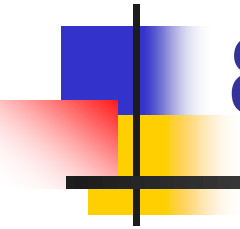
Lab 01



8051 Assembly Programming

https://icechewei.github.io/webpage/files/MCE2021Autumn/lab01-8051asm.pdf

The Goal of Lab 01

- Guide you to write your first 8051 assembly program
  - and perhaps your first assembly program

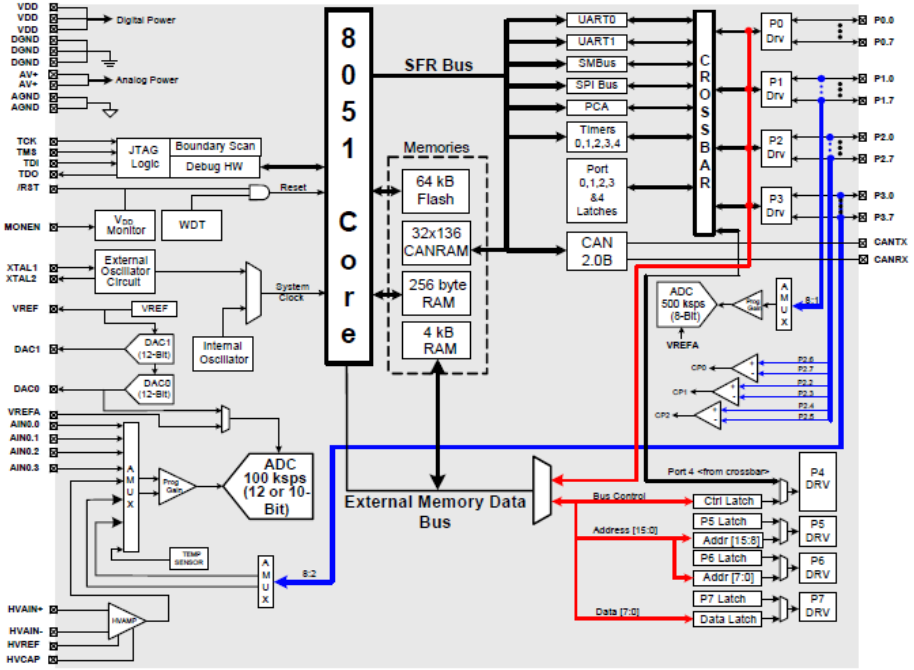
- Your work: write a program to compute

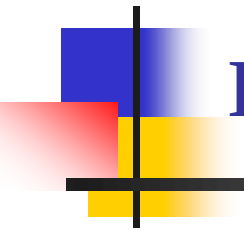
$$S = \sum_{i=0}^{N-1} A[i] * B[i]$$

  - where A[i], B[i] are integer arrays (8-bit) in 8051's internal memory

Overview: the C8051F040 SoC

- a system-on-a-chip integrating the processor core, memory, peripheral devices, everything in a computer system





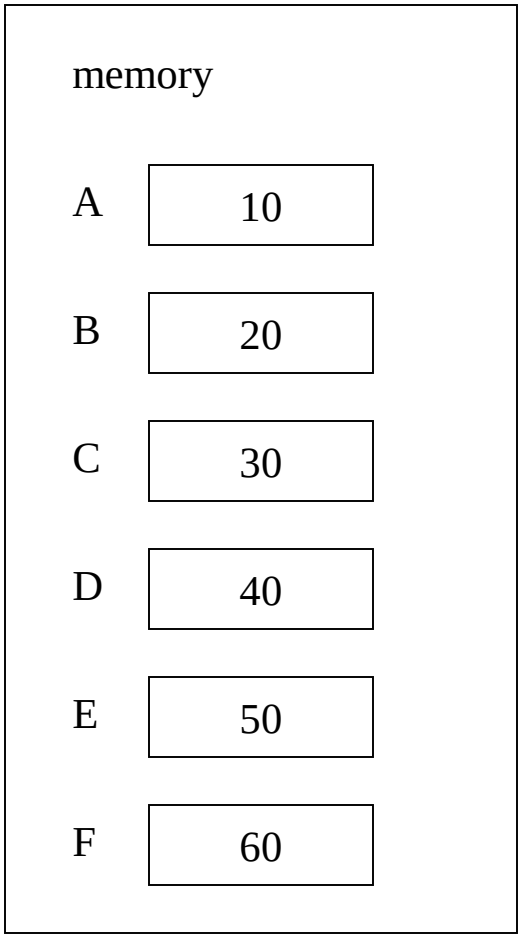
Fundamental: von Neumann model in assembly level

The Von Neumann Model

```
D = A+B*C;
E = D+F;
A = A-1;
```

CPU

PC: program counter



The Von Neumann Model

PC →

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D = A+B*C;
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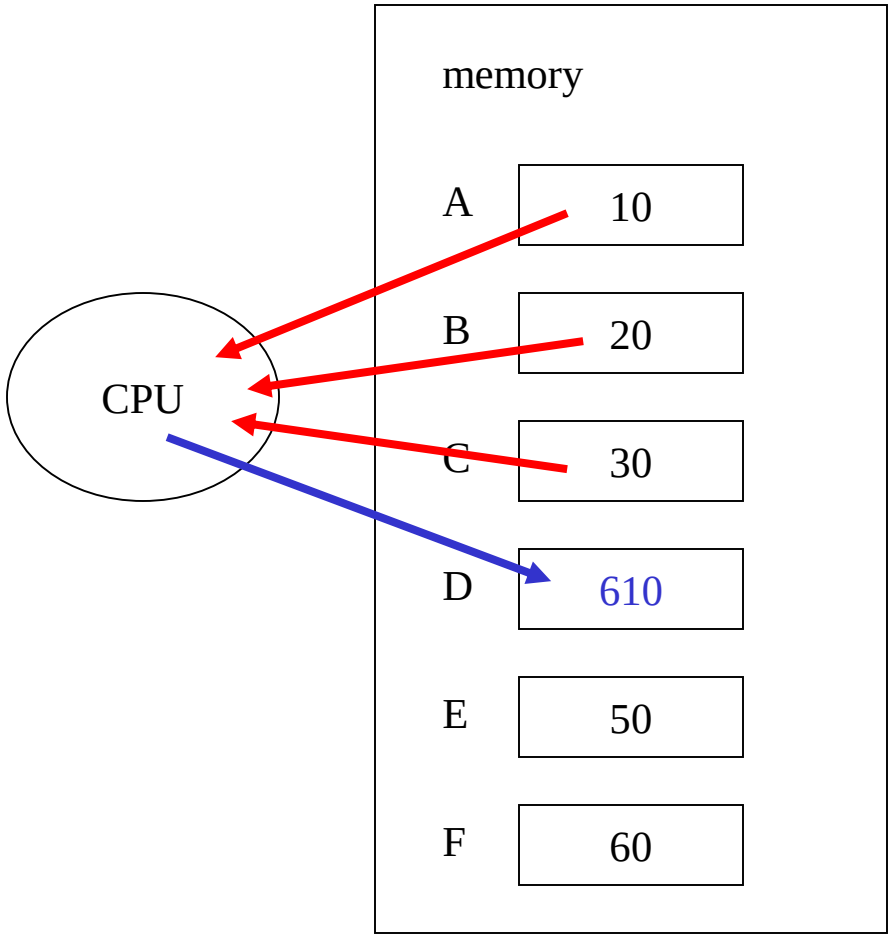
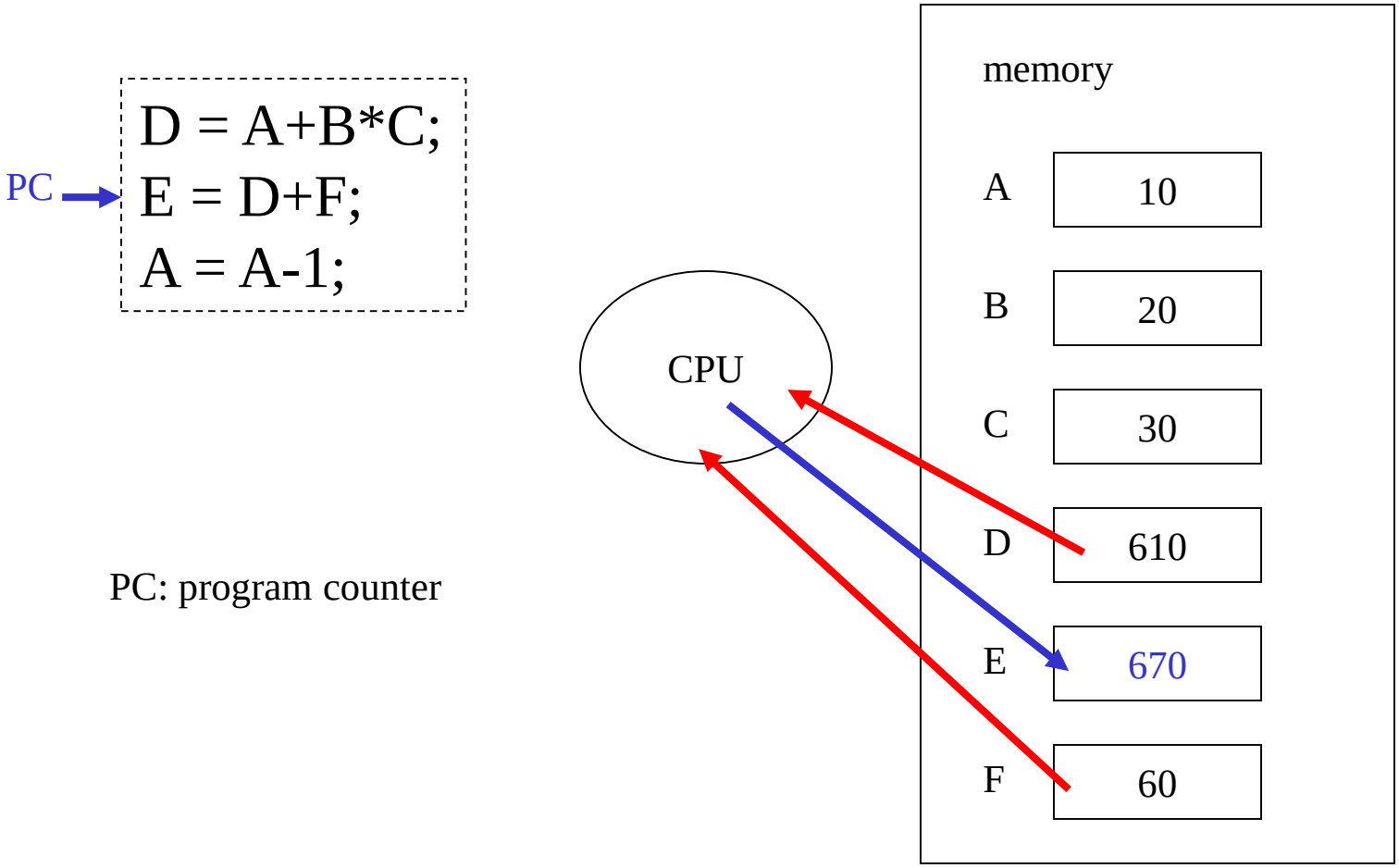
PC: program counter



The Von Neumann Model



PC: program counter

The Von Neumann Model

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D = A+B*C;
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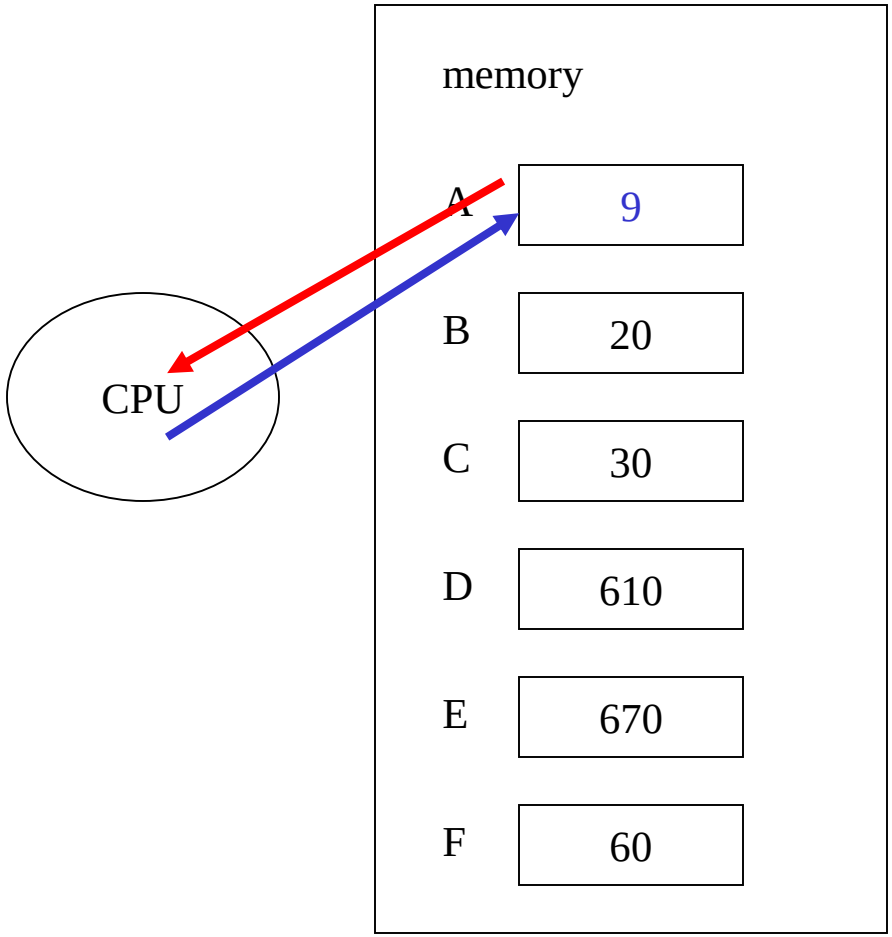
```

PC →

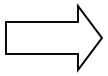
PC: program counter



How a CPU works?

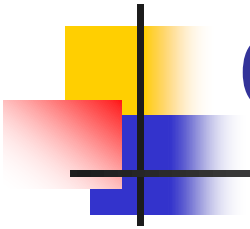
- follow the von Neumann model
  - step by step
  - one *instruction* per step
- but decompose operations into primitive and regular ones

