3

PC
2006

DECODE

MAR
2004

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
1005

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

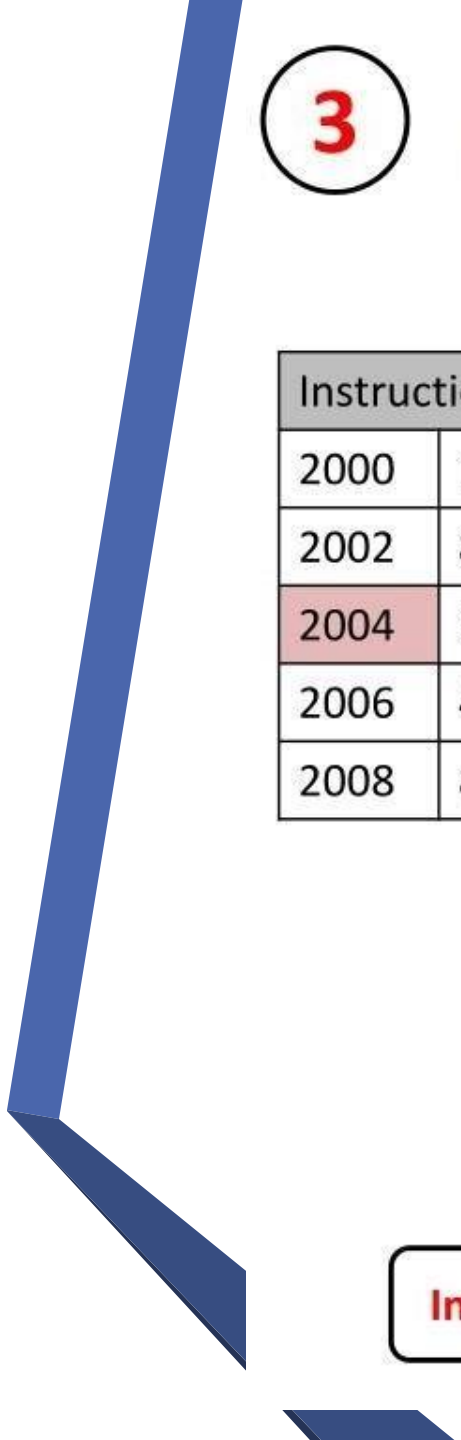
Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 0101

