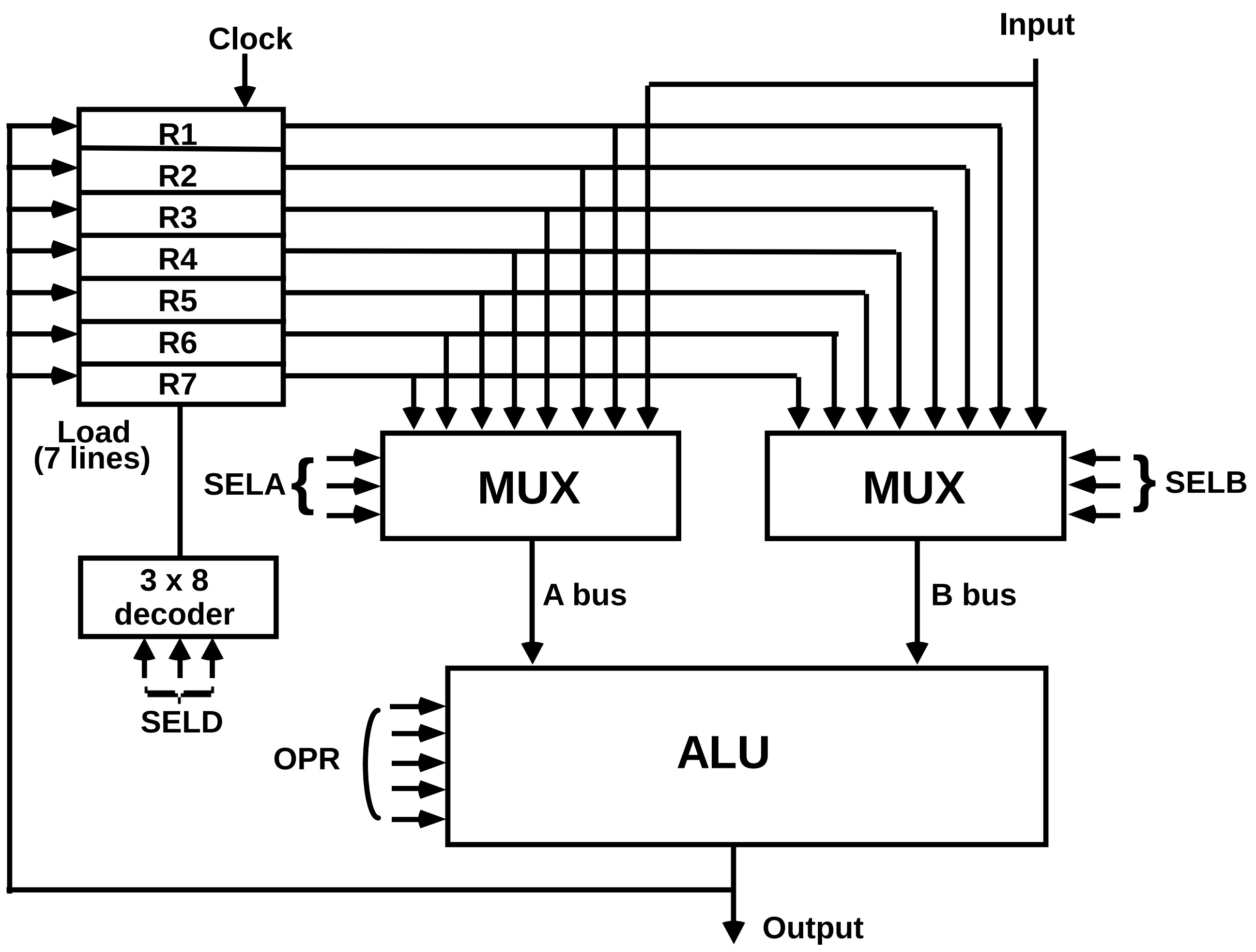
GENERAL REGISTER ORGANIZATION



OPERATION OF CONTROL UNIT

The control unit directs the information flow through ALU by:

- Selecting various *Components* in the system
- Selecting the *Function* of ALU

Example: R1 <- R2 + R3

[1] MUX A selector (SELA): BUS A ← R2
[2] MUX B selector (SELB): BUS B ← R3
[3] ALU operation selector (OPR): ALU to ADD
[4] Decoder destination selector (SELD): R1 ← Out Bus

