

# Osnovi računarstva I

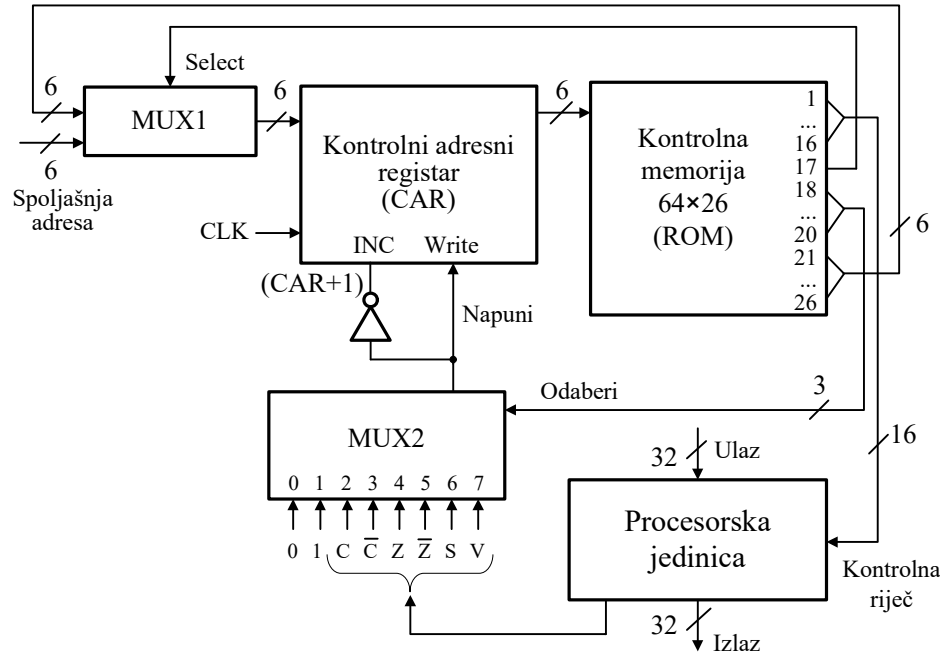
**Centralna procesorska jedinica**

**II dio: Kontrolna jedinica**

**– Primjeri  $\mu$ -programa –**

# REKAPITULACIJA (neophodna znanja za pisanje $\mu$ -programa):

## Kontrola procesorske jedinice, mnemonici i binarni zapisi operacija ALU, pomjeračke jedinice i multipleksora MUX2



Binarno	Mnemonik	Operacija ALU	Z	S	C	V
0000	TSF	$F=A$	N	N	N	N
0001	INC	$F=A+1$	D	D	N	N
0010	ADD	$F=A+B$	D	D	D	D
0101	SUB	$F=A-B$	D	D	D	D
0110	DEC	$F=A-1$	D	D	N	N
0111	TRC	$F=A$ i $C=0$	D	D	0	N
1000	AND	$F=A \wedge B$	D	D	N	N
1010	OR	$F=A \vee B$	D	D	N	N
1100	XOR	$F=A \oplus B$	D	D	N	N
1110	COM	$F=\text{com}(A)$	D	D	N	N

