

EE309 - Project
IITB-RISC

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15	11	8	5	2	.	0
OPCODE	Register A	Register B	Register C	Unused	Condition(CZ)	2 bit

1) ADD [op2 → IR(11-9), opr1 → IR (8 - 6), dest → IR(5-3)]

PC → MemA, alu-A	IR
+1 → alu-B	ADD-NM
aluC → PC	S1
MemD → IR.	S2

(S1)

I ₁₁₋₉ → RF-A ₁	-
I ₈₋₆ → RF-A ₂	X-X
RF-D ₁ → T ₁	S2
RF-D ₂ → T ₂	S3

(S2)

T ₁ → aluA	-
T ₂ → aluB	ADD-modify _{2,C}
aluC → T ₃	S3

(S3)

T ₃ → RF-D ₃	-
I ₅₋₃ → RF-A ₃	X-X

(S4)

IB

2) ADC

(S1)

PC \rightarrow Mem A, alu-A+1 \rightarrow alu-Balu-C \rightarrow PCMem D \rightarrow IR

IR

ADD-X

S1

S2

(S2)

I₄₋₉ \rightarrow RF-A₁I₈₋₆ \rightarrow RF-A₂RF-S₁ \rightarrow T₁RF-S₂ \rightarrow T₂

-

X-X

S₂S₃ $[I_6 \text{ JR}(1-0) = 10]$

(S3)

T₁ \rightarrow alu-AT₂ \rightarrow alu-Balu-C \rightarrow T₃

-

ADD-Modif
Z,CS₃

BC

↓

(S4)

T₃ \rightarrow RF-D₃I₅₋₃ \rightarrow RF-A₃

-

X-X

S₄

JB

3) ADZ

(S1)

$PC \rightarrow MemA, alu - A$	JR
$+1 \rightarrow alu - B$	$ADD - X$
$alu C \rightarrow PC$	$S1$
$MemD \rightarrow IR$	$S2$



(S2)

$I_{11-9} \rightarrow RF - A1$	$X - X$
$I_{8-6} \rightarrow RF - A2$	$X - X$
$RF - D1 \rightarrow T1$	$S2$
$RF - D2 \rightarrow T2$	BC

 $If \ zero = 1$ 

(S3)

$T1 \rightarrow alu - A$	$S - S$
$T2 \rightarrow alu - B$	$ADD - Modify$
$alu - C \rightarrow T3$	$S3$

S4



(S4)

$T3 \rightarrow RF - D3$	$S - S$
$I_{5-3} \rightarrow RF - A3$	$X - X$

S4

IB

4) ADL

S_1	$PC \rightarrow \text{mem } A, \text{alu } - A$ $+1 \rightarrow \text{alu } - B$ $\text{alu } - C \rightarrow PC$ $\text{mem } D \rightarrow IR$	$- IR$ $ADD - X$ S_1 S_2
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S_2	$I_{11-9} \rightarrow RF - A_1$ $I_{8-6} \rightarrow RF - A_2$ $RF - D_1 \rightarrow T_1$ $RF - D_2 \rightarrow T_2$	$-$ $X - X$ S_2 S_3
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S_3	$T_2 \rightarrow 1S \rightarrow \text{alu } - A$ $T_2 \rightarrow \text{alu } - B$ $\text{alu } - C \rightarrow T_3$	$-$ $ADD - Z, C$ S_3 S_4
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S_4	$T_3 \rightarrow RF - D_3$ $I_{5-3} \rightarrow RF - A_3$	$-$ $X - X$ S_4 JB
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Op code (4-bit)	Register A (3-bit)	Register B (3-bit)	flag Immediate (6-bit)
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5) ADI

$PC \rightarrow mem A, alu - A$	JR
$+1 \rightarrow alu B$	ADD-X
$alu - C \rightarrow PC$	S1
<u>Mem D \rightarrow IR</u>	S2



