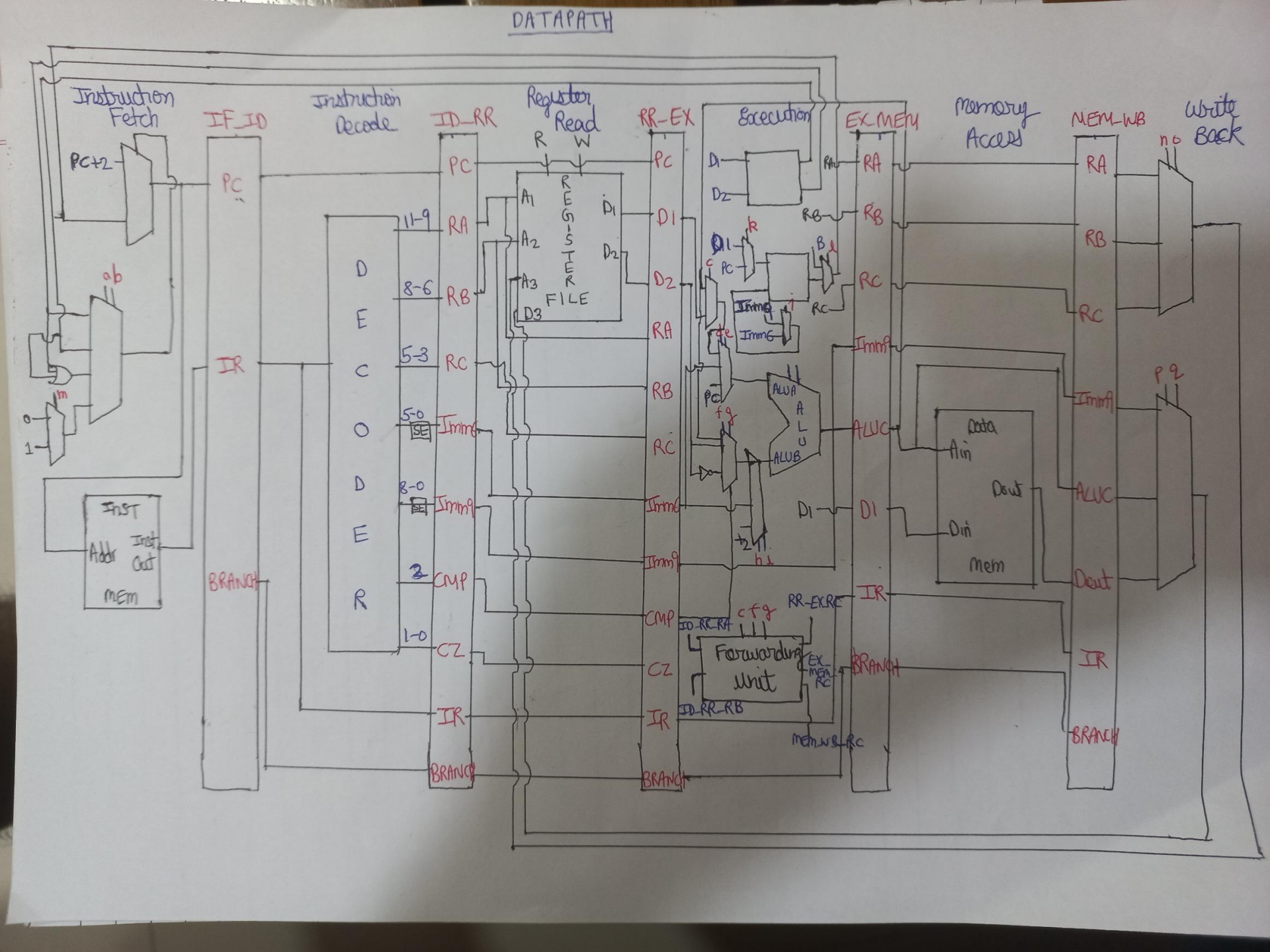
DATAPATH
Instruction Fetch
IF_ID
Instruction Decode
ID_RR
Register Read
RR-EX
Execution
EX_MEM
Memory Access
MEM_WB
Write Back
PC+2
PC
IR
BRANCH
INST
Addr
Inst Out
MEM
DECODER
11-9
8-6
5-3
5-0
8-0
2
1-0
SE
CMP
CZ
REGISTER FILE
A1
A2
A3
D3
D1
D2
R
W
RA
RB
RC
Imm6
Imm9
ALUA
ALUB
ALU
ALUC
Forwarding unit
RR-EXRC
ID_RR_RA
ID_RR_RB
EX_MEM_RC
MEM_WB_RC
Ain
Dout
Din
mem
Data

