EE 224 Course Project : CPU

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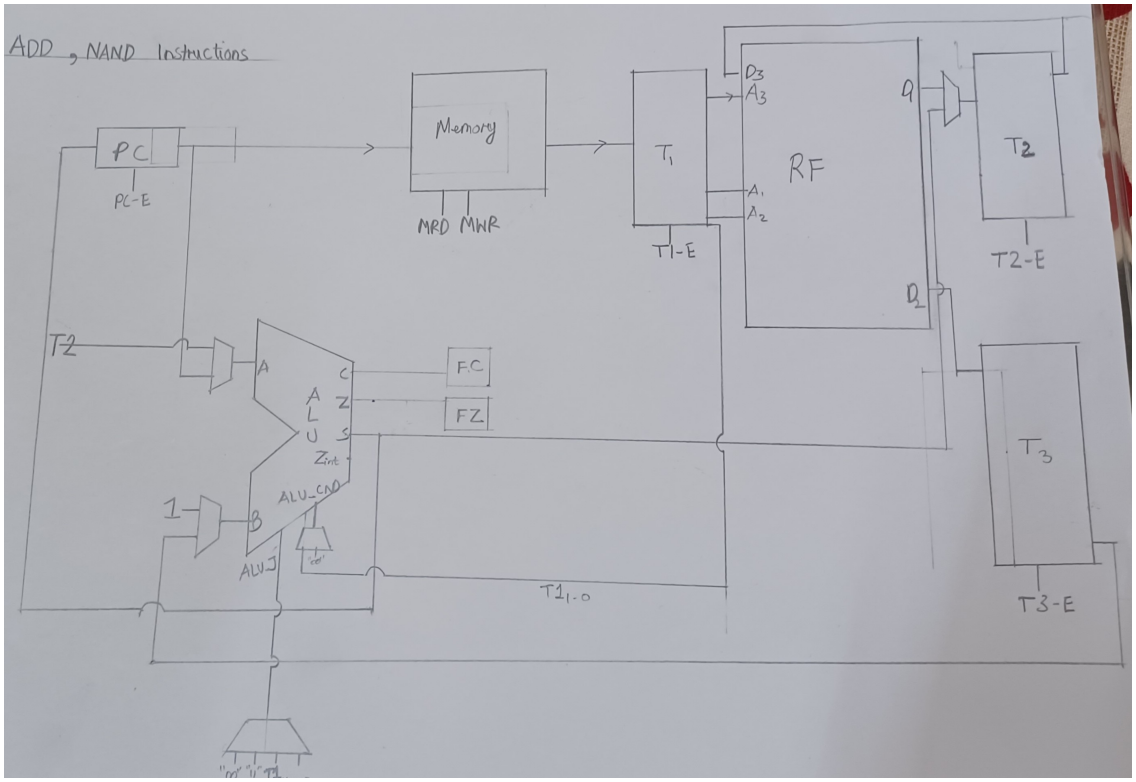
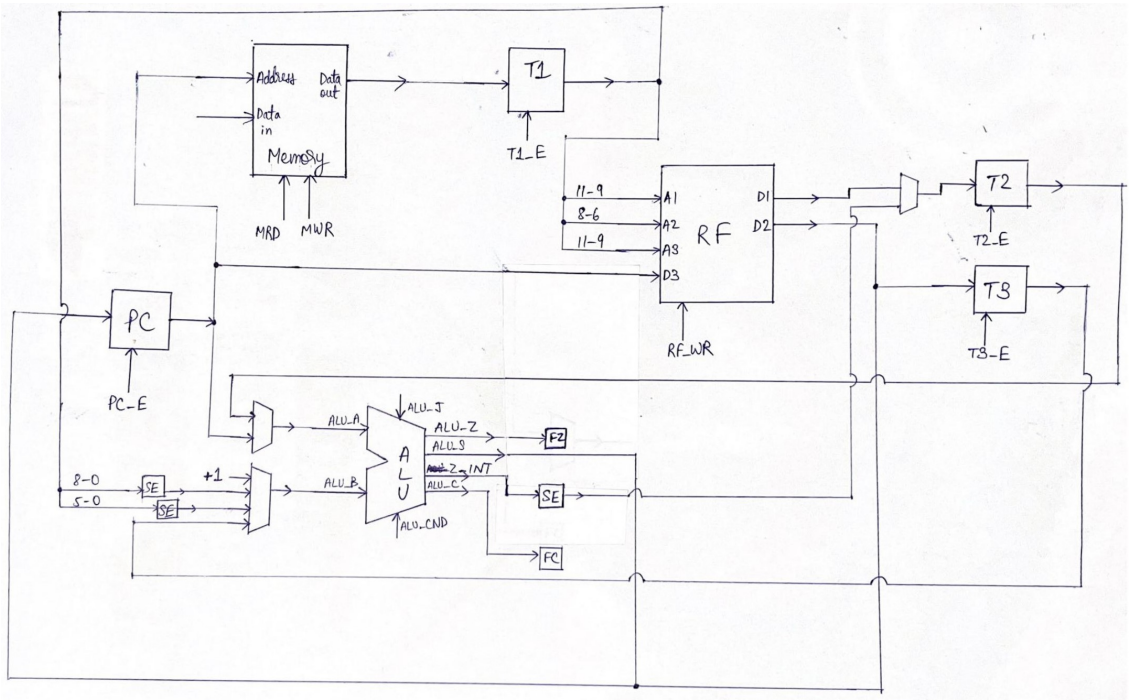
9 Nov 2022