Control Word

3	3	3	5
SELA	SELB	SELD	OPR

Encoding of register selection fields

Binary Code	SELA	SELB	SELD
000	Input	Input	None
001	R1	R1	R1
010	R2	R2	R2
011	R3	R3	R3
100	R4	R4	R4
101	R5	R5	R5
110	R6	R6	R6
111	R7	R7	R7

ALU CONTROL

Encoding of ALU operations

OPR Select	Operation	Symbol
00000	Transfer A	TSFA
00001	Increment A	INCA
00010	ADD A + B	ADD
00101	Subtract A - B	SUB
00110	Decrement A	DECA
01000	AND A and B	AND
01010	OR A and B	OR
01100	XOR A and B	XOR
01110	Complement A	COMA
10000	Shift right A	SHRA
11000	Shift left A	SHLA

Examples of ALU Microoperations

	Symbolic Designation				
Microoperation	SELA	SELB	SELD	OPR	Control Word
$R1 \leftarrow R2 - R3$	R2	R3	R1	SUB	010 011 001 00101
$R4 \leftarrow R4 \vee R5$	R4	R5	R4	OR	100 101 100 01010
$R6 \leftarrow R6 + 1$	R6	-	R6	INCA	110 000 110 00001
$R7 \leftarrow R1$	R1	-	R7	TSFA	001 000 111 00000
Output $\leftarrow$ R2	R2	-	None	TSFA	010 000 000 00000
Output $\leftarrow$ Input	Input	-	None	TSFA	000 000 000 00000
$R4 \leftarrow$ shl R4	R4	-	R4	SHLA	100 000 100 11000
$R5 \leftarrow 0$	R5	R5	R5	XOR	101 101 101 01100

ALU CONTROL

Encoding of ALU operations

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Examples of ALU Microoperations

	Symbolic Designation				
Microoperation	SELA	SELB	SELD	OPR	Control Word
$R1 \leftarrow R2 + R3$					
$R4 \leftarrow R4$					
$R5 \leftarrow R5 - 1$					
$R6 \leftarrow \text{Shl } R1$					
$R7 \leftarrow \text{Input}$					

ALU CONTROL

Encoding of ALU operations

OPR Select	Operation	Symbol
00000	Transfer A	TSFA
00001	Increment A	INCA
00010	ADD A + B	ADD
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10000	Shift right A	SHRA
11000	Shift left A	SHLA

Examples of ALU Microoperations

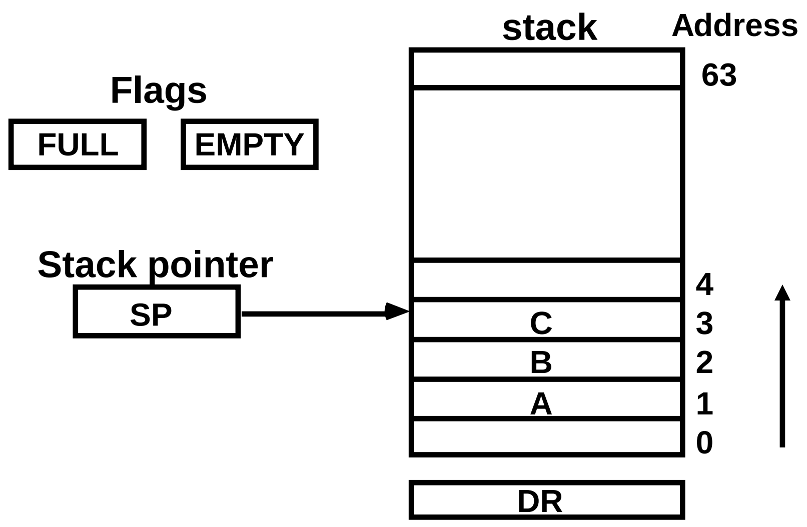
	Symbolic Designation				
Microoperation	SELA	SELB	SELD	OPR	Control Word
$R1 \leftarrow R2 + R3$	R2	R3	R1	ADD	
$R4 \leftarrow R4$	R4	-	R4	TSFA	
$R5 \leftarrow R5 - 1$	R5	-	R5	DECA	
$R7 \leftarrow R1$	R1	-	R7	TSFA	
Output $\leftarrow$ R2	R2	-	None	TSFA	