1. ADA

IF

PC → IM → IF-ID.IR

PC → IF-ID.PC

ID

IE_ID-IR$_{11-9}$ – R_A

IE_ID-IR$_{8-6}$ – R_B

IE_ID-IR$_{5-3}$ – R_C

RR

R_A → RF_A_1

R_B → RF_A_2

RF_D_1 → RR-EX_D_1

RF_D_2 → RR_EX_D_2

R_C → RR_EX_C

Ex

RR-EX_D1 → ALU.a

RR_EX_D2 ALU.b

ALU.C → EX_MEM_ALU_C

RR_EX_C → EX_MEM_C

MEM

EX_MEM_C → MEM_WB_C

ALU.C → MEM_WB_ALU.C

WB

MEM-WB_C → RF-A_3

MEM_WB_ALU.C → RF-D_3

(2.) ADC

similar to ADA

changes in Ex stage

if C flag is set

WRITE_BACK_CTRL = 1

else

WRITE_BACK_CTRL = 0

WB

if C flag is set

same as ADA

else

nothing

(3.) ADZ

similar to ADC

instead of C flag if Z flag is set.

(4.) AWC

Similar to ADA

Ex

Even Carry gets added.

(5.) ACA

Similar to ADA

changes in Ex

not (RR - EX - D2) → ALU.V

(6) ACC

Similar ADC

Changes in Ex

not (RR - Ex - D_2) → ALU.C

(7) ACZ

similar to ADZ and ACA

(8) ACW

similar to AWC

Changes in Ex

not (RR - Ex - D_2) → ALU.C

(9) ADI

IF → same

ID

IF - ID_{5-0} SE → Imm6

IF - ID - IR_{11-9} → R_A

IF - ID - IR_{8-6} → R_B

RR

R_A → RF.A

RF.D_1 → RR - Ex - D_1

R_B → RR - Ex - B

Imm6 → RR - Ex - Imm6

Ex

RR - Ex - D_1 → ALU.A

RR - Ex - Imm → ALU.B

ALU.C → Ex - Mem - ALU.C

RB → Ex - Mem - B

MEM

EX - MEM - B → MEM_WB_B

ALU.C → MEM_WB_ALU.C

WB

RB → RF.A3

RC → RF.D3

(10.) NDU

same as ADA

Ex

NAND instead of Add.

(11) NDC

same as ADC

Ex

NAND instead of Add

(12) ND2

same as AD2

Ex

NAND instead of Add

(13.) NCU

same as ACA

Ex

NAND instead of Add

(14) NCC

same as ACC

Ex

NAND instead of ADD

(15.) NCZ

same as ACZ

Ex

NAND instead of ADD

(16.) CCI

IF → same

ID

IF_ID_IR8-0 → SE → Imm9 (ID_RR)

IF_ID_IR11-9 → RA

ID

IF_ID_IR8-0 → SE → Imm9 (ID_RR)