Instruction Decoded

ALU

ACC



3

PC
2006

EXECUTE

MAR
2004

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
1005

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0001	0000 0000 0101

ALU



ACC
05

4

PC
2006

FETCH

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

ALU

ACC
05

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

4

PC
2008

FETCH

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

ALU

ACC
05

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

4

PC
2008

FETCH

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC
05

4

PC
2008

FETCH

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
4019

CIR	
Op-Code	Operand

ALU

ACC
05

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

4

PC
2008

DECODE

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
4019

CIR	
Op-Code	Operand
0100	0000 0001 1001

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC
05

4

PC
2008

DECODE

MAR
2006

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
4019

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0100	0000 0001 1001

Instruction Decoded

ALU

ACC
05

4

PC
2008

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

CIR	
Op-Code	Operand
0100	0000 0001 1001

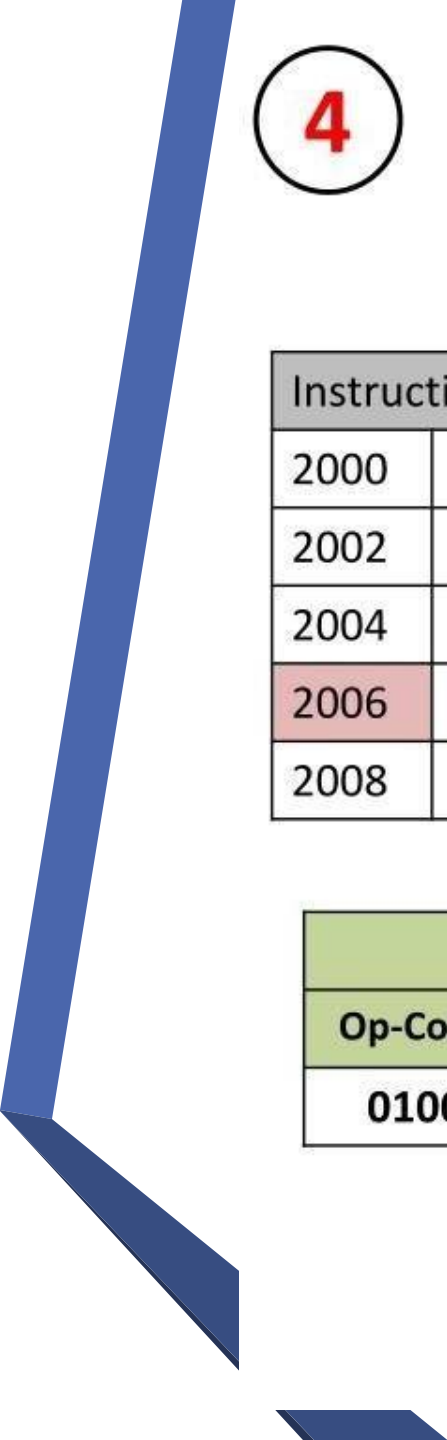
MAR
019

MBR

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC
05



4

PC
2008

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MAR
019

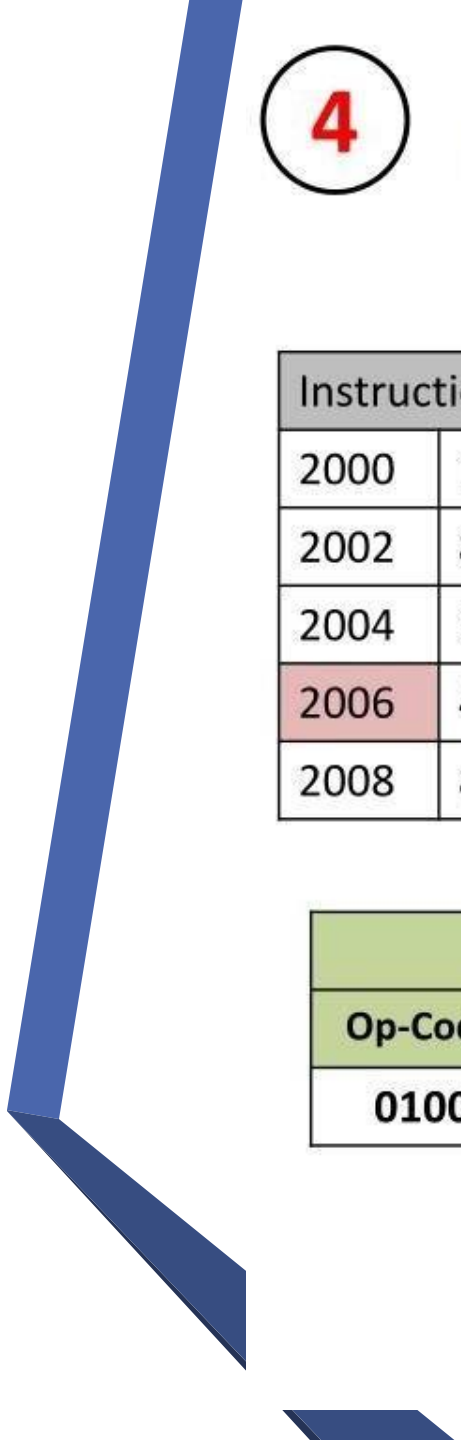
Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

MBR

CIR	
Op-Code	Operand
0100	0000 0001 1001

ALU

ACC
05



4

PC
2008

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MAR
019

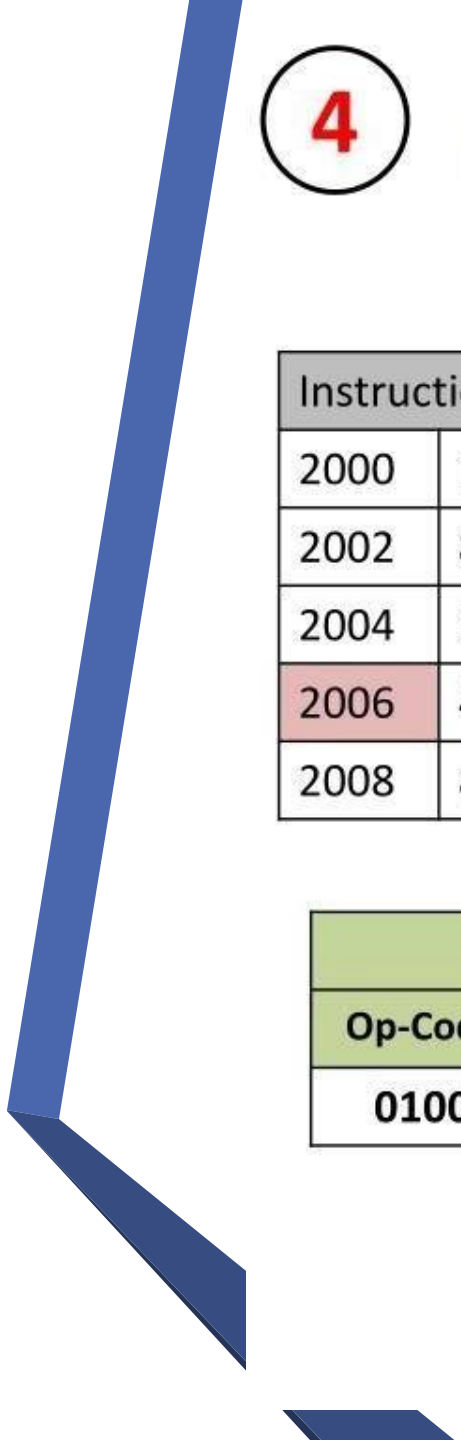
Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0100	0000 0001 1001