$I_{16-9} \rightarrow RF-A_1$	-
$I_{8-6} \rightarrow RF-A_2$	X-X
$RF-D_1 \rightarrow T_1$	S2
$RF-D_2 \rightarrow T_2$	S6



$T_1 \rightarrow alu - A$	-
$I_{5-0} \rightarrow SEID \rightarrow alu - B$	ADD-Modify Z,C
$alu C \rightarrow T_3$	S6 S39



$T_3 \rightarrow RF-D_3$	-
$I_{8-5} \rightarrow RF-A_3$	X-X S39 IB

6)

NDU

S_1	$PC \rightarrow \text{memA, alu-A}$ $+1 \rightarrow \text{alu-B}$ $\text{alu C} \rightarrow PC$ $\text{MemD} \rightarrow IR$	IR $ADD-X$ S_1 S_2
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S_2	$I_{11-9} \rightarrow RF-A_1$ $I_{8-6} \rightarrow RF-A_2$ $RF-D1 \rightarrow T_1$ $RF-D2 \rightarrow T_2$	- $X-X$ S_2 S_{40}
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S_{40}	$T_1 \rightarrow \text{alu-A}$ $T_2 \rightarrow \text{alu-B}$ $\text{alu C} \rightarrow T_3$	- $NAND-Modify Z$ S_{40} S_4
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S_4	$T_3 \rightarrow RF-D_3$ $I_{5-3} \rightarrow RF-A_3$	- $X-X$ S_4 I_B
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7) NDC

(S1)

$PC \rightarrow \text{mem } A, \text{alu } - A$	JR
$I_1 \rightarrow \text{alu } - B$	ADD-X
$\text{alu } - C \rightarrow PC$	S1
$\text{Mem } D \rightarrow IR$	S2



(S2)

$I_{11-9} \rightarrow RF - A_1$	-
$I_{8-6} \rightarrow RF - A_2$	X-X
$RF - D_1 \rightarrow T_1$	S2
$RF - D_2 \rightarrow T_2$	B C



If carry = 1



(S3)

$T_1 \rightarrow \text{alu } - A$	-
$T_2 \rightarrow \text{alu } - B$	NAND-modify Z, C
$\text{alu } C \rightarrow T_3$	S40

+ S4



(S4)

$T_3 \rightarrow RF - D_3$	-
$I_{5-3} \rightarrow RF - A_3$	X-X

S4
IB

8) NDZ

S1

$PC \rightarrow MemA,alu-A$	IR	71
$+1 \rightarrow alu-B$	ADD-X	72
$alu-C \rightarrow PC$	ASR	73
$MemD \rightarrow IR$	S2	74



S2

$I_{11-9} \rightarrow RF-A_1$	-	-
$I_{8-6} \rightarrow RF-A_2$	X-X	75
$RF-D_1 \rightarrow T_1$	S2	76
$RF-D_2 \rightarrow T_2$	FB C	77

$$T_f = 300 \approx 1$$



S3

$T_1 \rightarrow alu-A$	-	-
$T_2 \rightarrow alu-B$	NAND	Modifying
$alu-C \rightarrow T_3$	S - S4	-



S4

$T_3 \rightarrow RF-D_3$	-	-
$I_{5-3} \rightarrow RF-A_3$	X-X	84
		JB

9)

Dp code (4 bit)	Register A (3 bit)	Immediate (9 bits signed)
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(S1)

PC → mem A, alu A	011	JR
+1 → alu-B		ADD-X
alu-C → -PC	81	
mem D → IR	87	



(S7)

IR ₈₋₀ → TS → RF-D ₃	Q-	
IR ₁₁₋₉ → RF-A ₃	X-X	
	87	
	JB	

10) LW

A = B1[2]

(E4E)

B = D1[2]

(E4D)

S1

PC \rightarrow mem A, alu-A
 $+1 \rightarrow$ alu-B
alu-C \rightarrow PC
mem D \rightarrow IR