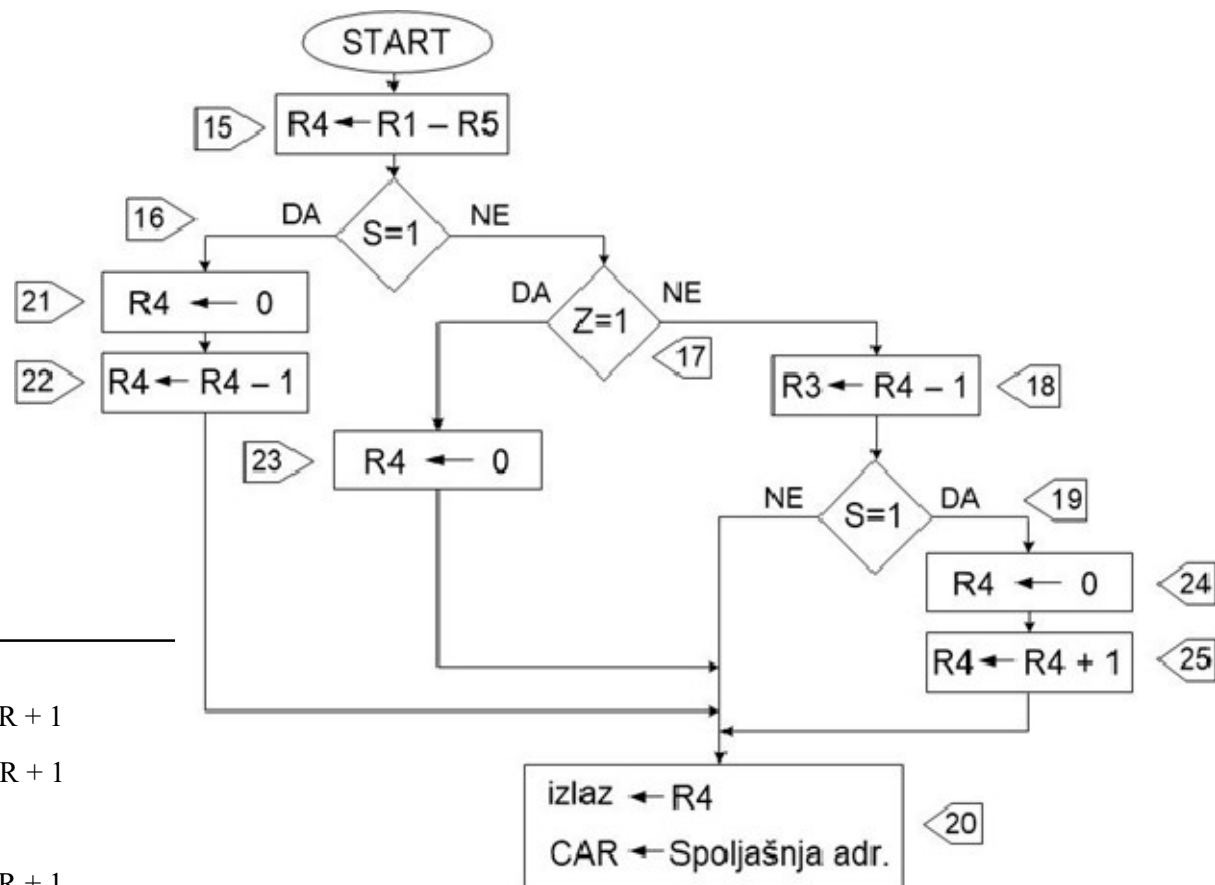
Operacija Pomjeračke jedinice	Binarno	Mnemonik
	000	NSH
	001	SHL
	010	SHR
	011	ZERO
	100	RLC
	101	ROL
	110	ROR
111	RRC	

Binarno	Mnemonik	Budući sadržaj CAR zavisno od selekcionih bitova MUX2
000	NEXT	$CAR \leftarrow CAR+1$
001	LAD	$CAR \leftarrow$ Ads. odabrana sa MUX1
010	LC	If (C=1) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )
011	LNC	If (C=0) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )
100	LZ	If (Z=1) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )
101	LNZ	If (Z=0) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )
110	LS	If (S=1) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )
111	LV	If (V=1) then ( $CAR \leftarrow$ Ads. odabrana sa MUX1) else ( $CAR \leftarrow CAR+1$ )