STACK ORGANIZATION

Stack

- Efficient for arithmetic expression evaluation
- Storage which can be accessed in LIFO
- Pointer: SP
- Only PUSH and POP operations are applicable

Register Stack



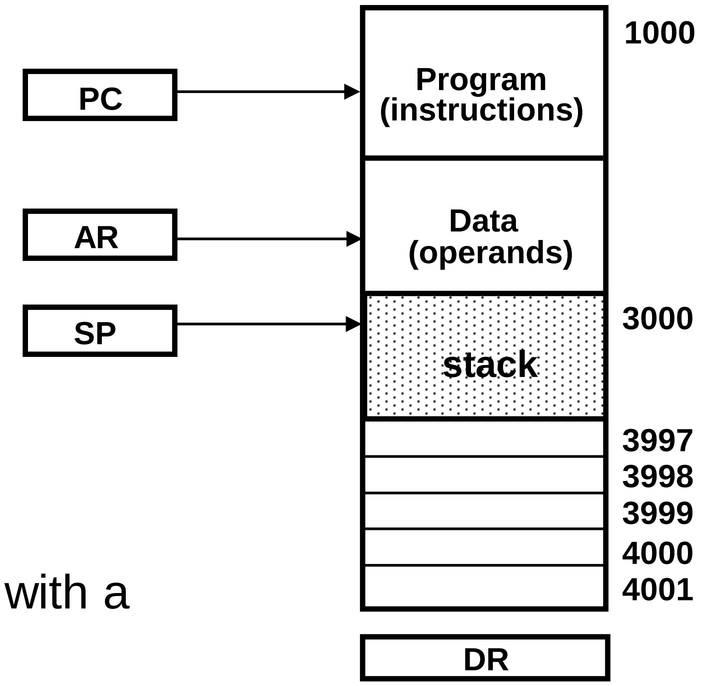
Push, Pop operations

/* Initially, SP = 0, EMPTY = 1, FULL = 0 */

<u>PUSH</u>	**<u>POP</u>**
SP ← SP + 1	**DR ← M[SP]**
M[SP] ← DR	**SP ← SP - 1**
If (SP = 0) then (FULL ← 1)	**If (SP = 0) then (EMPTY ← 1)**
EMPTY ← 0	**FULL ← 0**

MEMORY STACK ORGANIZATION

Memory with Program, Data,
and Stack Segments



- A portion of memory is used as a stack with a processor register as a stack pointer

- PUSH: $SP \leftarrow SP - 1$
  $M[SP] \leftarrow DR$
- POP: $DR \leftarrow M[SP]$
  $SP \leftarrow SP + 1$

REVERSE POLISH NOTATION

Arithmetic Expressions: A + B

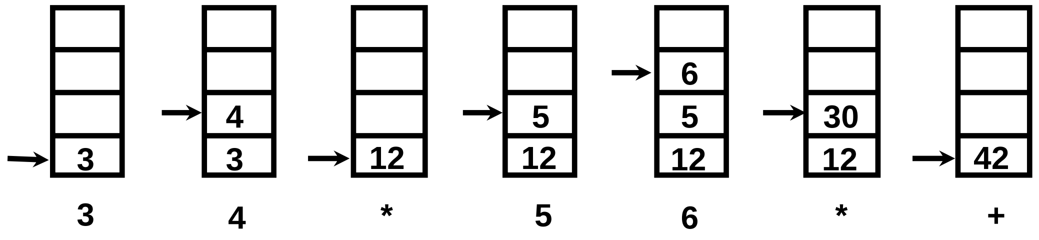
A + B	Infix notation
+ A B	Prefix or Polish notation
A B +	Postfix or reverse Polish notation

- The reverse Polish notation is very suitable for stack manipulation

Evaluation of Arithmetic Expressions

Any arithmetic expression can be expressed in parenthesis-free Polish notation, including reverse Polish notation

(3 * 4) + (5 * 6) ⇒ 3 4 * 5 6 * +



- Let SP=000000 in Fig1, then how many items are there in the stack if FULL=1 & EMTY=0 & FULL=0 & EMTY=1.

- A stack is organized such that SP can be initialized to 4000 in Fig. 2 and the first item in the stack is stored at location 4000. List the micro-operation for PUSH and POP operation.

- Convert the following arithmetic expressions in to reverse polish notation and show the stack operations for evaluating the numerical result:

  (3+4) [10*(2+6)+8]