IR

ADD-X

S8

S8

IR 8-6 \rightarrow RF-A1
RF-D1 \rightarrow T1

X-X

S8

S6

S6

T1 \rightarrow alu-A
IR 5-0 \rightarrow SE 10 \rightarrow alu-B
alu-C \rightarrow T3

ADD-modify

S6

S10

S10

T3 \rightarrow mem A
mem D \rightarrow T1

DR

X-X

S10

S11

S11

T1 \rightarrow RF-D3
IR 11-9 \rightarrow RF-A3

-

X-X

S11

JB

11) SW

(S1)

$PC \rightarrow mem\ A$, alu - A	IR
$+I \rightarrow alu - B$	ADD-X
$alu - C \rightarrow PC$	S1
$mem\ D \rightarrow IR$	S8



(S8)

$IR_{8-6} \rightarrow RF-A1$	-
$RF-D1 \rightarrow T_1$	S8



(S12)

$IR_{11-9} \rightarrow RF-A1$	-
$RF-D1 \rightarrow T_2$	
$IR_{5-0} \rightarrow SE_{10} \rightarrow alu - B$	ADD-Memory Z,C
$T_1 \rightarrow alu - A$	S12
$alu - C \rightarrow T_3$	S13



(S13)

$T_3 \rightarrow mem\ A$	X-X
$T_2 \rightarrow mem\ D$	S13

IR

SW

$T_3 \rightarrow mem\ A$

$T_2 \rightarrow mem\ D$

SW \rightarrow $mem\ A \rightarrow T_3$

SW \rightarrow $mem\ D \rightarrow T_2$

12)

LM

PC \rightarrow mem A, alu-A	JR
I1 \rightarrow alu-B	ADD-X
Mem D \rightarrow JR	S1
alu-C \rightarrow RC	S2



IR 11-9 \rightarrow RF-A1	S1
RF-D1 \rightarrow T1	X-X
IR 8-6 \rightarrow RF-A2	S2
RF-D2 \rightarrow T2	B C



$$I_f \text{ IF}_0 = 1$$



T1 \rightarrow Mem A	BR
Mem D \rightarrow T2	X-X
	S14
	S15

(S15)

T1 \rightarrow alu-A	8 - c
I1 \rightarrow alu-B	ADD-Modify 2, C
alu-C \rightarrow T1	S16
	B C

T2 \rightarrow RF-D3	X-X
000 \rightarrow RF-A3	S15
	S16

(S15)



$$I_f \text{ IF}_1 = 1$$



T1 \rightarrow mem A	DR
Mem D \rightarrow T2	X-X
	S14
	S17

(S16)



(S17)

 $T_2 \rightarrow RF - D_3$ $X - X$ $001 \rightarrow RF - A_3$ $S17$ $S16$ 

(S16)

 $T_1 \rightarrow ALU - A$ $X - X$ $T_1 \rightarrow ALU - B$ $ADD - Mody Z, C$ $ALU - C \rightarrow T_1$ $S16$ BC If $IF_2 = 1$ 

↓

(S14)

 $T_1 \rightarrow Mem A$ DR $X - Mem D \rightarrow T_2$ $X - X$ $S14$ $S18$ 

(S18)

 $T_2 \rightarrow RF - D_3$ $S1 -$ $010 \rightarrow RF - A_3$ $X - X$ $S18$ $S16$ 

(S16)

 $T_1 \rightarrow ALU - A$ $X -$ $T_1 \rightarrow ALU - B$ $ADD - Mody Z, C$ $ALU - C \rightarrow T_1$ $S16$ BC If $IF_3 = 1$ 

(S14)

 $T_1 \rightarrow Mem A$ DR $Mem D \rightarrow T_2$ $X - X$ $S14$ $S19$ 

S19

 $T_2 \rightarrow RF-D_3$ $X-X$ $D11 \rightarrow RF-A_3$

S19

S16

S16

 $T_1 \rightarrow alu - A$ $H \rightarrow alu - B$ ADD-modify
 Z, C $alu - C \rightarrow T_1$