```
D = A+B*C;
E = D+F;
A = A-1;
```



assembly program

```
load R1, A;          //R1 = mem[A];
load R2, B;          //R2 = mem[B];
load R3, C;          //R3 = mem[C];
mult R4, R2, R3;     //R4=R2*R3;
add  R5, R1, R4;     //R5=R1+R4;
store D, R5;         //mem[D] = R5;
load  R6, F;         //R6 = mem[D];
add   R7, R5, R6;    //R7 = R5+R6;
store  E, R7;        //mem[E] = R7;
sub    R1, R1, 1;    //R1 = R1-1;
store  A, R1;        //mem[A] = R1;
```



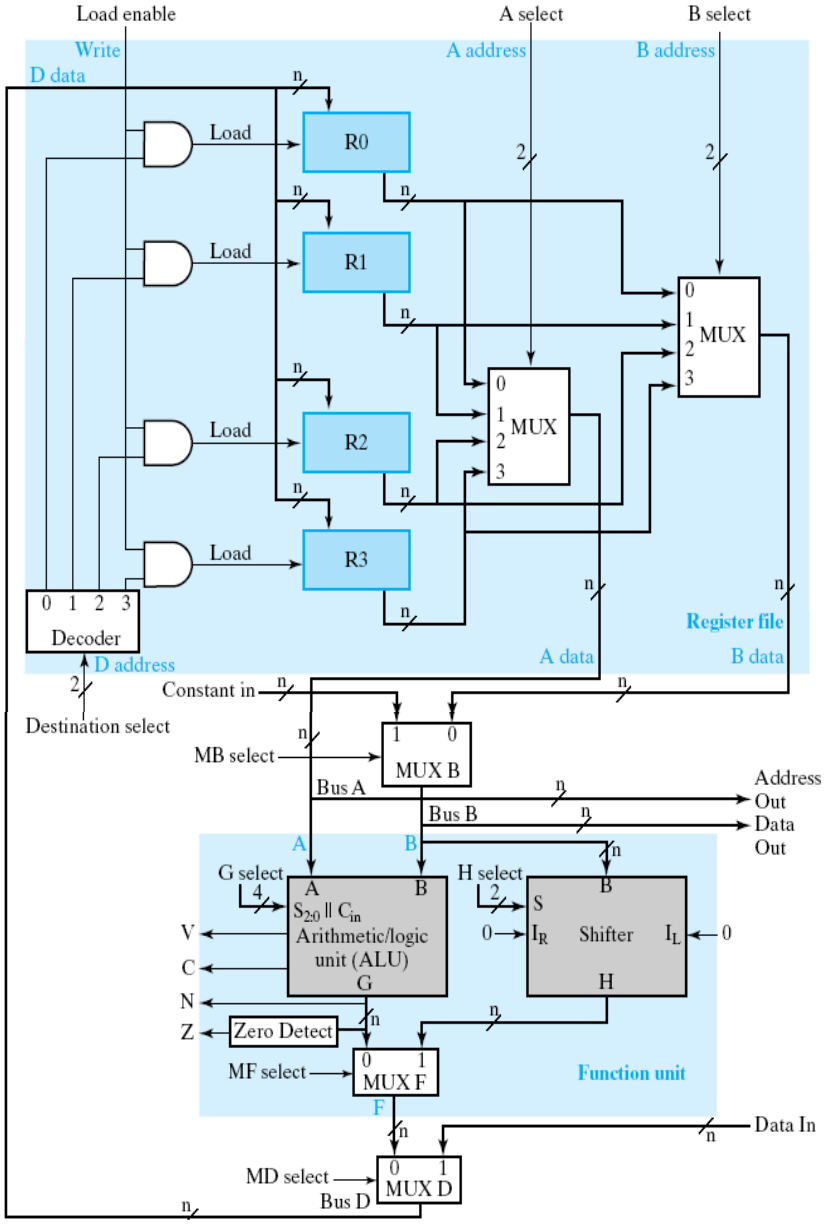
Question

- Q: what's the major difference between assembly programming and high-level language programming?

- A: you have to imagine how hardware works!

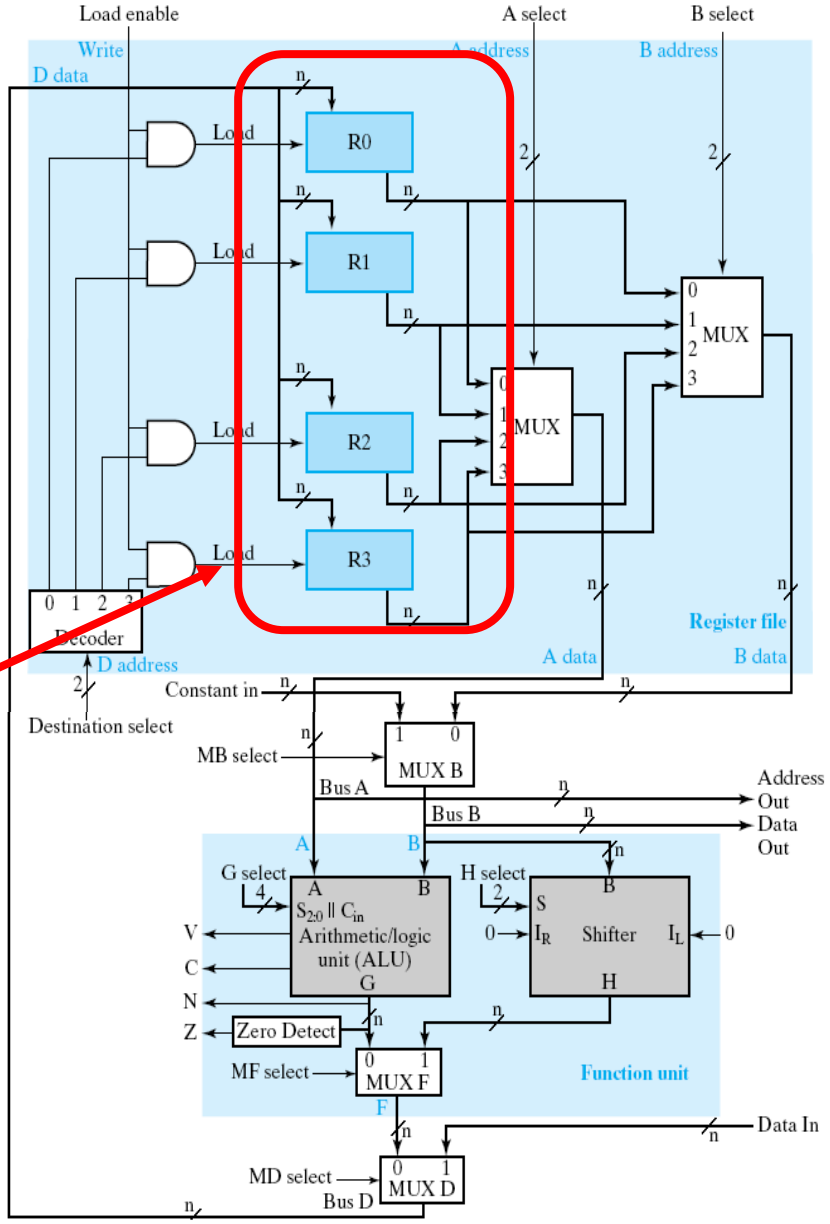
How a CPU works?

- from hardware design perspective
- the data path:



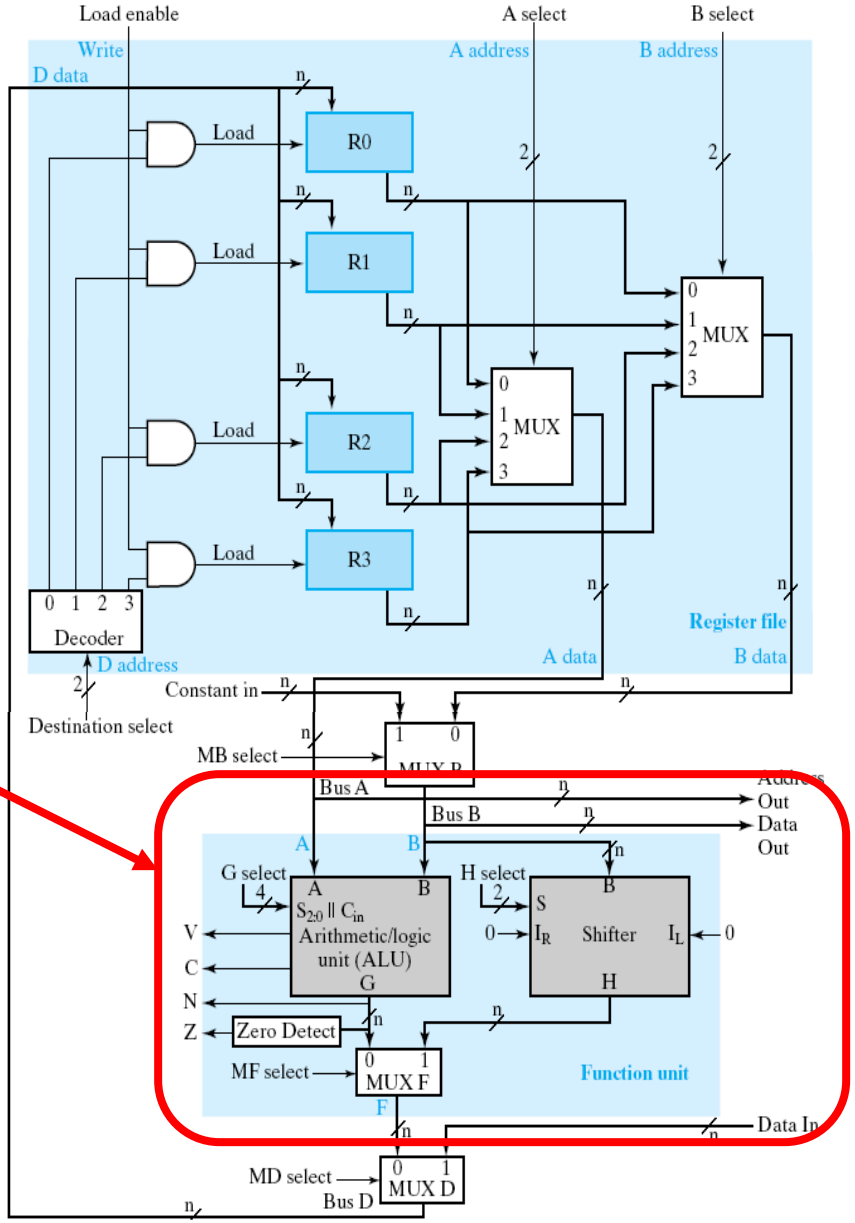
How a CPU works?

- registers to store *variables*



How a CPU works?

- function units to perform computation

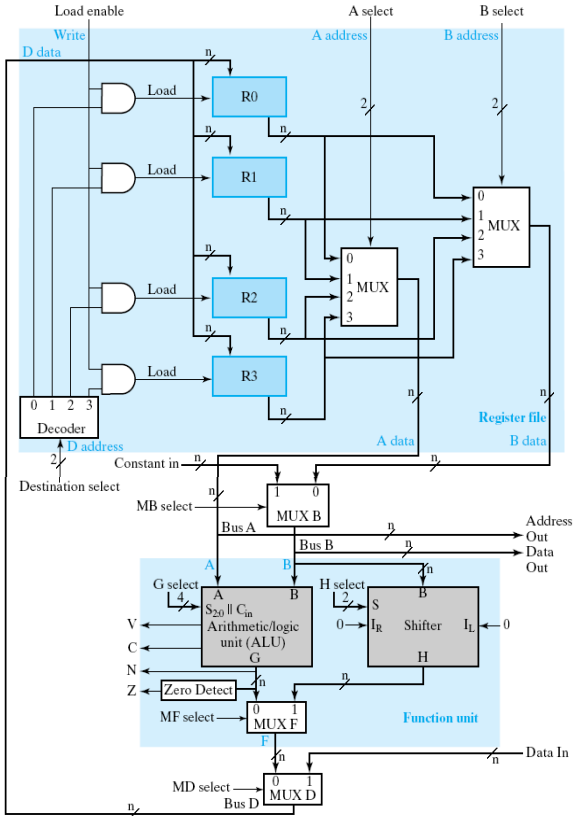


How a CPU works?

- still follows von Neumann model

A = B+C;

```
load R1, B;          //R1 = mem[B];
load R2, C;          //R2 = mem[C];
add R3, R1, R2;      //R3 = R1+R2;
store A, R3;         //mem[A] = R3;
```



memory

A

B

C

How a CPU works?

- still follows von Neumann model

A = B+C;

