

```
squash_D = val_X && (op_X == bne) && !eq_X
squash_F = squash_D || (val_D && ((op_D == jal) || (op_D == jr)))
```

```

stall_load_use_X_rs1_D =
    val_D && rs1_en_D && val_X && rf_wen_X
        && (inst_rs1_D == rf_waddr_X) && (rf_waddr_X != 0)
        && (op_X == lw)

stall_load_use_X_rs2_D =
    val_D && rs2_en_D && val_X && rf_wen_X
        && (inst_rs2_D == rf_waddr_X) && (rf_waddr_X != 0)
        && (op_X == lw)

```

```

        stall_D =
            val_D && ( stall_load_use_X_rs1_D || stall_load_use_X_rs2_D )

        bypass_waddr_X_rs1_D =
            val_D && rs1_en_D && val_X && rf_wen_X
                && (inst_rs1_D == rf_waddr_X) && (rf_waddr_X != 0)
                && (op_X != lw)

bne X1 X2 L1 F D X M W
    op A   F D --- --- |W X|, 0(x2) F D X M W
    op B   X --- --- add X1 X1 X0 F D D X M W
        F
        bypass_waddr_X_rs2_D =
            val_D && rs2_en_D && val_X && rf_wen_X
                && (inst_rs2_D == rf_waddr_X) && (rf_waddr_X != 0)
                && (op_X != lw)

```

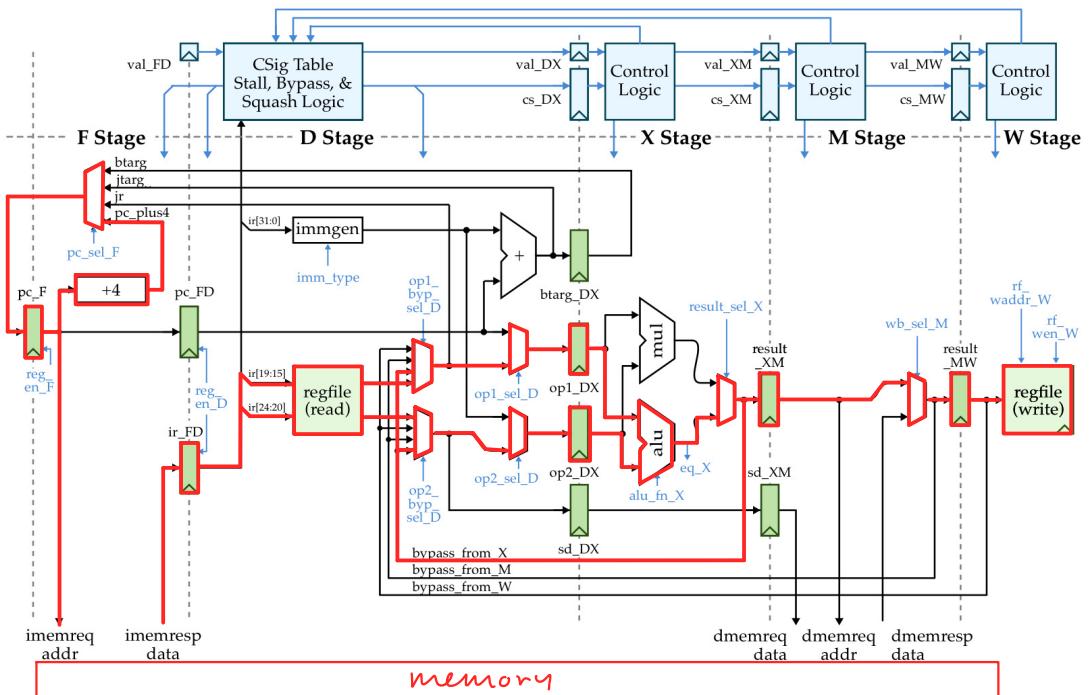
add  $(x_1)$   $x_1$   $x_0$  F D X M W  
 add  $(x_1)$   $(x_2)$   $x_0$  F D X M W  
 add  $x_1$   $(x_2)$   $x_D$  F D X M W