MBR
0A

ALU

ACC
05



4

PC
2008

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MAR
019

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

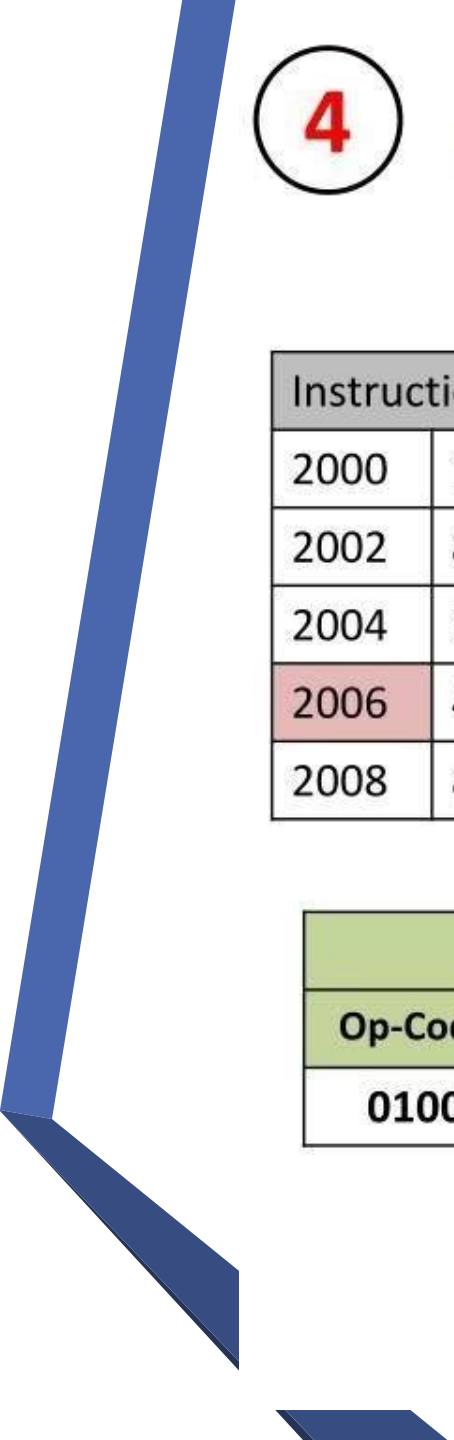
CIR	
Op-Code	Operand
0100	0000 0001 1001

MBR
0A

0A + 05 = 0F

ALU

ACC



4

PC
2008

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MAR
019

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
0100	0000 0001 1001

MBR
0A



5

FETCH

PC
2008

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC
0F

5

FETCH

PC
2010

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

CIR	
Op-Code	Operand

ALU

ACC
0F

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

5

PC
2010

FETCH

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand

ALU

ACC
0F

5

PC
2010

FETCH

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
801A

CIR	
Op-Code	Operand

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC
0F

5

PC
2010

DECODE

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
801A

CIR	
Op-Code	Operand
1000	0000 0001 1100

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

ALU

ACC
0F

5

PC
2010

DECODE

MAR
2008

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

MBR
801A

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

CIR	
Op-Code	Operand
1000	0000 0001 1100

Instruction Decoded

ALU

ACC
0F

5

PC
2010

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

CIR	
Op-Code	Operand
1000	0000 0001 1100

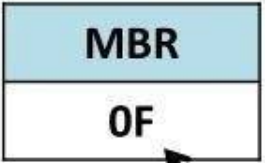
Data Memory	
0018	00
0019	0A
001A	00
001B	00
001C	00

MAR
001A

MBR
0F

ALU

ACC
0F



5

PC
2010

EXECUTE

PC	Program Counter
MAR	Memory Address Register
MBR	Memory Buffer Register
CIR	Current Instruction Register
ALU	Arithmetic and Logic Unit
ACC	Accumulator

Instruction Memory	
2000	100A (LOAD #10)
2002	8019 (STORE 25)
2004	1005 (LOAD #05)
2006	4019 (ADD 25)
2008	801A (STORE 26)

CIR	
Op-Code	Operand
1000	0000 0001 1100

MAR
001A

MBR
0F

Data Memory	
0018	00
0019	0A
001A	0F
001B	00
001C	00

ALU

ACC
0F