```
load R1, B;          //R1 = mem[B];
load R2, C;          //R2 = mem[C];
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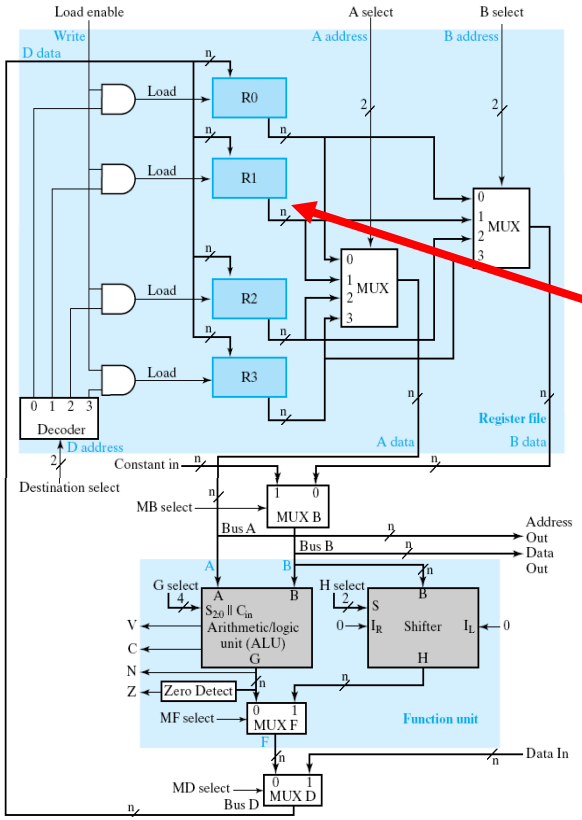

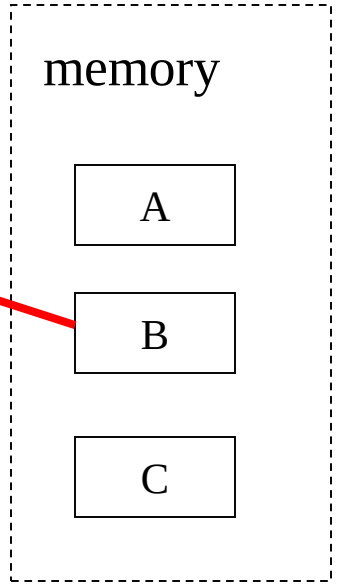

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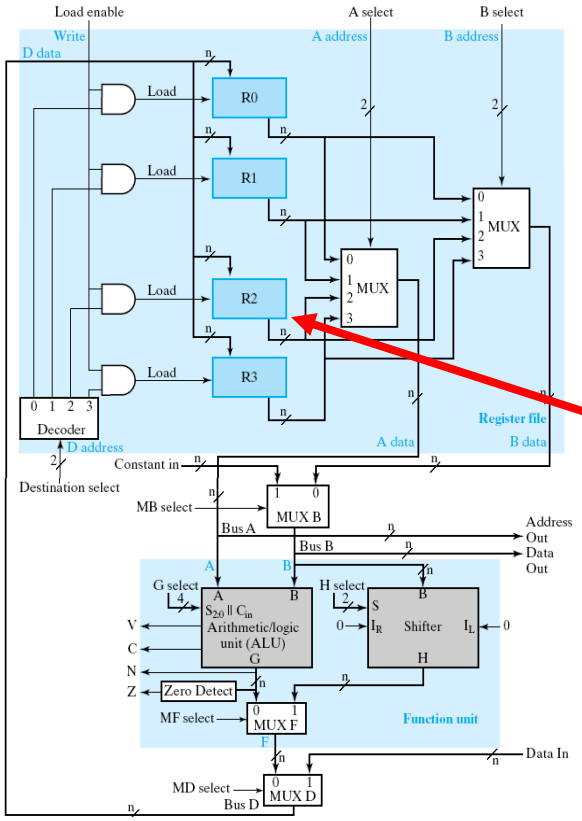
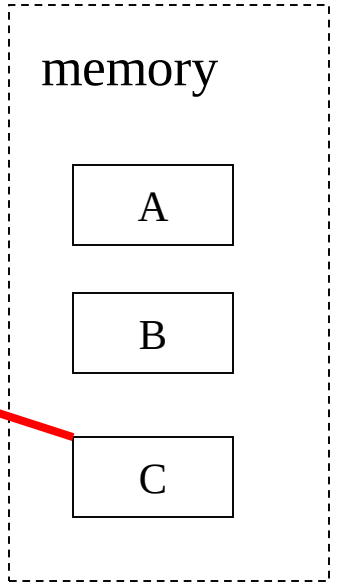


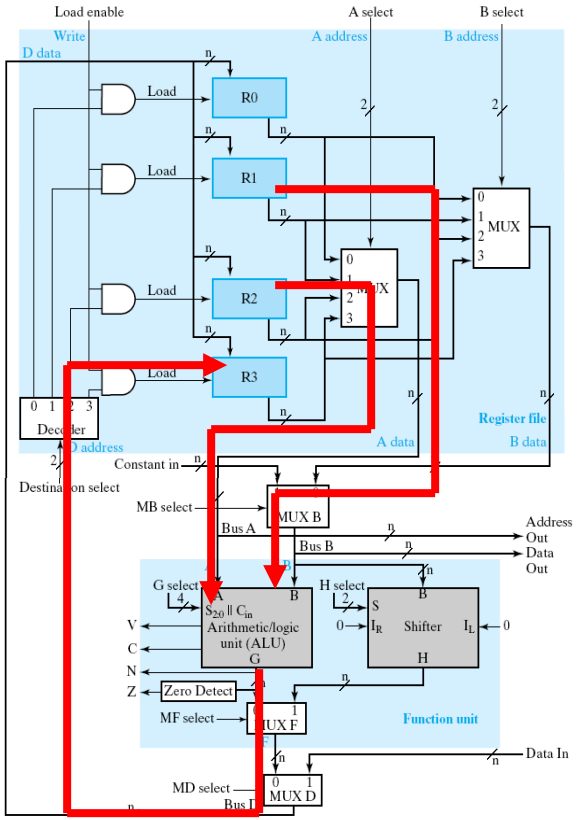


How a CPU works?

- still follows von Neumann model

A = B+C;

```
load R1, B;          //R1 = mem[B];
load R2, C;          //R2 = mem[C];
add R3, R1, R2;      //R3 = R1+R2;
store A, R3;         //mem[A] = R3;
```



memory

A

B

C

How a CPU works?