S16

BC

S14

 $T_1 \rightarrow Mem\ A$

DR

 $Mem\ D \rightarrow T_2$

X-X

S14

S20

S20

 $T_2 \rightarrow RF-D_3$

X-X

 $DOD \rightarrow RF-A_3$

S20

S16

S16

 $T_1 \rightarrow alu - A$

-

 $H \rightarrow alu - B$ ADD-modify
 Z, C $alu - C \rightarrow T_1$

S16

BC

S14

 $T_1 \rightarrow mem\ A$

DR

 $Mem\ D \rightarrow T_2$

X-X

S14

S21

(S21)

$T_2 \rightarrow RF-D_3$	-
$110 \rightarrow RF-A_3$	S21
	S1b

(S1b)

$T_1 \rightarrowalu - A$	-
$+1 \rightarrowalu - B$	ADD - Modify Z, C
$alu - C \rightarrow T_1$	S1b

If $IF_F = 1$

(S14)

$T_1 \rightarrow mem A$	DR
$Mem D \rightarrow T_2$	X-X
	S14
	S22

(S22)

$T_2 \rightarrow RF-D_3$	-
$110 \rightarrow RF-A_3$	X-X
	S22

(S1b)

$T_1 \rightarrowalu - A$	-
$+1 \rightarrowalu - B$	ADD - Modify Z, C
$alu - C \rightarrow T_1$	S1b

(S14)

$T_1 \rightarrow mem A$	DR
$Mem D \rightarrow T_2$	X-X
	S14

(S23)

$T_2 \rightarrow RF-D_3$	-
$111 \rightarrow RF-A_3$	X-X
	S23

IB

13)

SM

(S1)

$PC \rightarrow \text{mem A}$, alu-A	IR
$HI \rightarrow \text{alu-B}$	$ADD - X$
$\text{Mem D} \rightarrow IR$	S_1
$\text{alu-C} \rightarrow PC$	S_2

(S2)

	$B -$
$IR_{11-9} \rightarrow RF - A_1$	$X - X$
$RF - D_1 \rightarrow T_1$	S_2
	$B C$

If $IF_0 = 1$

↓

(S24)

$ODD \rightarrow RF - A_3$	$X - X$
$RF - D_3 \rightarrow T_2$	S_{24}
	S_{25}

(S25)

$T_2 \rightarrow \text{Mem-D}$	DW
$T_1 \rightarrow \text{mem A}$	$X - X$
	S_{25}
	S_{16}

(S16)

$T_1 \rightarrow \text{alu A}$	-
$HI \rightarrow \text{alu B}$	$ADD - Z/C$
$\text{alu C} \rightarrow T_1$	S_{16}
	$B C$

If $IF_1 = 1$

↓

(826)

001 → RF-A₃RF-D₃ → T₂

X-X

S26

S25

(825)

T₂ → Mem-DT₁ → Mem-A

DW

X-X

S25

S16

(816)

T₁ → alu A

+1 → alu B

alu C → T₁ADD $\frac{Z}{C}$ Modify

S16

BC

If IF₂ = 1

(827)

010 → RF-A₃RF-D₃ → T₂

-

X-X

S27

S25

(825)

T₂ → Mem-DT₁ → Mem-A

DW

X-X

S25

S16

(816)

T₁ → alu A

+1 → alu B

alu C → T₁ADD $\frac{Z}{C}$ Modify

S16

BC

If $IF_3 = 1$

S28

$0 \text{ H} \rightarrow RF-A_3$

x-x

$RF-D_3 \rightarrow T_2$

S28

S25

+

$T_2 \rightarrow \text{mem D}$

DW

$T_1 \rightarrow \text{mem A}$

x-x

S25

S25

S16

+

$T_1 \rightarrow \text{alu A}$

-
ADD - Modify
z,c

$H \rightarrow \text{alu B}$

S16

$\text{alu C} \rightarrow T_1$

BC

+

If $IF_4 = 1$

+

S29

$100 \rightarrow RF-A_3$

x-x

$RF-D_3 \rightarrow T_2$

S29

S25

+

$T_2 \rightarrow \text{mem D}$

DW

$T_1 \rightarrow \text{mem A}$

x-x

S25

S25

S16

If $IF_5 = 1 + 1$

S16

$T_1 \rightarrow \text{alu A}$

-
ADD - Modify
z,c

$H \rightarrow \text{alu B}$

S16

$\text{alu C} \rightarrow T_1$

BC

+

$I_f \quad IF_5 = 1$

(S30)