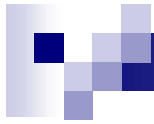
**Primjer:**  $\mu$ -program  
za izračunavanje

$$R4 \leftarrow f(R1 - R5),$$

$$f(x) = \begin{cases} -1, & x < 0 \\ 0, & x = 0 \\ 1, & 0 < x < 1 \\ x, & x \geq 1 \end{cases}$$



adresa	mikroinstrukcija
15	R4 ← R1 - R5, CAR ← CAR + 1
16	IF (S=1) then CAR ← 21 else CAR ← CAR + 1
17	IF (Z=1) then CAR ← 23 else CAR ← CAR + 1
18	R3 ← R4 - 1, CAR ← CAR + 1
19	IF (S=1) then CAR ← 24 else CAR ← CAR + 1
20	Izlaz ← R4, CAR ← Spoljašnja adresa
21	R4 ← 0, CAR ← CAR + 1
22	R4 ← R4 - 1, CAR ← 20
23	R4 ← 0, CAR ← 20
24	R4 ← 0, CAR ← CAR + 1
25	R4 ← R4 + 1, CAR ← 20



adresa mikroinstrukcija

- 15  $R4 \leftarrow R1 - R5, CAR \leftarrow CAR + 1$   
 16 IF (S=1) then  $CAR \leftarrow 21$  else  $CAR \leftarrow CAR + 1$   
 17 IF (Z=1) then  $CAR \leftarrow 23$  else  $CAR \leftarrow CAR + 1$   
 18  $R3 \leftarrow R4 - 1, CAR \leftarrow CAR + 1$   
 19 IF (S=1) then  $CAR \leftarrow 24$  else  $CAR \leftarrow CAR + 1$   
 20 Izlaz  $\leftarrow R4, CAR \leftarrow$  Spoljašnja adresa  
 21  $R4 \leftarrow 0, CAR \leftarrow CAR + 1$   
 22  $R4 \leftarrow R4 - 1, CAR \leftarrow 20$   
 23  $R4 \leftarrow 0, CAR \leftarrow 20$   
 24  $R4 \leftarrow 0, CAR \leftarrow CAR + 1$   
 25  $R4 \leftarrow R4 + 1, CAR \leftarrow 20$

Adresa	A	B	D	F	H	MUX1	MUX2	ADS
15	R1	R5	R4	SUB	NSH	–	NEXT	–
	001	101	100	0101	000	0	000	000000
16	–	–	NONE	TSF	NSH	INT	LS	21
	000	000	000	0000	000	0	110	010101
17	–	–	NONE	TSF	NSH	INT	LZ	23
	000	000	000	0000	000	0	100	010111
18	R4	–	R3	DEC	NSH	–	NEXT	–
	100	000	011	0110	000	0	000	000000
19	–	–	NONE	TSF	NSH	INT	LS	24
	000	000	000	0000	000	0	110	011000
20	R4	–	NONE	TSF	NSH	EXT	LAD	–
	100	000	000	0000	000	1	001	000000
21	–	–	R4	TSF	ZERO	–	NEXT	–
	000	000	100	0000	011	0	000	000000
22	R4	–	R4	DEC	NSH	INT	LAD	20
	100	000	100	0110	000	0	001	010100
23	–	–	R4	TSF	ZERO	INT	LAD	20
	000	000	100	0000	011	0	001	010100
24	–	–	R4	TSF	ZERO	–	NEXT	–
	000	000	100	0000	011	0	000	000000
25	R4	–	R4	INC	NSH	INT	LAD	20
	100	000	100	0001	000	0	001	010100