↙ similar for M, W

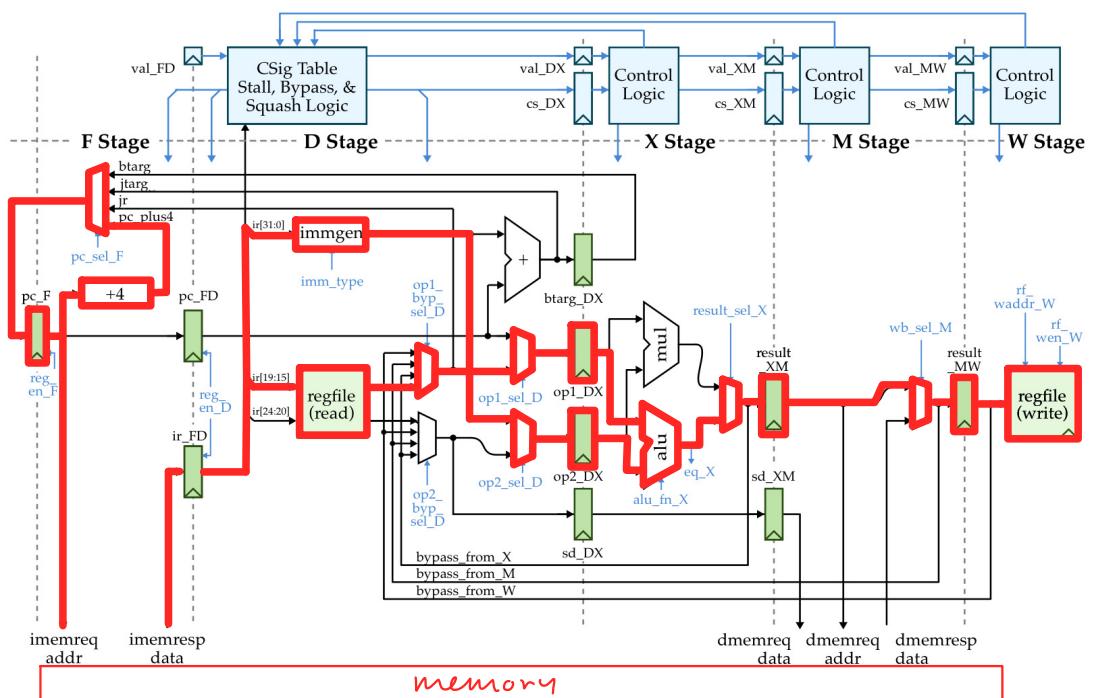
$\rightarrow x M w$

prioritize closer bypass path!