- still follows von Neumann model

A = B+C;

```
load R1, B;          //R1 = mem[B];
load R2, C;          //R2 = mem[C];
add R3, R1, R2;      //R3 = R1+R2;
store A, R3;         //mem[A] = R3;
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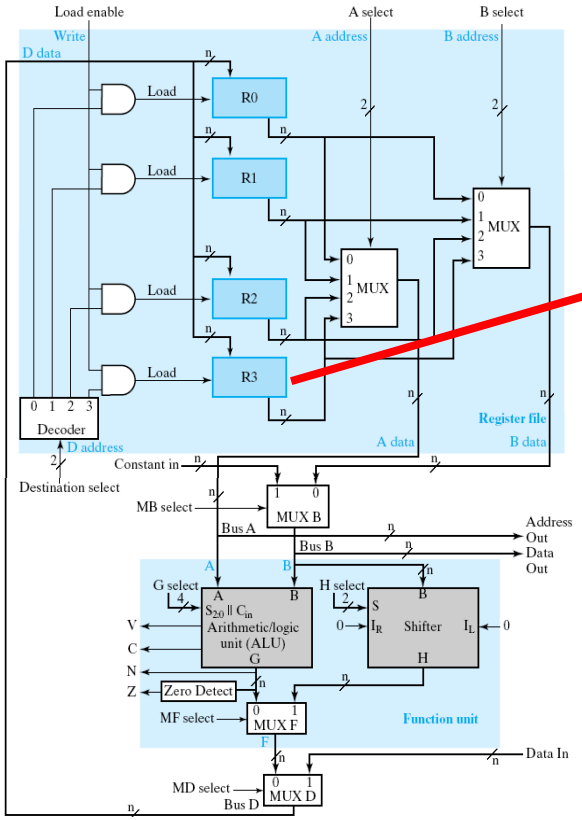
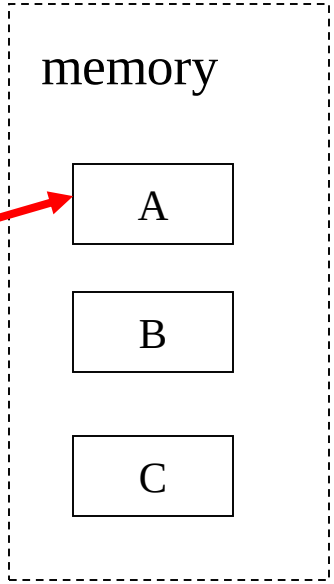
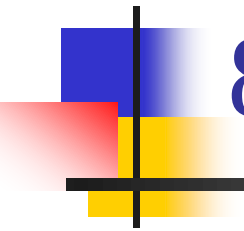


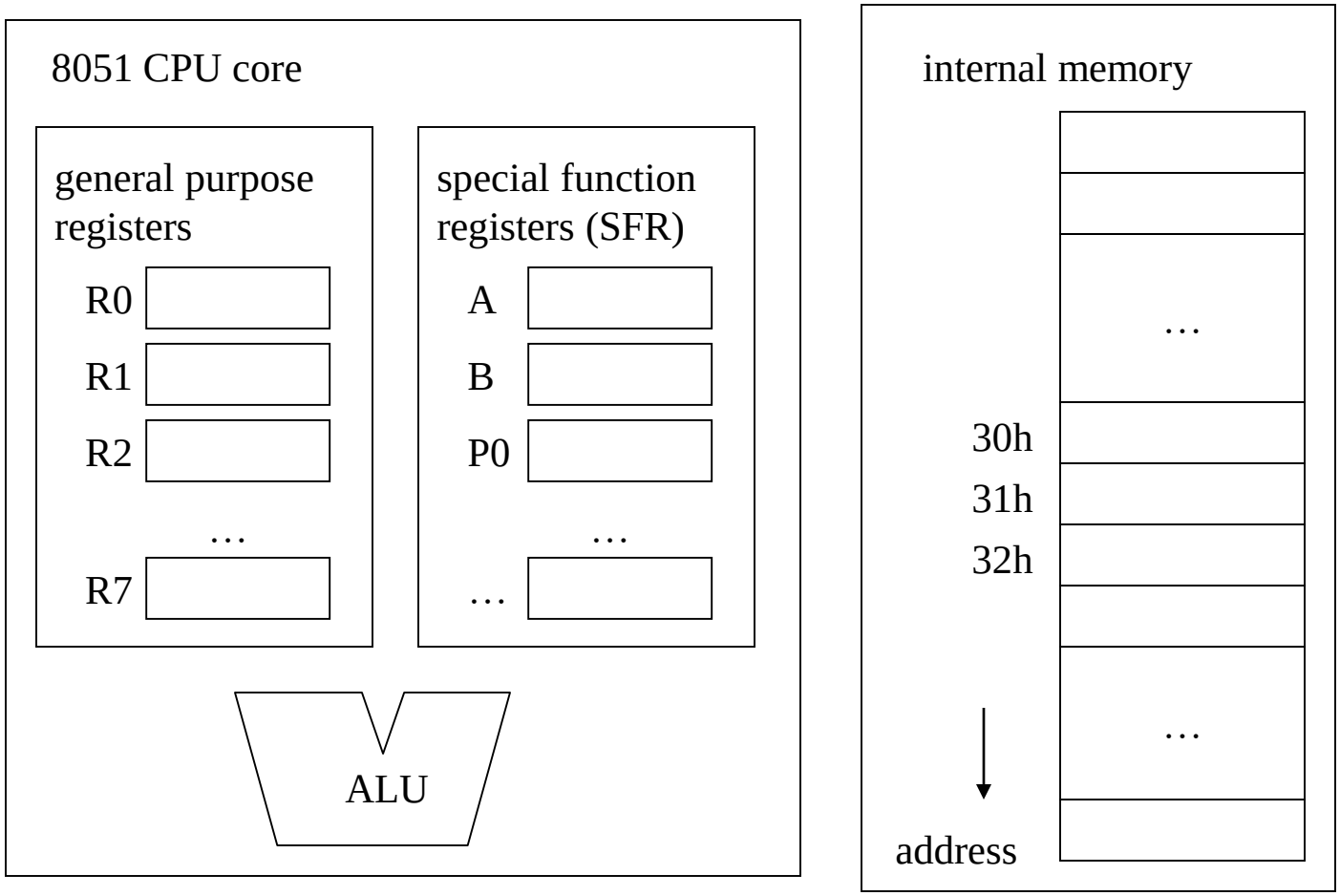




8051 Architecture Model

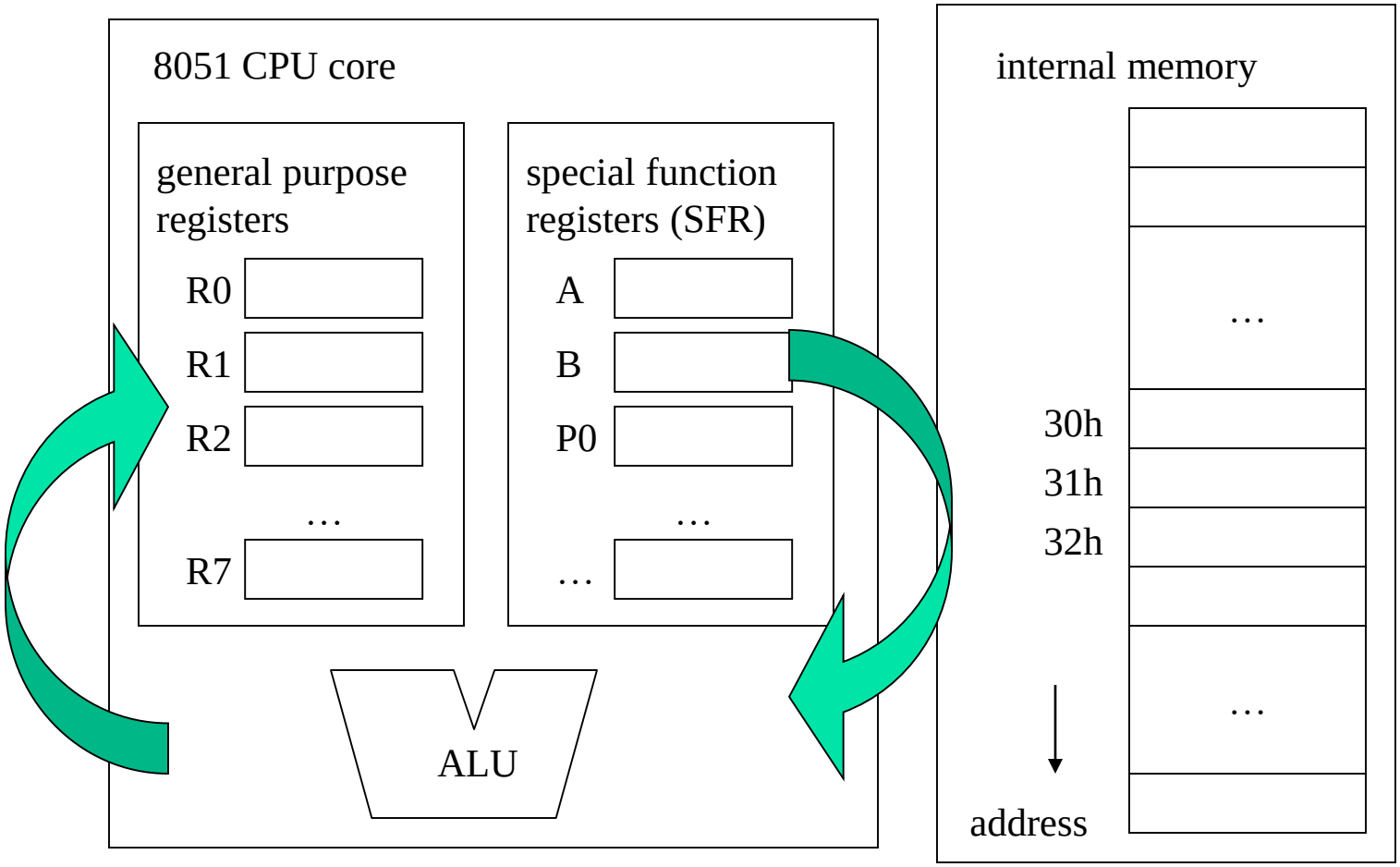
Imagination on 8051 architecture

- Imagine how data flow in the architecture!



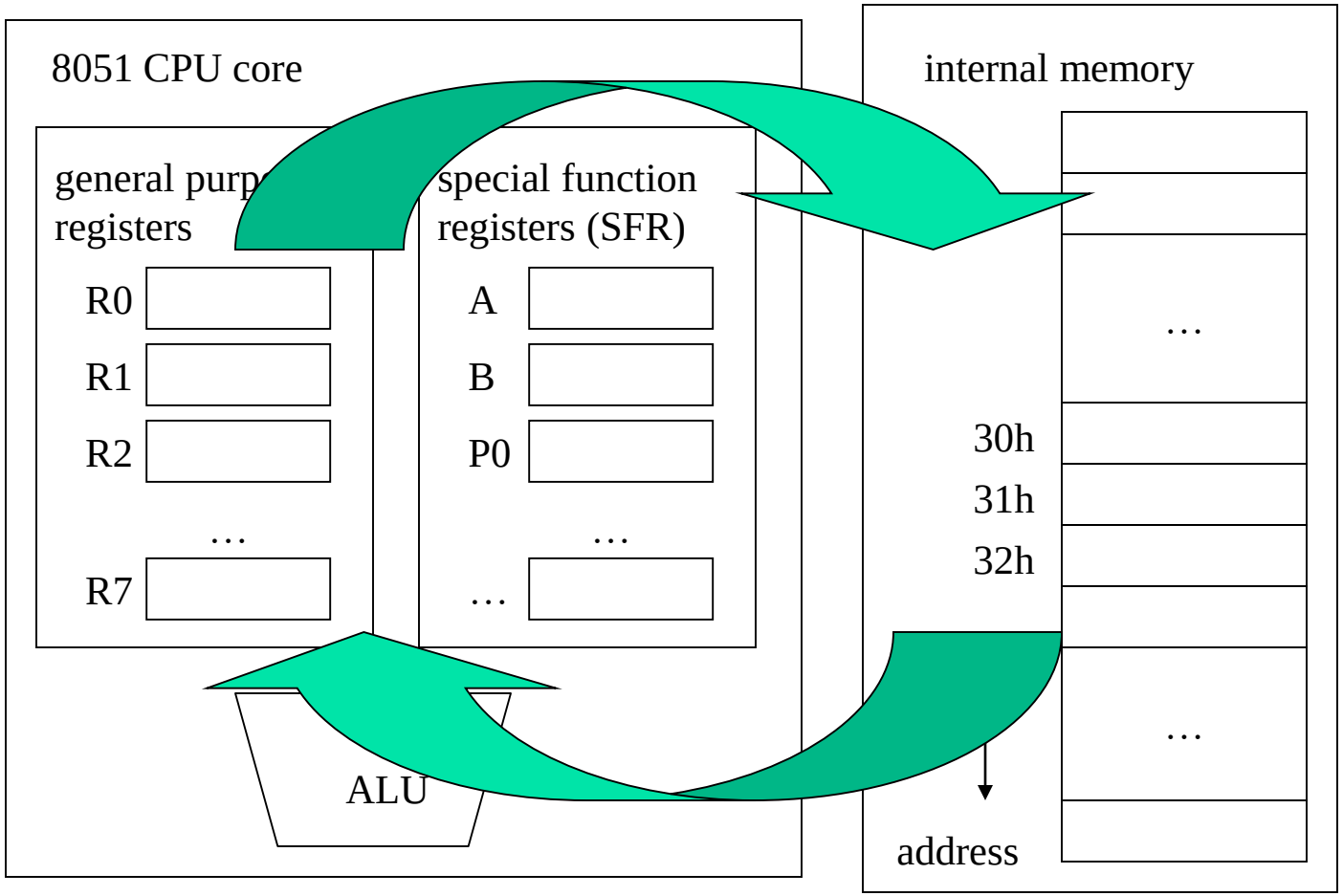
Imagination on 8051 architecture

- flow of an arithmetic instruction



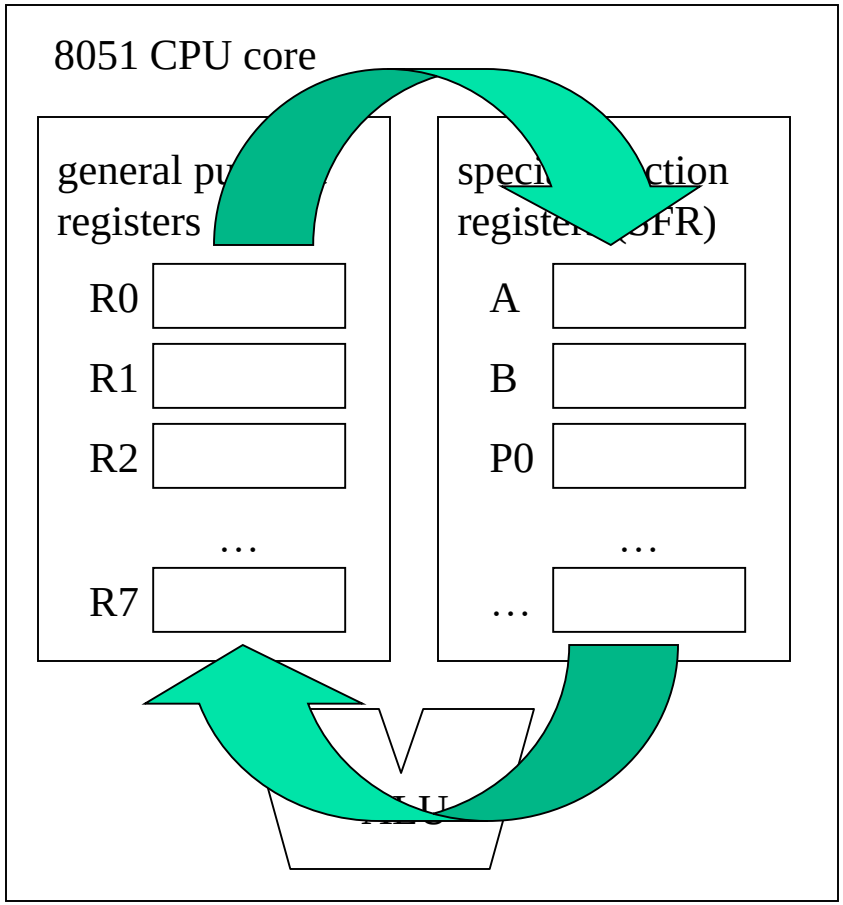
Imagination on 8051 architecture

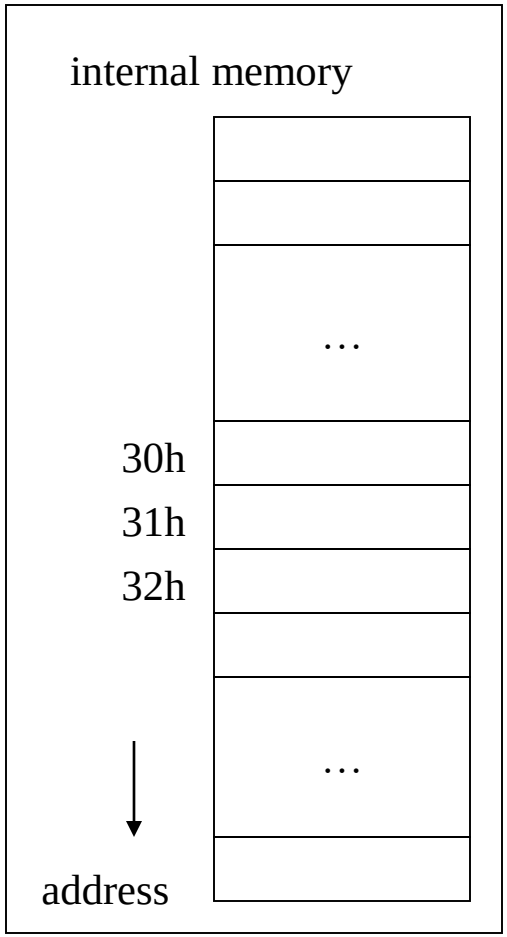
- data movement between memory and registers
- the MOV instruction



Imagination on 8051 architecture

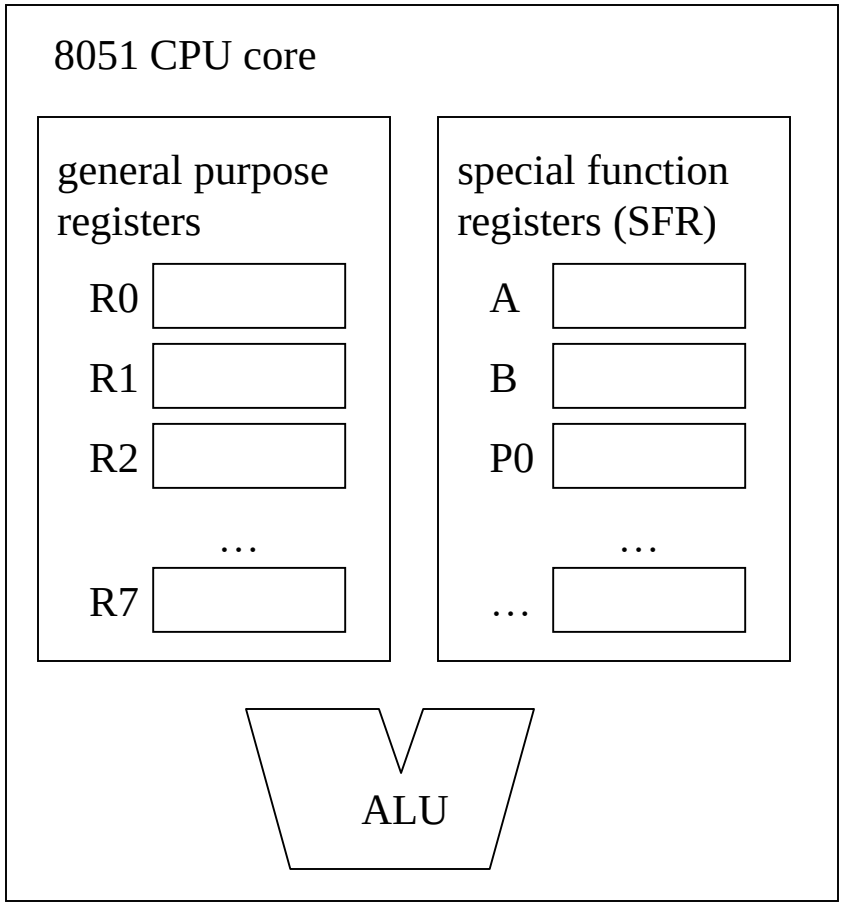
- the MOV also for registers

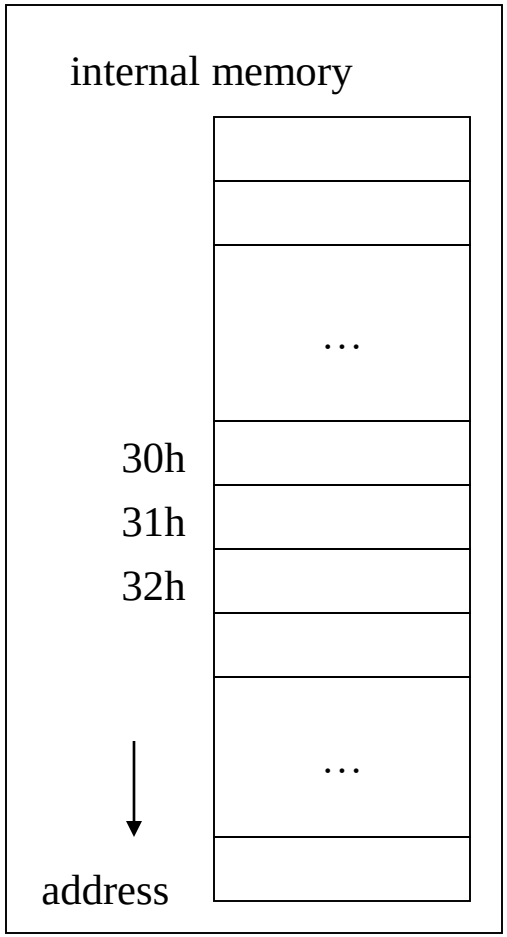




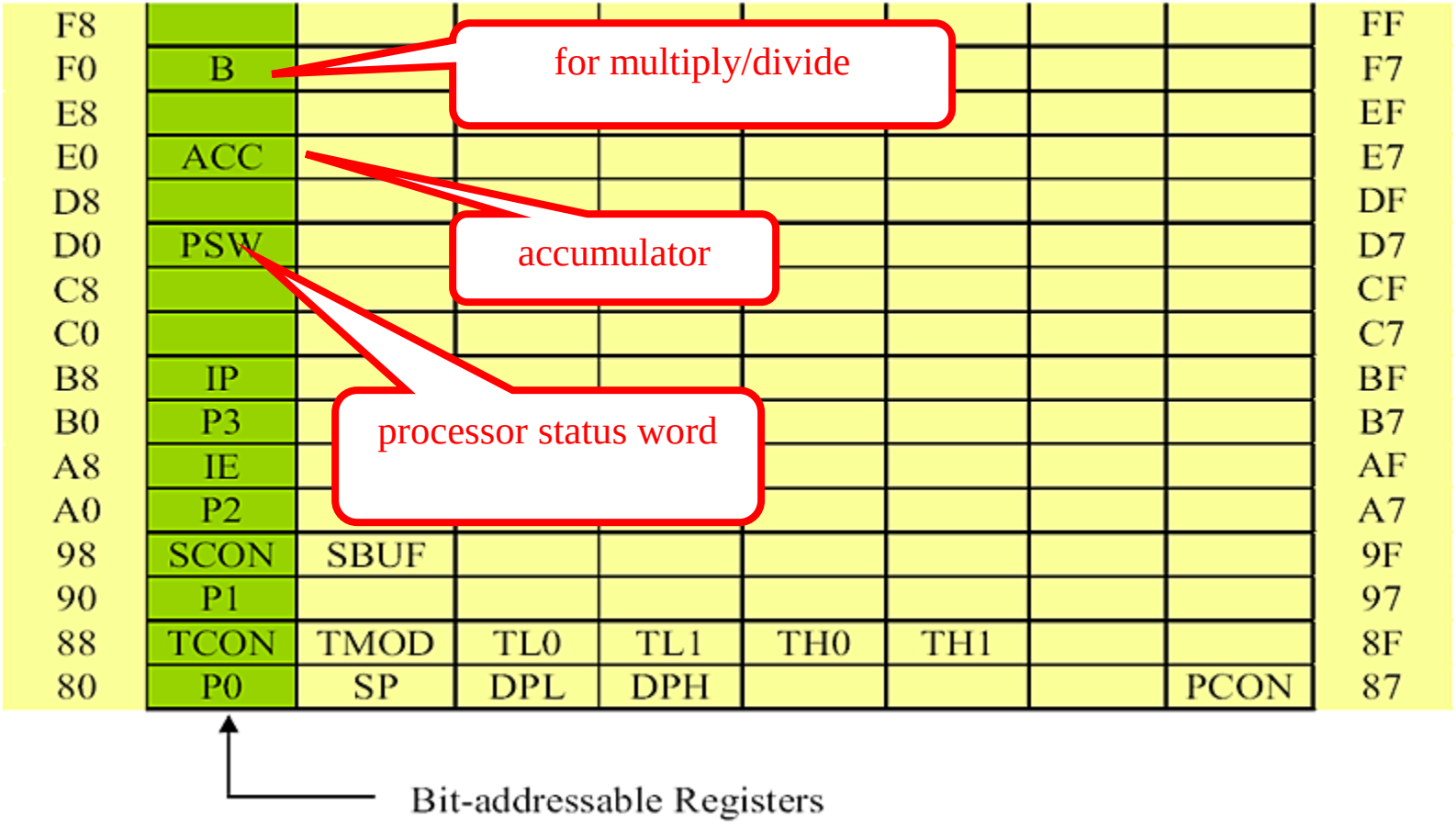
Imagination on 8051 architecture

- Feature: most of instructions have limited use on registers
- Example:
  - ADD uses ACC
  - MUL (multiply) uses A and B

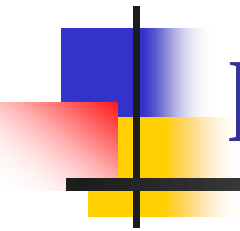




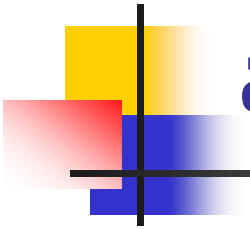
Special Function Registers (SFR)



A first look on 8051 assembly program



Features of 8051 CPU and assembly



- 8-bit data operation
- two-operand assembly instruction
  - Example: ADD A, R1 //A=A+R1

Classification of instructions

- Arithmetic (ADD, SUBB, MUL, etc.)
  - Notice: the use of register
  - e.g. ADD A, R0
  - e.g. MUL AB
- Branch (AJMP, ACALL, RET)
  - Notice: the jump range
- Data Transfer (MOV)
  - direct/indirect addressing mode
- Logical
  - bit-addressible instruction

8051 assembly language looks like

[label:] mnemonic [operands] [;comment]