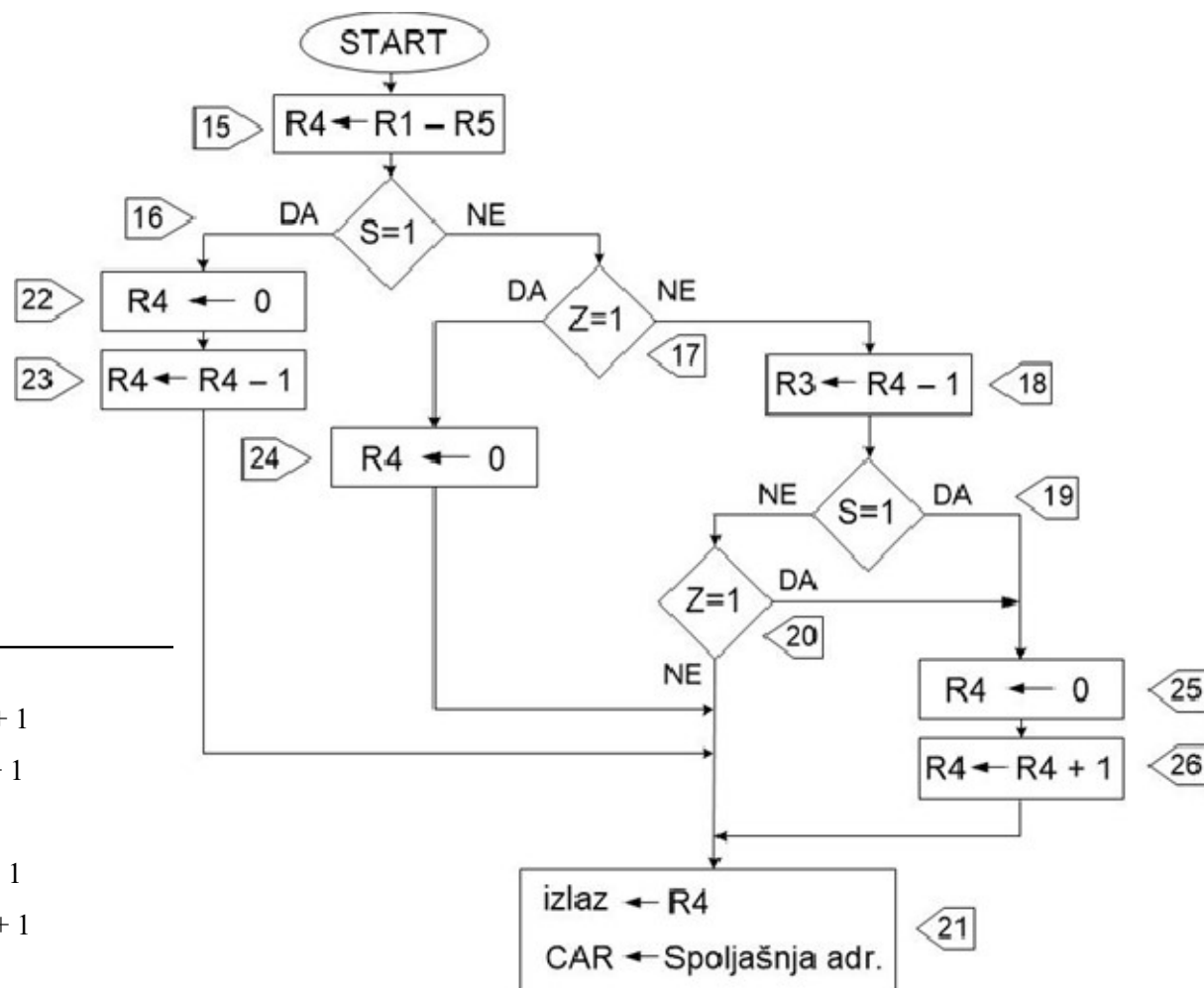
**Primjer:**  $\mu$ -program  
za izračunavanje

$$R4 \leftarrow f(R1 - R5),$$

$$f(x) = \begin{cases} -1, & x < 0 \\ 0, & x = 0 \\ 1, & 0 < x \leq 1 \\ x, & x > 1 \end{cases}$$