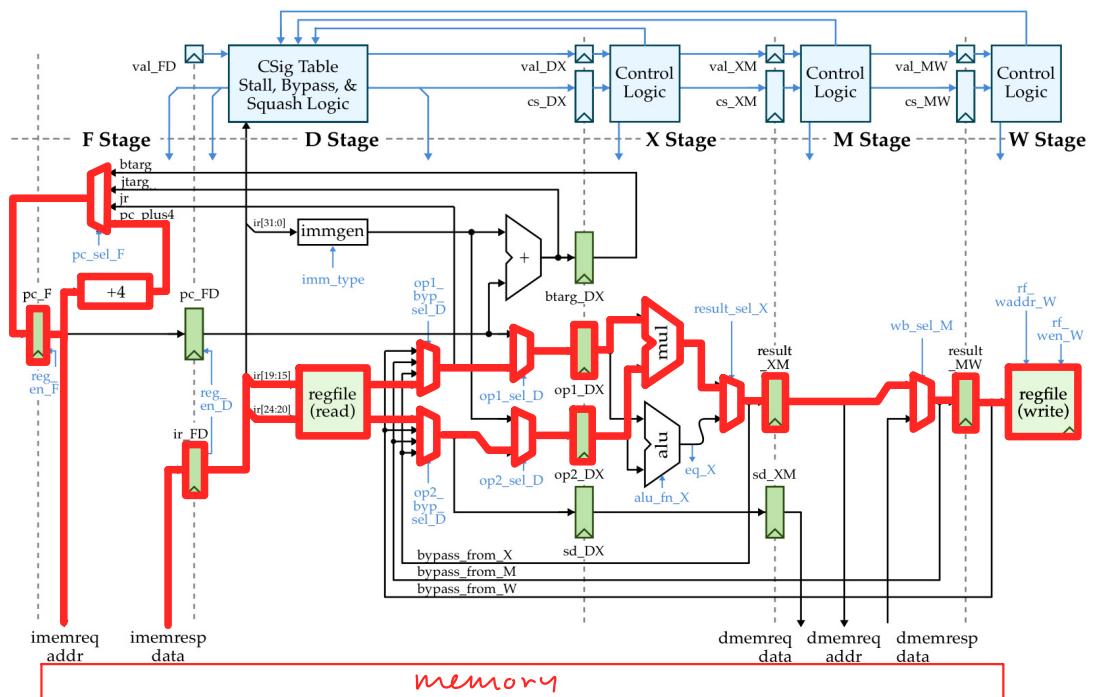
# ADD



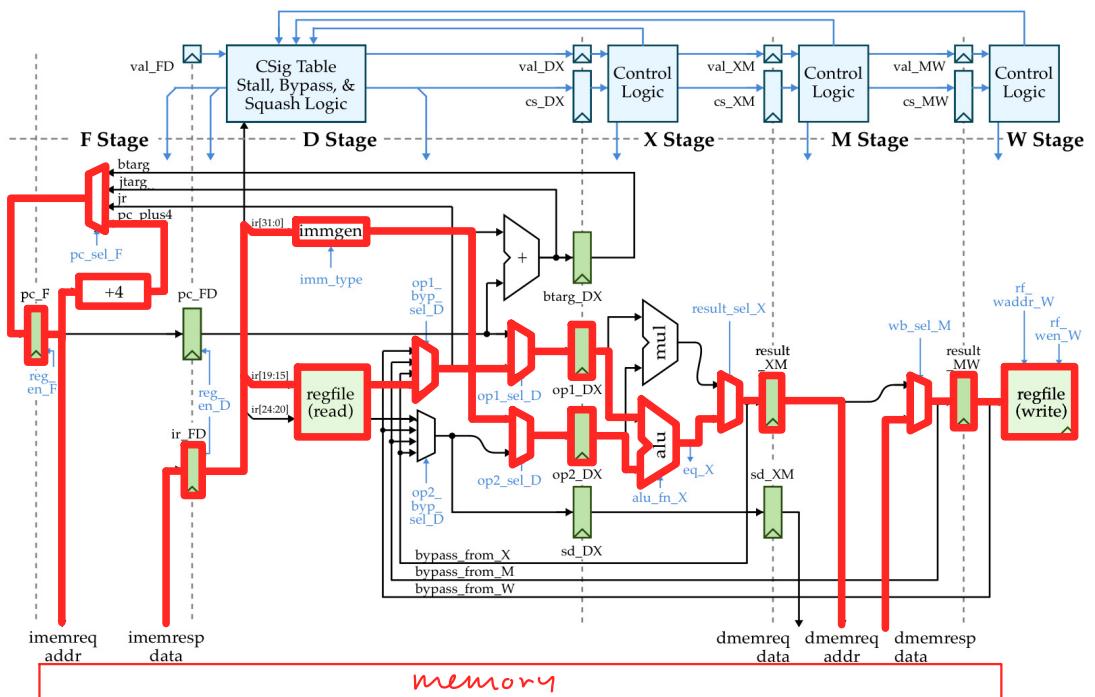
# ADDI



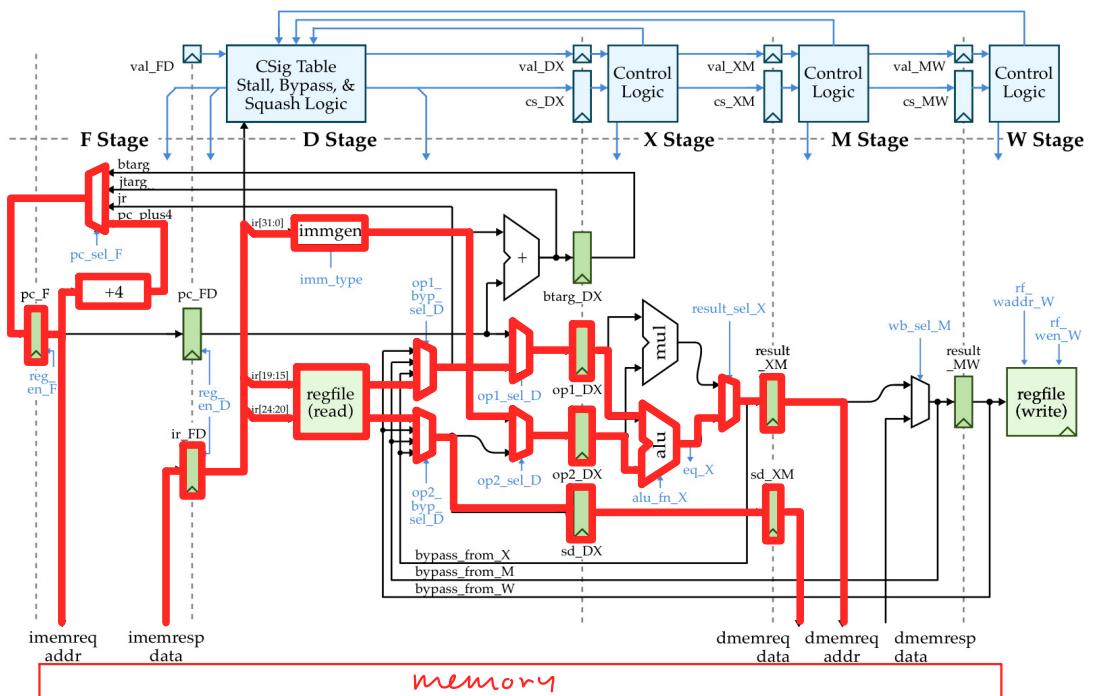
# MVL



LW

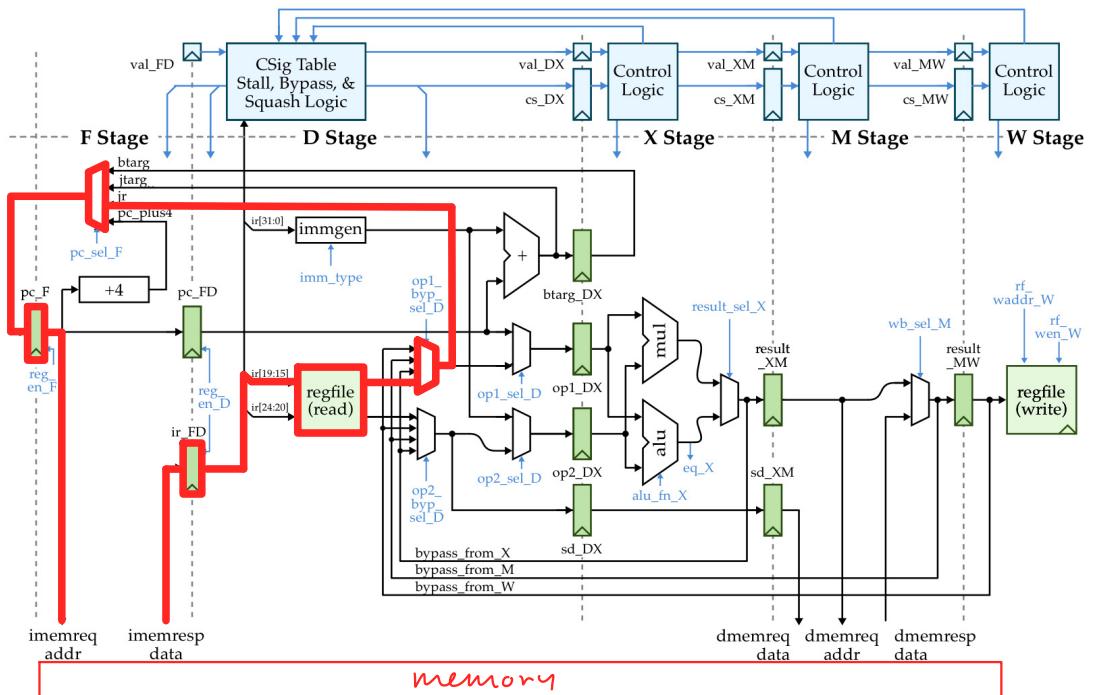


SW