```
ORG   0H                    ;start (origin) at location 0
          MOV  R5,#25H      ;load 25H into R5
          MOV  R7,#34H      ;load 34H into R7
          MOV  A,#0         ;load 0 into A
          ADD  A,R5         ;add contents of R5 to A
                            ;now A = A + R5
          ADD  A,R7         ;add contents of R7 to A
                            ;now A = A + R7
          ADD  A,#12H       ;add to A value 12H
                            ;now A = A + 12H
HERE: SJMP HERE             ;stay in this loop
           END              ;end of asm source file
```

8051 assembly language looks like

general form

```
[label:]    mnemonic   [operands]      [;comment]
```

```
ORG   0H                        ;start (origin) at location 0
          MOV  R5,#25H          ;load 25H into R5
          MOV  R7,#34H          ;load 34H into R7
          MOV  A,#0                  ;load 0 into A
          ADD  A,R5                  ;add contents of R5 to A
                                     ;now A = A + R5
          ADD  A,R7                  ;add contents of R7 to A
                                     ;now A = A + R7
          ADD  A,#12H                ;add to A value 12H
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      ADD  A,R5             ;add contents of R5 to A
                            ;now A = A + R5
      ADD  A,R7             ;add contents of R7 to A
                            ;now A = A + R7
      ADD  A,#12H           ;add to A value 12H
                            ;now A = A + 12H
HERE: SJMP HERE             ;stay in this loop
      END                   ;end of asm source file
```

R7=0x34

8051 assembly language looks like

```
[label:]    mnemonic   [operands]      [;comment]

ORG   0H                          ;start (origin) at location 0
          MOV  R5,#25H            ;load 25H into R5
          MOV  R7,#34H            ;load 34H into R7
          MOV  A,#0               ;load 0 into A
          ADD  A,R5               ;add contents of R5 to A
                                  ;now A = A + R5
          ADD  A,R7                                    o A
                                  ;
          ADD  A,#12H             ;add to A value 12H
                                  ;now A = A + 12H
HERE: SJMP HERE                ;stay in this loop
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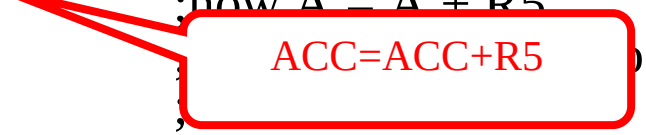
```



8051 assembly language looks like

[label:] mnemonic [operands] [;comment]

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        MOV  R5,#25H        ;load 25H into R5
        MOV  R7,#34H        ;load 34H into R7
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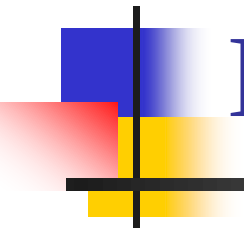
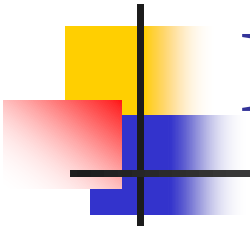
        ADD  A,R5           ;add contents of R5 to A
                            ;now A = A + R5
        ADD  A,R7           ;add contents of R7 to A
                            ;now A = A + R7
        ADD  A,#12H         ;add to A value 12H
                            ;now A = A + 12H
HERE: SJMP HERE         ;stay in this loop
        END                 ;end of asm source file
```

goto HERE



Example 1: d=a*b+c



In-Class Exercise

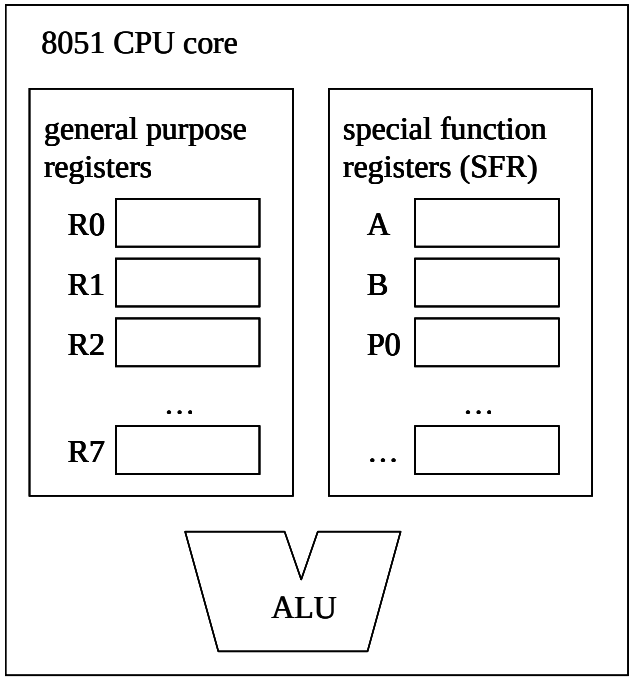
- write the program d=a*b+c
  - where a, b, c are originally in the memory
- Hint: 8051 instructions needed
  - add
  - mul (multiplication)
  - inc (increment)
  - mov (move)
- Check the instruction reference manual for restrictions on using register operands!

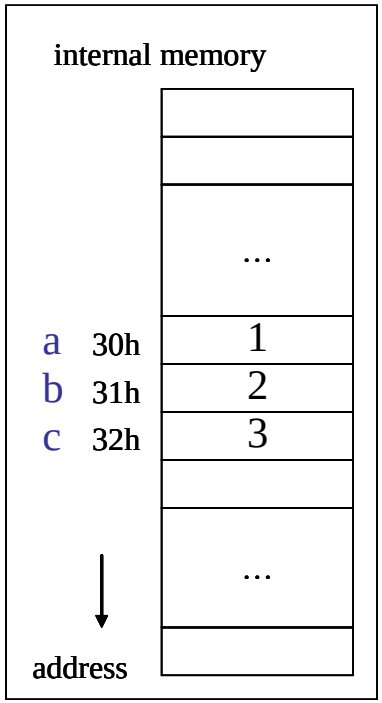
Example: d=a*b+c

```
        mov     R1, #30h    ; R1=30
        mov     A, @R1      ; A=mem[R1]
        inc     R1          ; R1++
        mov     B, @R1      ; B=mem[R1]
        inc     R1          ; R1++
        mov     R0, @R1     ; R0=mem[R1]=C

        mul     AB          ;{A,B} = A*B
        add     A, R0       ; A=A+R0

wait:
        sjmp    wait
```