adresa    mikroinstrukcija

- | adresa | mikroinstrukcija  |
|--------|---|
| 15     | $R4 \leftarrow R1 - R5, CAR \leftarrow CAR + 1$                 |
| 16     | IF (S=1) then $CAR \leftarrow 22$ else $CAR \leftarrow CAR + 1$ |
| 17     | IF (Z=1) then $CAR \leftarrow 24$ else $CAR \leftarrow CAR + 1$ |
| 18     | $R3 \leftarrow R4 - 1, CAR \leftarrow CAR + 1$                  |
| 19     | IF (S=1) then $CAR \leftarrow 25$ else $CAR \leftarrow CAR + 1$ |
| 20     | IF (Z=1) then $CAR \leftarrow 25$ else $CAR \leftarrow CAR + 1$ |
| 21     | Izlaz $\leftarrow R4, CAR \leftarrow$ Spoljašnja adresa         |
| 22     | $R4 \leftarrow 0, CAR \leftarrow CAR + 1$                       |
| 23     | $R4 \leftarrow R4 - 1, CAR \leftarrow 21$                       |
| 24     | $R4 \leftarrow 0, CAR \leftarrow 21$                            |
| 25     | $R4 \leftarrow 0, CAR \leftarrow CAR + 1$                       |
| 26     | $R4 \leftarrow R4 + 1, CAR \leftarrow 21$                       |



adresa mikroinstrukcija

- 15  $R4 \leftarrow R1 - R5, CAR \leftarrow CAR + 1$   
 16 IF (S=1) then  $CAR \leftarrow 22$  else  $CAR \leftarrow CAR + 1$   
 17 IF (Z=1) then  $CAR \leftarrow 24$  else  $CAR \leftarrow CAR + 1$   
 18  $R3 \leftarrow R4 - 1, CAR \leftarrow CAR + 1$   
 19 IF (S=1) then  $CAR \leftarrow 25$  else  $CAR \leftarrow CAR + 1$   
 20 IF (Z=1) then  $CAR \leftarrow 25$  else  $CAR \leftarrow CAR + 1$   
 21 Izlaz  $\leftarrow R4, CAR \leftarrow$  Spoljašnja adresa  
 22  $R4 \leftarrow 0, CAR \leftarrow CAR + 1$   
 23  $R4 \leftarrow R4 - 1, CAR \leftarrow 21$   
 24  $R4 \leftarrow 0, CAR \leftarrow 21$   
 25  $R4 \leftarrow 0, CAR \leftarrow CAR + 1$   
 26  $R4 \leftarrow R4 + 1, CAR \leftarrow 21$

Adresa	A	B	D	F	H	MUX1	MUX2	ADS
15	R1	R5	R4	SUB	NSH	–	NEXT	–
	001	101	100	0101	000	0	000	000000
16	–	–	NONE	TSF	NSH	INT	LS	22
	000	000	000	0000	000	0	110	010110
17	–	–	NONE	TSF	NSH	INT	LZ	24
	000	000	000	0000	000	0	100	011000
18	R4	–	R3	DEC	NSH	–	NEXT	–
	100	000	011	0110	000	0	000	000000
19	–	–	NONE	TSF	NSH	INT	LS	25
	000	000	000	0000	000	0	110	011001
20	–	–	NONE	TSF	NSH	INT	LZ	25
	000	000	000	0000	000	0	100	011001
21	R4	–	NONE	TSF	NSH	EXT	LAD	–
	100	000	000	0000	000	1	001	000000
22	–	–	R4	TSF	ZERO	–	NEXT	–
	000	000	100	0000	011	0	000	000000
23	R4	–	R4	DEC	NSH	INT	LAD	21
	100	000	100	0110	000	0	001	010101
24	–	–	R4	TSF	ZERO	INT	LAD	21
	000	000	100	0000	011	0	001	010101
25	–	–	R4	TSF	ZERO	–	NEXT	–
	000	000	100	0000	011	0	000	000000
26	R4	–	R4	INC	NSH	INT	LAD	21
	100	000	100	0001	000	0	001	010101