 $110 \rightarrow RF - A_3$ $RF - D_3 \rightarrow T_2$ $x - x$

(S30)

(S25)

(S25)

 $T_2 \rightarrow Mem D$ $T_1 \rightarrow Mem A$

DW

 $x - x$

(S25)

(S16)

(S16)

 $T_1 \rightarrowalu A$ $+I \rightarrowalu B$ $alu C \rightarrow T_2$ ADD - Modify
Z, C

(S16)

BC

 $I_f \quad IF_6 = 1$

(S31)

 $110 \rightarrow RF - A_3$ $RF - D_3 \rightarrow T_2$ $x - x$

(S31)

(S25)

(S25)

 $T_2 \rightarrow Mem D$ $T_1 \rightarrow Mem A$

DW

 $x - x$

(S25)

(S16)

(S16)

 $T_1 \rightarrowalu A$ $+I \rightarrowalu B$ $alu C \rightarrow T_2$ ADD - Modify
Z, C

(S16)

BC

$\text{If } \text{IF}_7 = 1$

(832)

		-	
	$111 \rightarrow RF - A_3$	$x - x$	
	$RF - D_3 \rightarrow T_2$	832	
		825	

(S25)

	$T_2 \rightarrow \text{Mem } D$	DW	
	$T_1 \rightarrow \text{Mem } A$	$x - x$	
		825	
		JB	

14) BEQ

JAT

(20)

(S1)

PC → mem A, alu - A
 + 1 → alu - B
 alu - C → PC
 Mem D → IR

IR
 ADD-X
 S1
 S2



(S2)

IR 11-9 → RF-A1
 RF-D1 → T1
 IR 8-6 → RF-A2
 RF-D2 → T2

-
 X-X
 S2
 S4)

(S4)

T1 → alu - A
 T2 → alu - B
 alu - C → T3

CMP - Z, C
 S4)
 BC



If Zero = 1
 +

(S33)

PC → alu - A
 IR 5-0 → SE10 → alu - B
 alu C → PC

-
 ADD - Z, C
 S33
 S38



(S38)

PC → alu A
 -1 → alu B
 alu C → PC

-
 ADD - Z, C
 S38
 JB

(15)

JAL

Page

S1

	PC → alu A, Mem A	IR
+ I → alu B		ADD-X
alu C → PC		S1
Mem D → IR		S34

S34

	IR 11-9 → RF-A	-
PC → RF-D		X-X
		S34
		S33

S33

	IR 5-0 → SE10 → alu-A	-
PC → alu-B		ADD-Modify
alu C → PC		Z,C
		S33

JB

16)

JLR

(81)

$PC \rightarrow \text{alu A, mem A}$	IR
$H \rightarrow \text{alu B}$	$AD-X$
$\text{alu C} \rightarrow PC$	SI
$\text{Mem D} \rightarrow IR$	S3S



(83S)

$IR_{11-9} \rightarrow RF-A1$	8 -
$PC \rightarrow RF-D1$	X-X
$IR_{8-6} \rightarrow RF-A2$	S3S
$RF-D2 \rightarrow PC$	IB