Example: d=a*b+c

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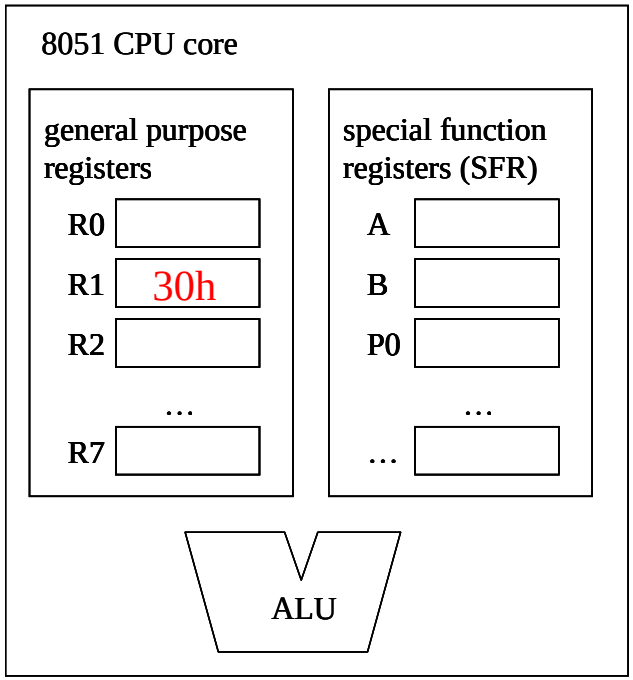
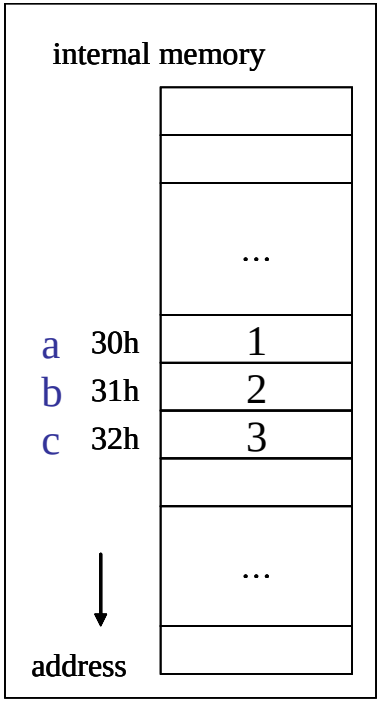
        mov     R1, #30h    ; R1=30
        mov     A, @R1      ; A=mem[R1]
        inc     R1          ; R1++
        mov     B, @R1      ; B=mem[R1]
        inc     R1          ; R1++
        mov     R0, @R1     ; R0=mem[R1]=C

        mul     AB          ;{A,B} = A*B
        add     A, R0       ; A=A+R0

wait:
        sjmp    wait
```



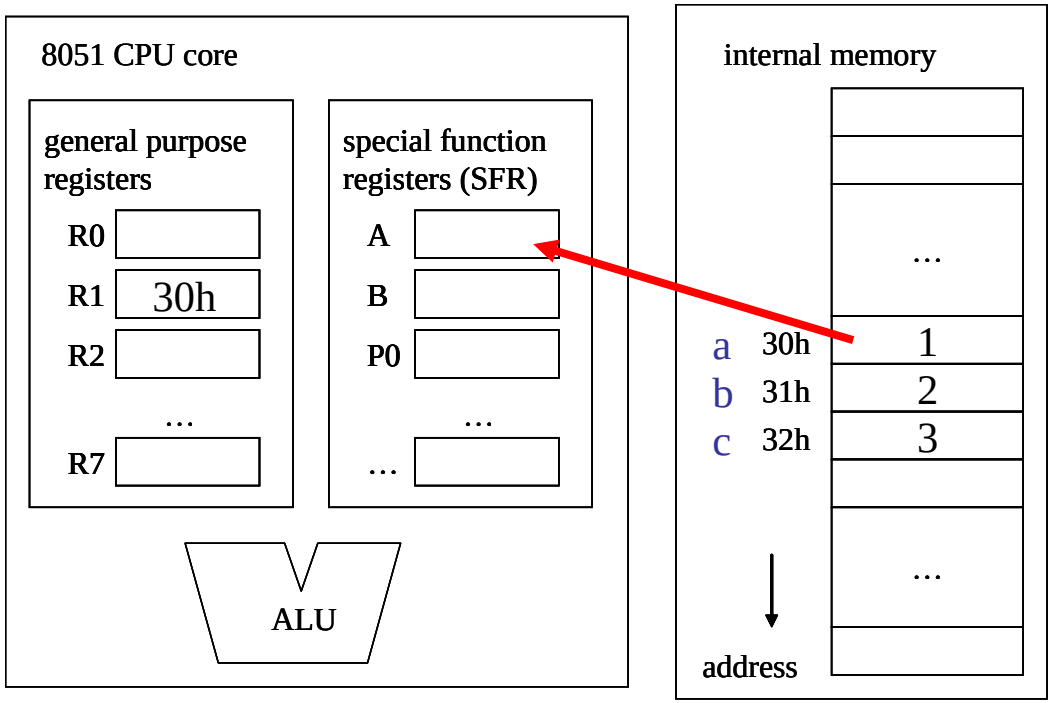


Example: d=a*b+c

```
        mov     R1, #30h    ; R1=30
        mov     A, @R1      ; A=mem[R1]
        inc     R1          ; R1++
        mov     B, @R1      ; B=mem[R1]
        inc     R1          ; R1++
        mov     R0, @R1     ; R0=mem[R1]=C