**Primjer:**  $\mu$ -program za izračunavanje

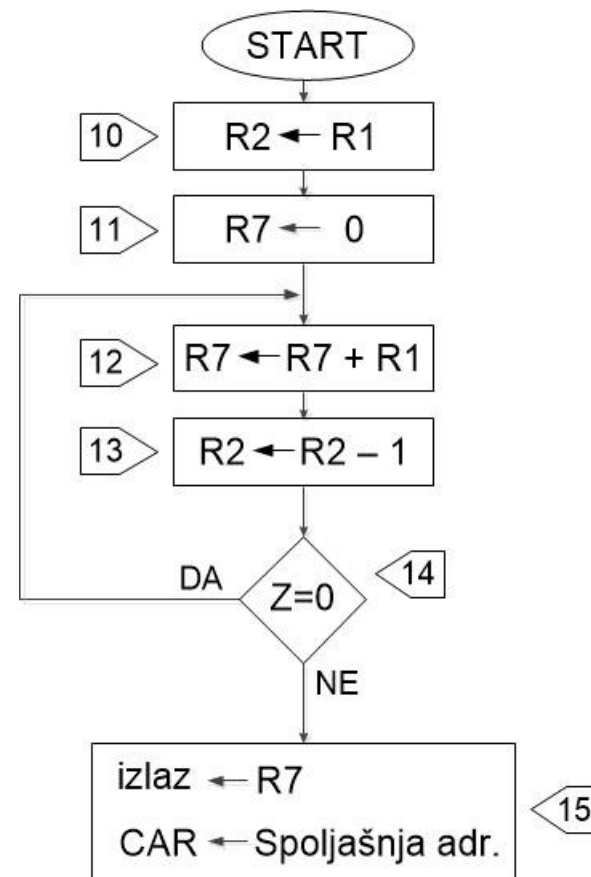
$R7 \leftarrow f(R1),$

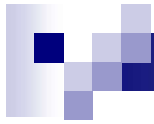
$$f(x) = x^2$$

**Rješenje:** Primijetimo da je:

$$f(x) = x^2 = x \cdot x = \underbrace{x + x + \dots + x}_{x \text{ puta}}$$

adresa	mikroinstrukcija
10	$R2 \leftarrow R1, CAR \leftarrow CAR + 1$
11	$R7 \leftarrow 0, CAR \leftarrow CAR + 1$
12	$R7 \leftarrow R7 + R1, CAR \leftarrow CAR + 1$
13	$R2 \leftarrow R2 - 1, CAR \leftarrow CAR + 1$
14	IF (Z=0) then $CAR \leftarrow 12$ else $CAR \leftarrow CAR + 1$
15	Izlaz $\leftarrow R7, CAR \leftarrow$ Spoljašnja adresa





adresa    mikroinstrukcija

- 
- 10     $R2 \leftarrow R1, CAR \leftarrow CAR + 1$
  - 11     $R7 \leftarrow 0, CAR \leftarrow CAR + 1$
  - 12     $R7 \leftarrow R7 + R1, CAR \leftarrow CAR + 1$
  - 13     $R2 \leftarrow R2 - 1, CAR \leftarrow CAR + 1$
  - 14    IF (Z=0) then  $CAR \leftarrow 12$  else  $CAR \leftarrow CAR + 1$
  - 15    Izlaz  $\leftarrow R7, CAR \leftarrow$  Spoljašnja adresa

Adresa	A	B	D	F	H	MUX1	MUX2	ADS
10	R1	–	R2	TSF	NSH	–	NEXT	–
	001	000	010	0000	000	0	000	000000
11	–	–	R7	TSF	ZERO	–	NEXT	–
	000	000	111	0000	011	0	000	000000
12	R7	R1	R7	ADD	NSH	–	NEXT	–
	111	001	111	0010	000	0	000	000000
13	R2	–	R2	DEC	NSH	–	NEXT	–
	010	000	010	0110	000	0	000	000000
14	–	–	NONE	TSF	NSH	INT	LNZ	12
	000	000	000	0000	000	0	101	001100
15	R7	–	NONE	TSF	NSH	EXT	LAD	–
	111	000	000	0000	000	1	001	000000