(7) JR I

S1

PC → Mem A, alu A

Mem D → IR

+1 → alu B

alu C → PC

IR

ADD - X

S1

S3b

+

S3b

IR 11-9 → RF - A1

RF - D1 → T1

X - X

S3b

S3f

+

S3f

IR 8-0 → SE7 → alu B

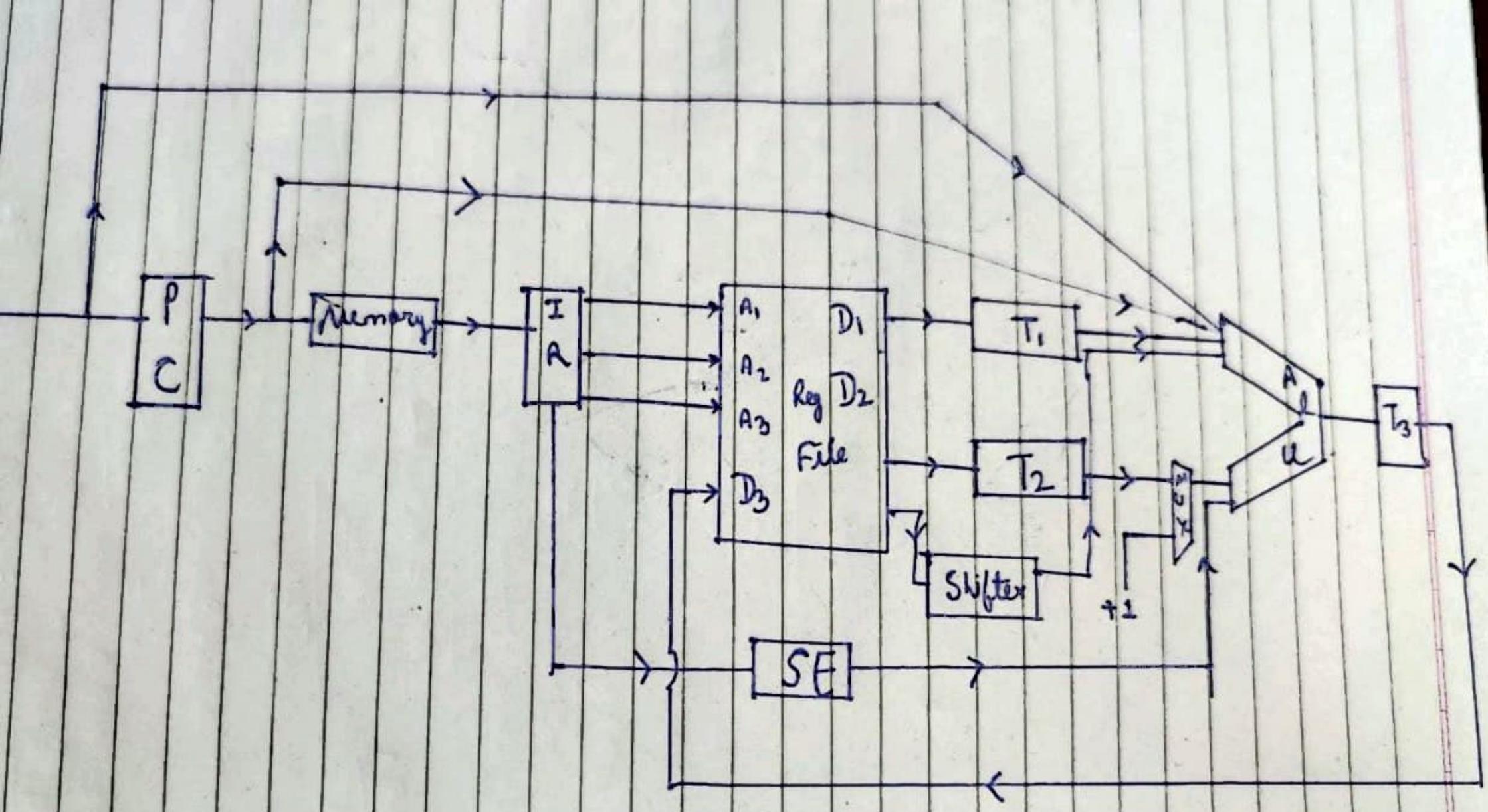
T1 → alu A

alu C → PC

ADD - Modify
Z, C

S3f

JR



Datapath Organization