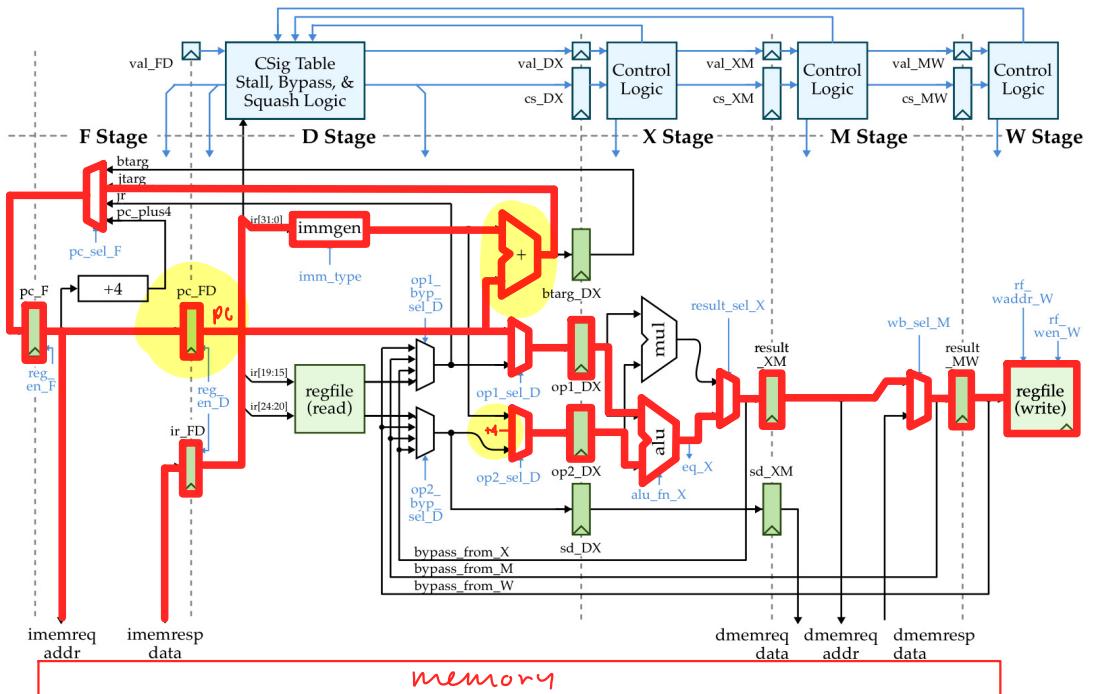
sw rs2 imm(rs1)

JR



jr rs1

# JAL



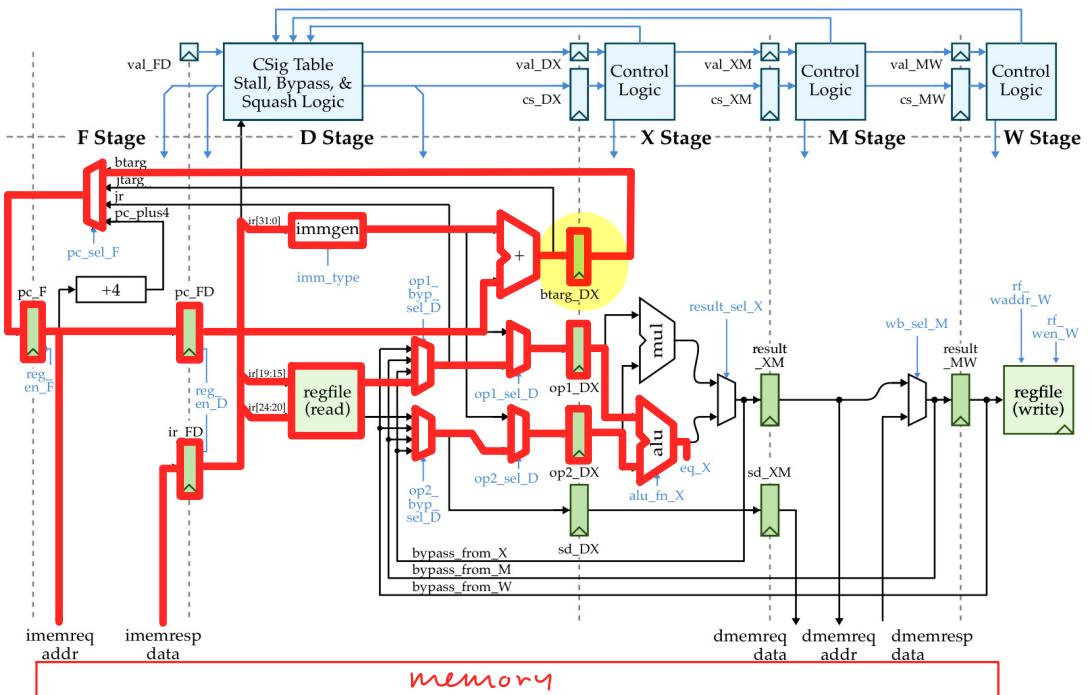
jal rd addr

$$R[rd] \leftarrow PC + 4$$

$$PC \leftarrow \underbrace{addr}_{\text{PC} + sext(cimm)}$$

$$\text{PC} + \text{sext}(\text{cimm})$$

BNE



bne rs1 rs2 addr

if  $R[rs1] == R[rs2]$

$PC \leftarrow PC + 4$

if  $R[rs1] \neq R[rs2]$

$PC \leftarrow addr$

$\sim$

$PC + sext(imm)$

# CSR R/W