        mul     AB          ;{A,B} = A*B
        add     A, R0       ; A=A+R0

wait:
        sjmp    wait
```



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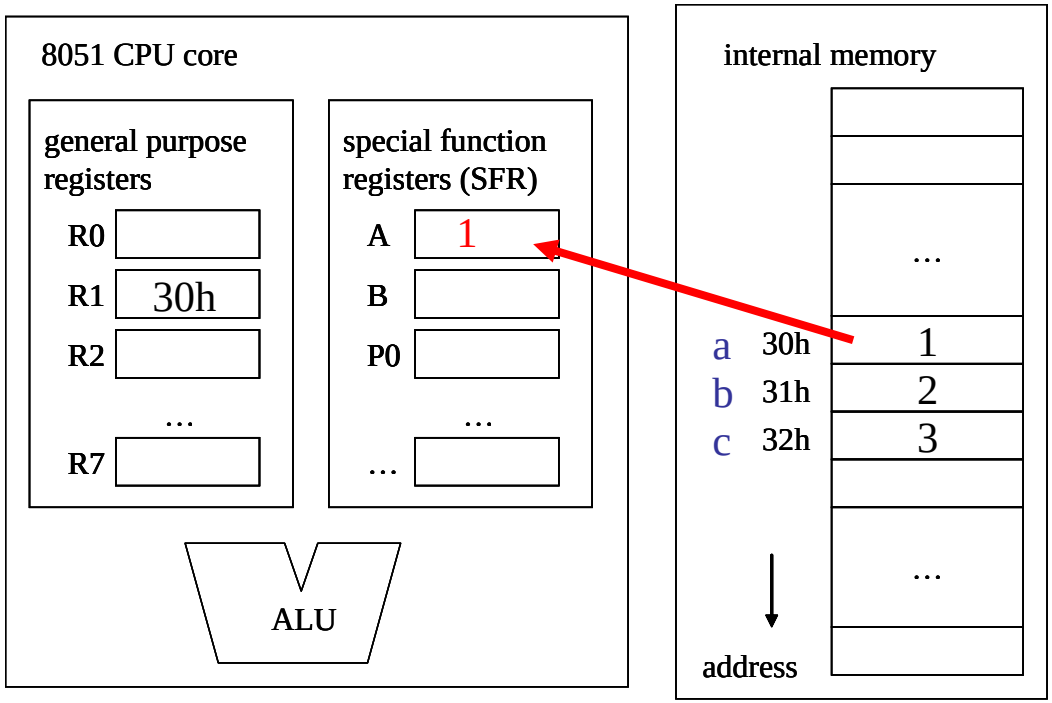

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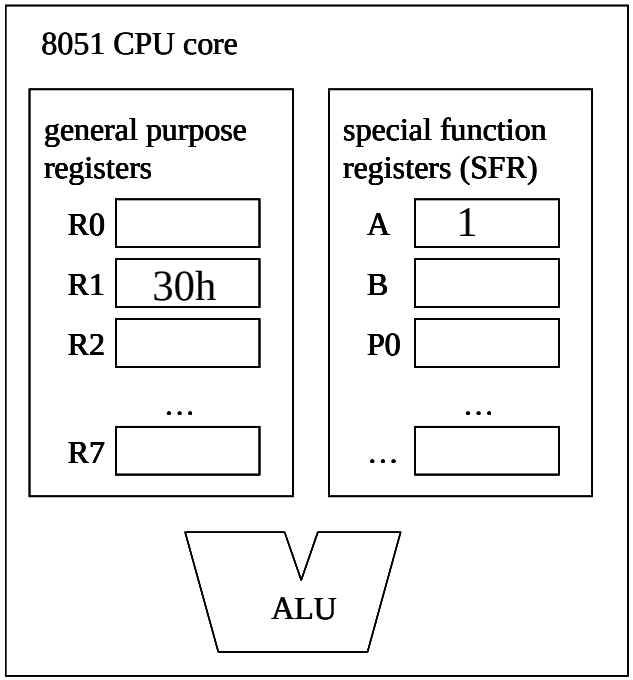

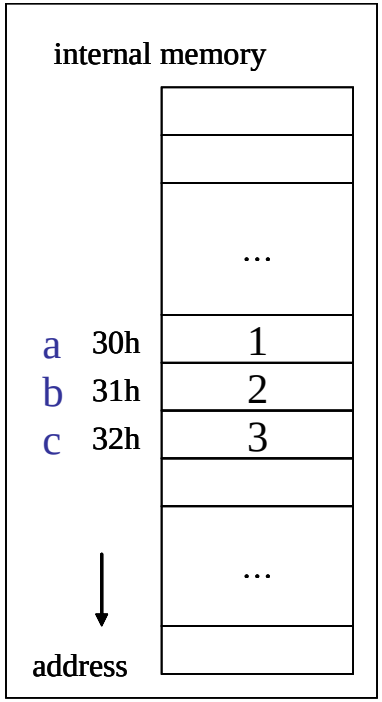

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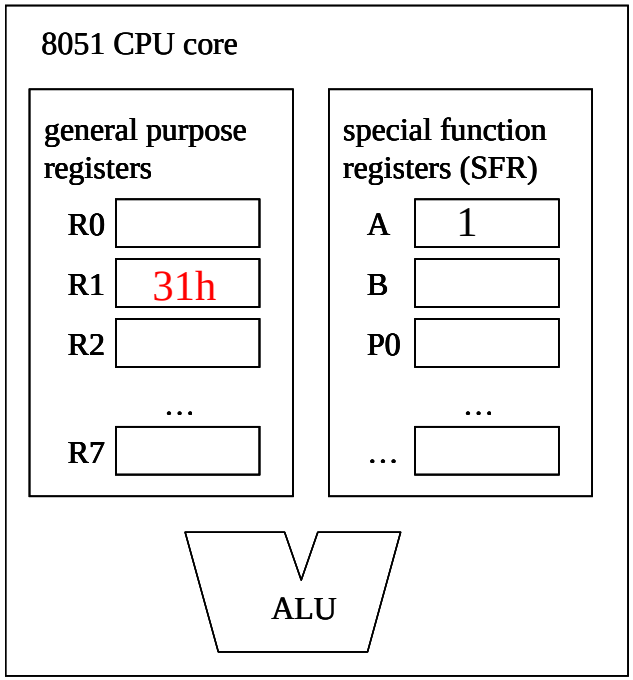

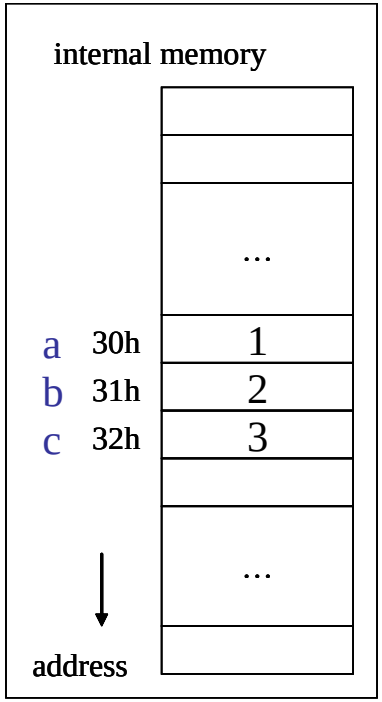

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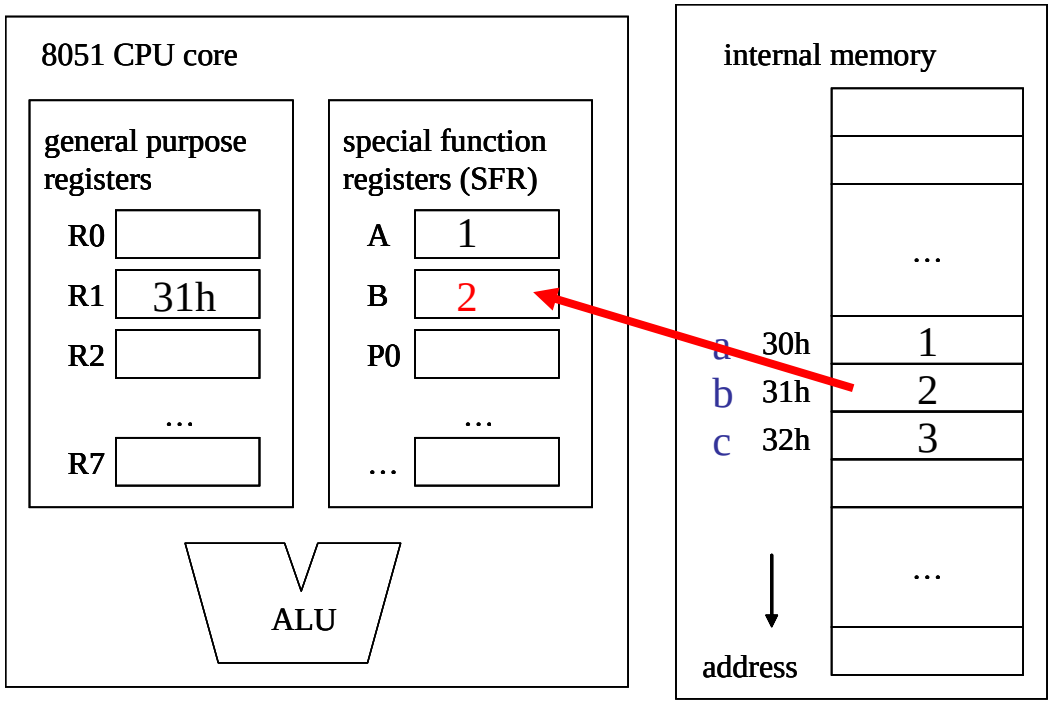

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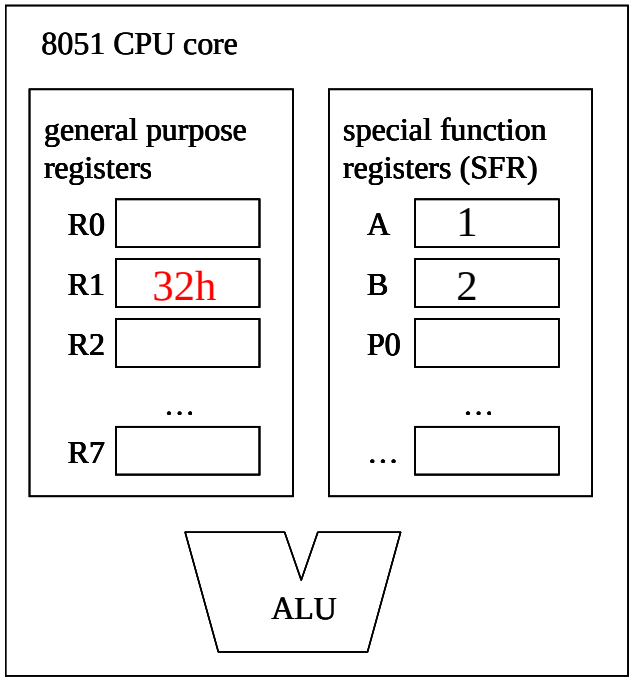

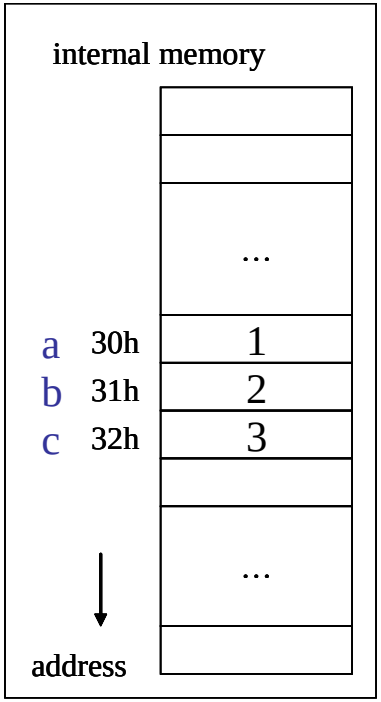

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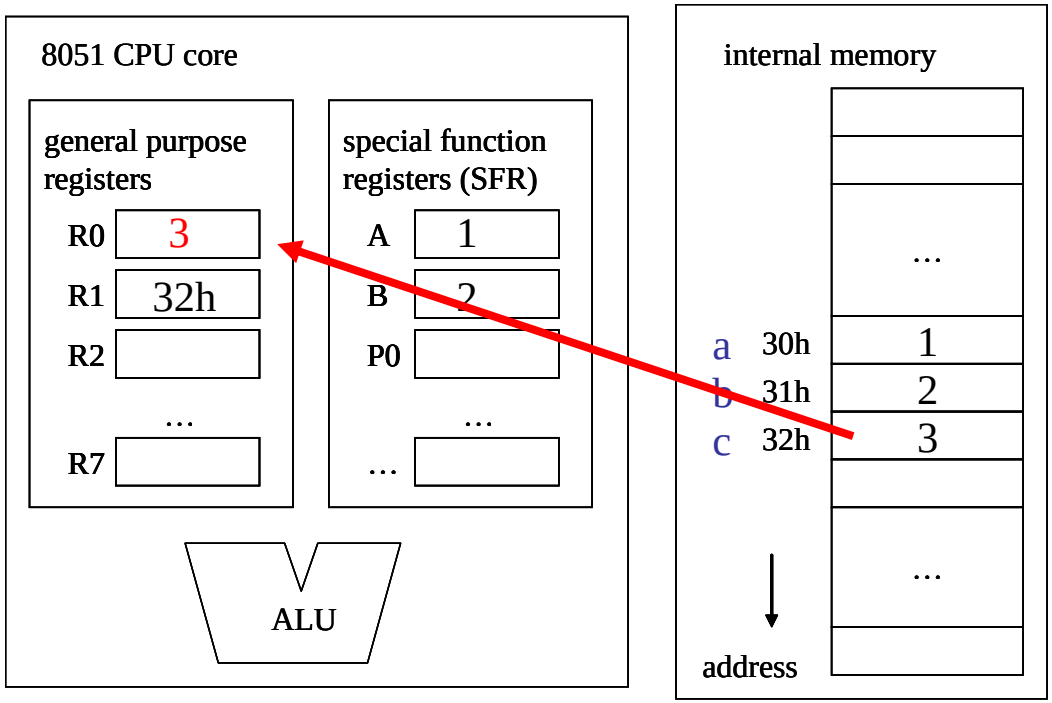

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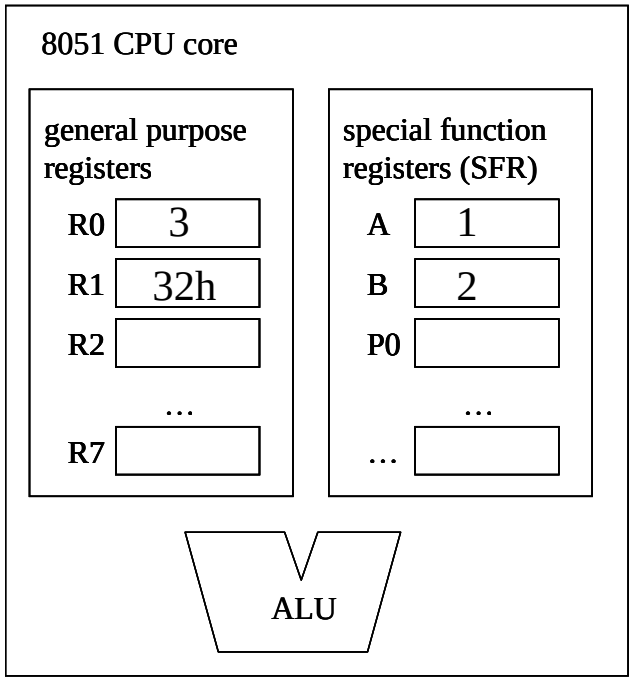

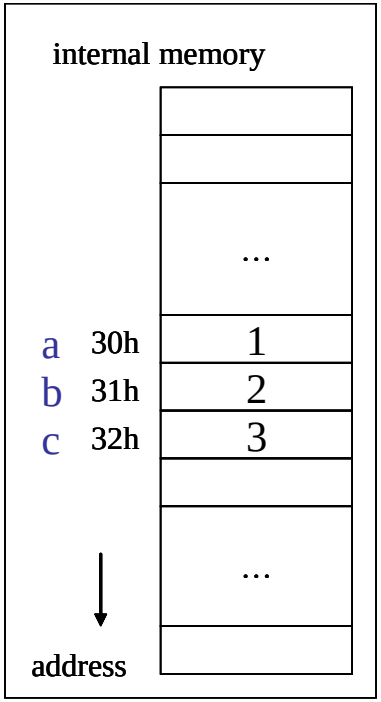

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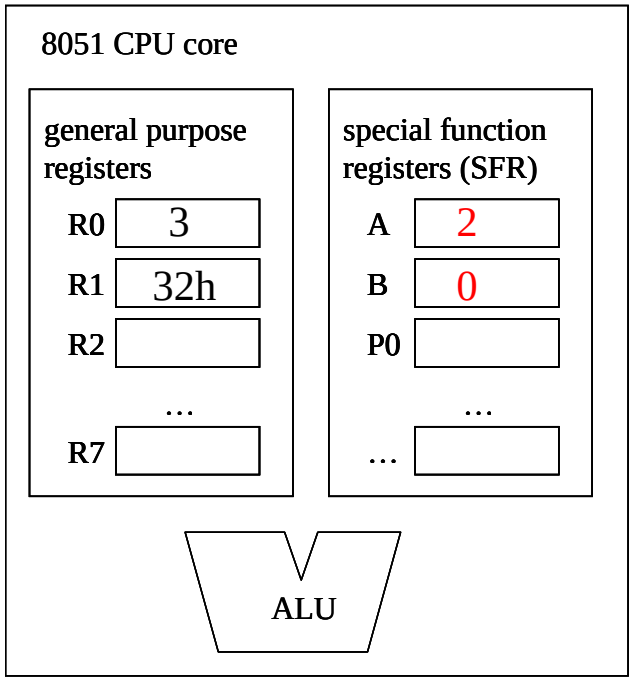

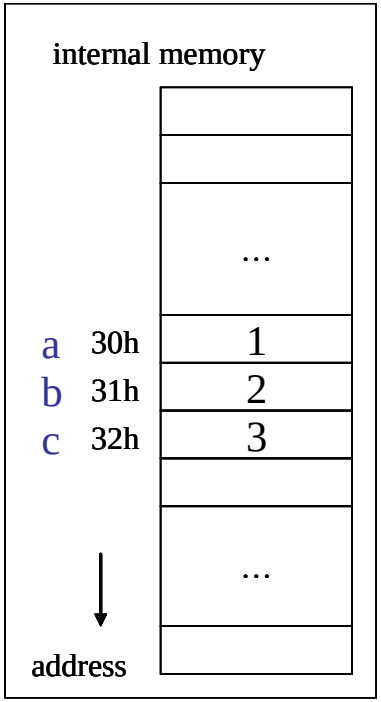

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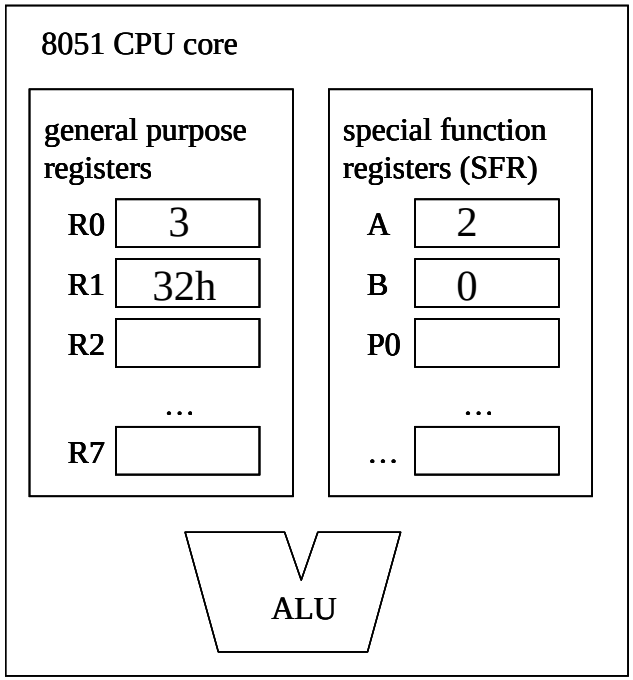

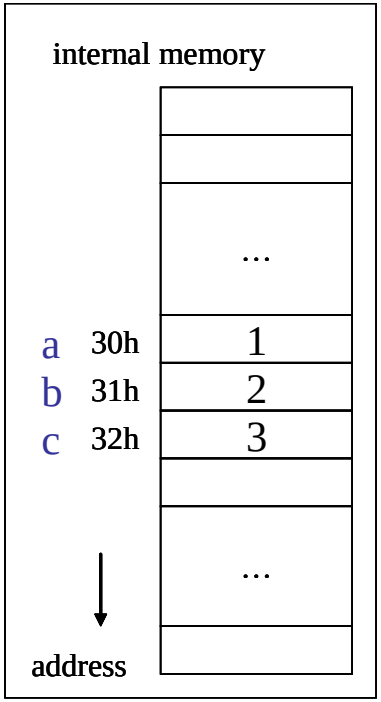

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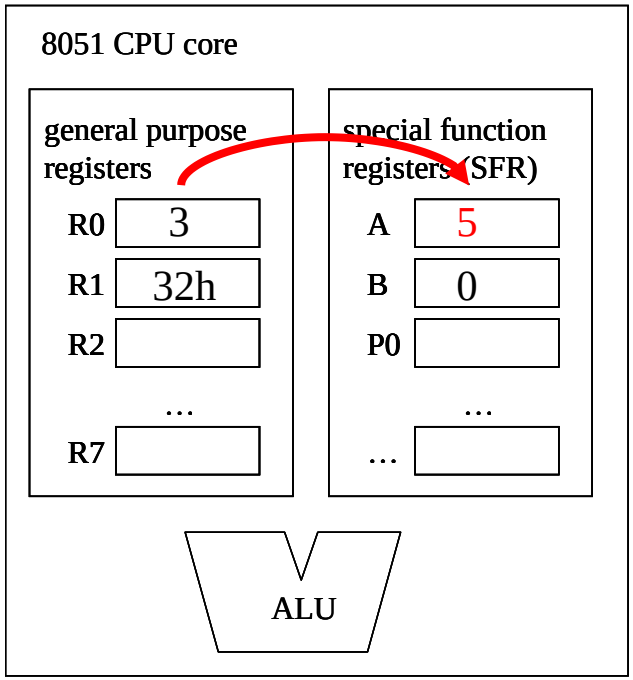
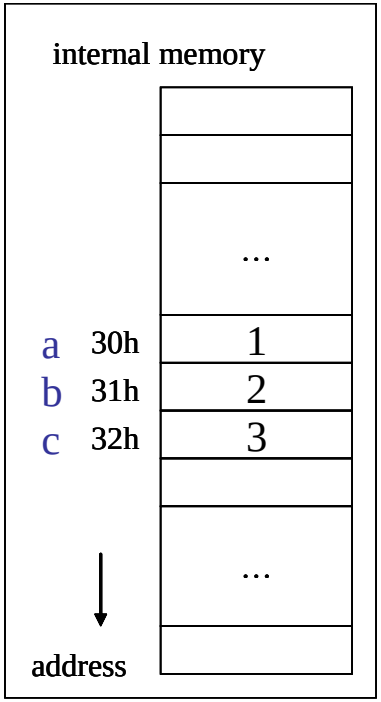
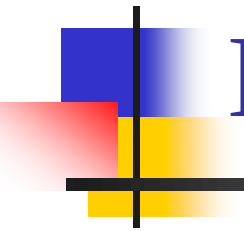


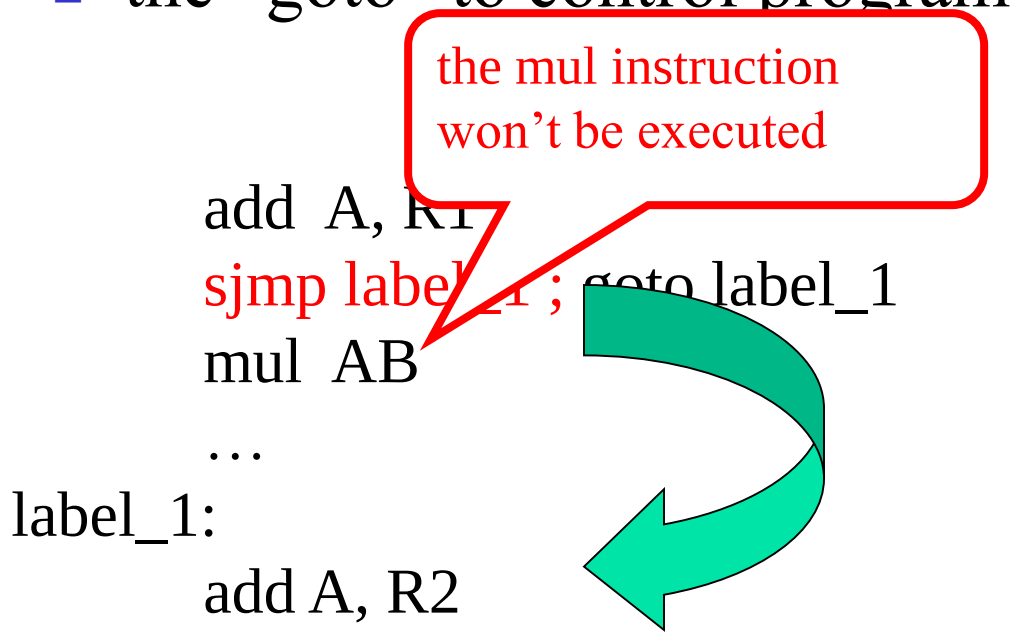




Branch (Jump) Instruction

What is a branch/jump instruction

- the “goto” to control program execution path

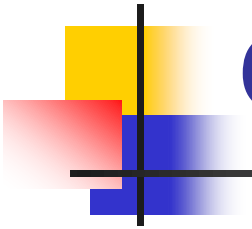


Frequently used branch instructions of 8051

LJMP addr16	Long jump	3	4
SJMP rel	Short jump (from –128 to +127 locations relative to the following instruction)	2	3
JC rel	Jump if carry flag is set. Short jump.	2	3
JNC rel	Jump if carry flag is not set. Short jump.	2	3
JB bit,rel	Jump if direct bit is set. Short jump.	3	4
JBC bit,rel	Jump if direct bit is set and clears bit. Short jump.	3	4
JMP @A+DPTR	Jump indirect relative to the DPTR	1	2
JZ rel	Jump if the accumulator is zero. Short jump.	2	3
JNZ rel	Jump if the accumulator is not zero. Short jump.	2	3

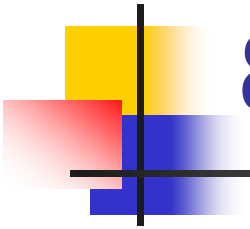
for more, check http://www.mikroe.com/en/books/8051book/ch3/

Conditional Branch Instructions



- JC: Jump if Carry=1
- JNC: Jump if Carry=0
- JZ: Jump if A=0
- JNZ: Jump if A!=0
- DJNZ Rn, location
  - Rn = Rn-1
  - jump if Rn!=0

How conditional branch works in 8051?



- an arithmetic instruction sets bits in PSW
- the conditional branch checks bits in PSW to determine whether to jump or not

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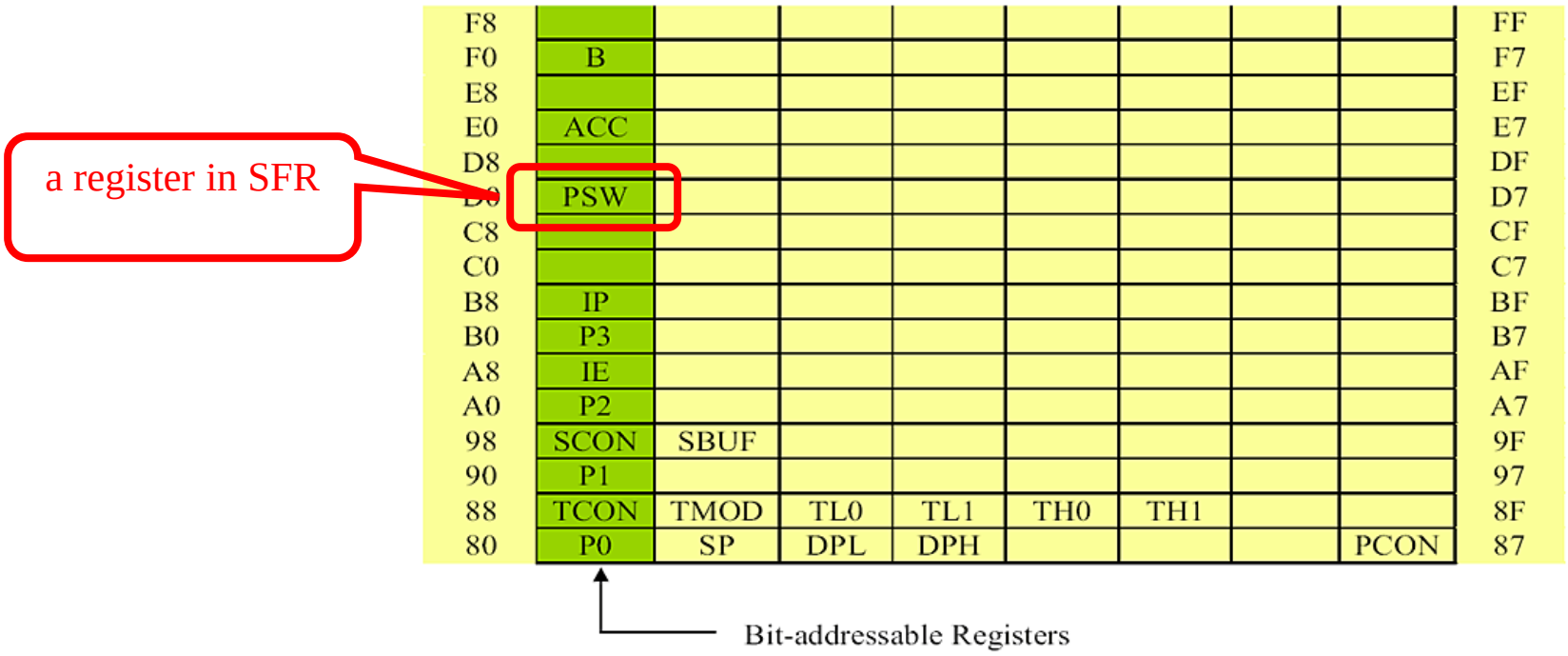

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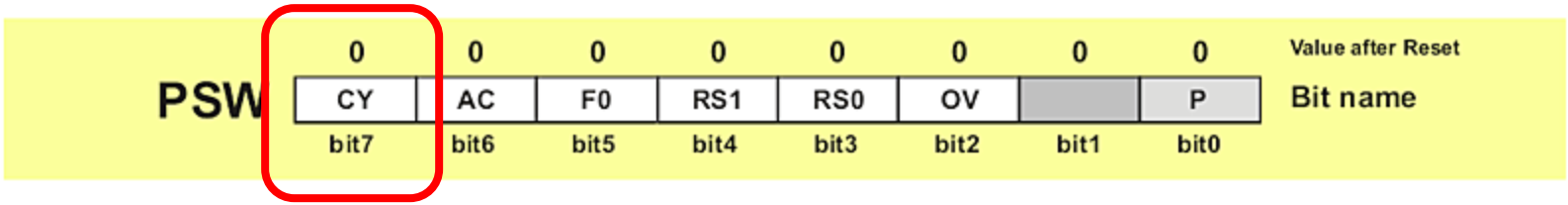
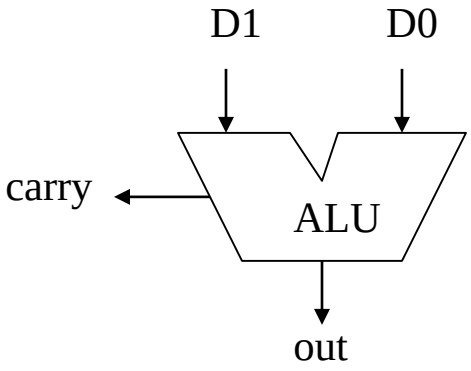
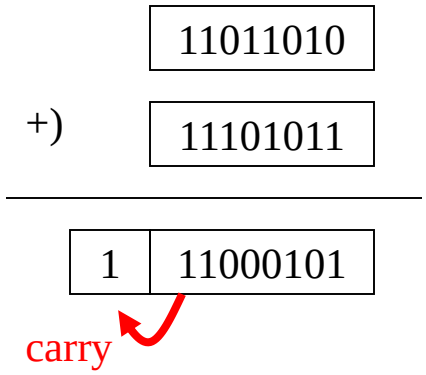
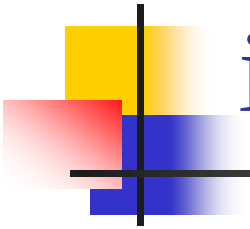


carry flag set by ALU





Example of conditional branch instruction



- JC *label*
  - if (C==1) goto *label*
- JNC *label*
  - if (C==0) goto *label*

In-Class Exercise

- write the program:

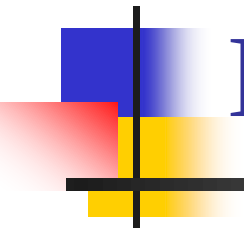
```
if (R0+R1>0xff)
    A = 0xff;
else
    A = R0+R1
```

Example: using JNC