IF_ID_IR11-9 → RA

RR

Imm9 → RR_Ex_Imm9

RA → RR_Ex_RA

Ex

RR_Ex_Imm9 → Ex_Mem_Imm9

RR_Ex_RA → Ex_Mem_RA

Mem

Ex_Mem_Imm9 → Mem_WB_Imm9

Ex_Mem_RA → Mem_WB_RA

WB

0000000111111111 & Mem_WB_Imm9 → RF_D3

Ex_Mem_RA → RF_A3

(17.) LW

IF

same

ID

IE_ID - $IR_{11-9} \rightarrow R_A$

~~$IR_{8-6} \rightarrow R_B$~~

$IE\_ID\_IR_{8-6} \rightarrow R_B$

$IE\_ID\_IR_{5-0} \rightarrow SE \rightarrow ID\_RR\_Imm6$

RR

$R_B \rightarrow RF_{A_2}$

$RF_{D_2} \rightarrow RR\_Ex\_D_2$

$R_A \rightarrow RR\_Ex\_R_A$

$ID\_RR\_Imm6 \rightarrow RR\_Ex\_Imm6$

Ex

$RR\_Ex\_D_2 \rightarrow ALU.b$

$RR\_Ex\_Imm6 \rightarrow ALU.a$

$ALU.c \rightarrow Ex\_Mem\_ALU.c$

$RR\_Ex\_R_A \rightarrow Ex\_Mem\_R_A$

Mem

$Ex\_Mem\_ALU.c \rightarrow D\ Mem.add$

$DM.dout \rightarrow Mem\_WB\_dout$

$Ex\_Mem\_R_A \rightarrow Mem\_WB\_R_A$

WB

~~$Ex\_Mem\_ALU.c \rightarrow A4$~~

$Mem\_WB\_R_A \rightarrow RF\_A_3$

$Mem\_WB\_dout \rightarrow RF\_D_3$.

(18) SW

IF → same

ID

IE_ID_IR11-9 → RA

IE_ID_IR8-6 → RB

IE_ID_IR5-0 → Imm6 ID_RR_Imm6

RR

RB → RF_A2

RF_D2 → RR_Ex_D2

RA → RF_A1

ID_RR_Imm6 → RR_Ex_Imm6

RF_D1 → RR_Ex_D1

Ex

RR_Ex_D2 → ALU.b

RR_Ex_D1 → Ex_Mem_D1

RR_Ex_Imm6 → ALU.a

ALU.c → Ex_Mem_ALU.c

Mem

Ex_Mem_ALUC → DM.addr

Ex_Mem_B → DM.din

WB

—

(19) BEQ

IF → same

IE_ID_IR11-9 → RA

IE_ID_IR8-6 → RB

IE_ID_IR5-0 → Imm6 ID_RR_Imm6

RR

$R_A \rightarrow RF\_A_1$

$R_B \rightarrow RF\_A_2$

$RF\_D_1 \rightarrow RR\_EX\_D_1$

$RF\_D_2 \rightarrow RR-EX\_D_2$

IP_RR_Imm6 → RR-Ex_Imm6

Ex

if $D_1 == D_2$ then

PC = PC + Imm6

else

–

Mem

—

WB

—

(20) BLT

similar to BEQ

Ex

if $D_1 < D_2$ then

PC = PC + Imm6

else

–

Mem

–

WB

–

(21) BLE

Similar to ~~BEQ~~ BLT

Ex condition $D_1 \leq D_2$

(22) JAL

IF → same

ID

IF – ID – IR 11-9 → R_A

IF – ID – IR 8-0 → ~~[redacted]~~ ID – RR – Imm9

RR

– (Previous Pipeline is forwarded)

Ex

RR – Ex – R_A → Ex – Mem – R_A

PC → ALU.a

+1 → ALU.b

ALU.c → Ex – Mem – ALU.c

Mem

Ex – Mem – R_A → Mem – W_B – R_A

Ex – Mem – ALU.c → Mem – W_B – ALU.c

W_B

Mem – W_B – R_A → $RF A_3$

Mem – W_B – ALU.c → $RF D_3$

(23) JLR

IF → same

ID

IF – ID – IR 11-9 → R_A

IF – ID – IR 8-6 → R_B

RR

R_A → RR – Ex – R_A

R_B → RF – A_2

RF – D_2 → RR – Ex – D_2

PTO

Ex

RR_Ex_R_A → Ex_Mem_R_A

RC → alu.a

+1 → alu.b

alu.C → Ex_Mem_alu.c

Mem

Ex_Mem_R_A → Mem_WB_R_A

Ex_Mem_alu.C → Mem_WB_alu.c

WB

Mem_WB_R_A → RF.A_3

Mem_WB_alu.C → RF.D_3

(2) JR1

IF → same

ID

IF_ID_IR_{11-7} → R_A

RR

R_A → RFD_1

RFD_1 → RR_Ex_D_1

Ex

—

Mem

—

WB

—