```
if (R0+R1>0xff)
    A = 0xff;
else
    A = R0+R1
```

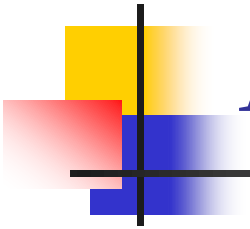
```
            A = R0;
            A = A+R1;  //implicitly set C
            if (C==0) goto exit;
            A = 0xff;
exit:
            …
```

```
            mov     A, R0
            add     A, R1
            JNC     exit
            mov     A, #ffh
exit:
            …
```



Example: a simple for loop

A useful instruction



- DJNZ Rn, location
  - Rn = Rn-1
  - jump if Rn!=0

Loop example

```
sum = 0;

for (i=10;i>0;i--)
    sum = sum+i;
```

```
            A = 0;        //A is sum
            R0 = 10;      //R0 is i

loop_start:
            A = A+R0;
            if (--R0) goto loop_start;
```

```
                  mov       A, #0
                  mov       R0, #10

loop_start:
                  add       A, R0
                  djnz      R0, loop_start
```

Now you should be able to do your work

- write a program to compute

$$S = \sum_{i=0}^{N-1} A[i] * B[i]$$

  - where A[i], B[i] are integer array (8-bit) in 8051's internal memory
- instructions you may use:
  - ADD (addition)
  - MUL (multiply)
  - MOV (move data)
  - DJNZ (decrement and jump if not zero)
- Check the instruction reference manual!

Lab01 Study Report

- File name: Bxxxxxxx-MCE-Lab1-Study
- File type: PDF only
- The requirements of report
  - Summarize the content of this slide set
  - Provide your plan for this lab exercise
  - No more than one A4 page
  - Grading: 80 ± 15
- Deadline: 2021/10/13 23:00 (不收遲交)
- Upload to e-learning system

Lab01 Lab Exercise Report

- File name: Bxxxxxxx-MCE-Lab1-Result
- File type: PDF only
- The requirements of report
  - Summarize the problems and results you have in this exercise
  - Some screen shots or some code explanation can be provdied
  - No more than two A4 pages
  - Grading: 80 ± 15
- Deadline: 2021/10/20 23:00 (不收遲交)
- Upload to e-learning system