ALU:

Data-flow





We have separated data-flow diagrams for ADD, NAND instructions from other instructions for simplicity.

Inputs:

ALU_A: Takes 16-bit input
ALU_B: Takes 16-bit input

Registers storing the flags:

FC and FZ
These are connected to ALU_C and ALU_Z respectively.

Control Signals:

ALU_J: Takes 2-bit input. This specifies whether to perform addition, subtraction or NAND.
ALU_CND: Takes 2-bit input. This is used to find the new values to be updated to FZ and FC(may or may not be the same as the previous values in FZ and FC) based upon ALU_J(see table).

Outputs:

ALU_C: Outputs the carry flag to be put in the FZ register at the end of the clock cycle.
ALU_Z: Outputs the zero flag to be put in the FZ register at the end of the clock cycle. This may or may not be the same as Z_int.
ALU_S: Outputs sum, NAND, or the difference based on the bits provided in ALU_J.
Z_int: Evaluates to 1 when ALU_S is zero. Else, it evaluates to 0.

ALU_J	Function
00	Addition
01	NAND
11	Subtraction

ALU_J	ALU_CND	Output from ALU_C	Output from ALU_Z
00 (Add)	00	Modified value of carry flag.	Modified value of zero flag.
00 (Add)	10	Modified value of carry flag if input FC is 1. Same as the previous value in FC if FC is 0.	Modified value of zero flag if input FC is 1. Same as the previous value in FZ if FC is 0.
00 (Add)	01	Modified value of carry flag if input FZ is 1. Same as the previous value in FC if FZ is 0.	Modified value of zero flag if input FZ is 1. Same as the previous value in FZ if FZ is 0
00 (Add)	11 (Used for updating PC)	Same as the previous value in FC.	Same as the previous value in FZ.
01 (NAND)	00	Same as the previous value in FC.	Modified value of zero flag.
01 (NAND)	10	Same as the previous value in FC.	Modified value of zero flag if input FC is 1. Same as the previous value in FZ if FC is 0.
01 (NAND)	01	Same as the previous value in FC.	Modified value of zero flag if input FZ is 1. Same as the previous value in FZ if FZ is 0.
11 (Subtract)	xx	Same as the previous value in FC.	Same as the previous value in FZ.

State Descriptions

(PC ≡ R7)

S_0 (Fetching instruction from memory)

Data Transfer	Commands
PC → M_add	MDR
M_data → T1	T1_E

S_1 (Updating PC)

Data Transfer	Commands
PC → ALU_A	PC_E
+1 → ALU_B	ALU_J ← 00
ALU_CND ← 11	
ALU_S → PC	

S_2 (Reading operands)

Data Transfer	Commands
$T1_{11-9}$ → RF_A1	T2_E
$T1_{8-6}$ → RF_A2	T3_E
RF_D1 → T2	
RF_D2 → T3	

S_3 (Execution)

Data Transfer	Commands
T2 → ALU_A	T2_E
T3 → ALU_B	ALU_J ← $T1_{14-13}$
$T1_{1-0}$ → ALU_CND	
ALU_S → T2	
ALU_C → FC	
ALU_Z → FZ	

S_4 (Storing the output)

Data Transfer	Commands
T2 → RF_D3	RF_WR
$T1_{5-3}$ → RF_A3	

S_5 (Reading operands (for ADI))

Data Transfer	Commands
$T1_{11-9}$ → RF_A1	T2_E
RF_D1 → T2	T3_E
$T1_{5-0}$ → SE_6 → T3	

S_6 **(Evaluating condition for BEQ)**

Data Transfer	Commands
T2 → ALU_A T3 → ALU_B Z_int → SE_1 → T2 ALU_CND ← 00	ALU_J ← 11 T2_E

S_7 **(Updating PC in BEQ)**

Data Transfer	Commands
PC → ALU_A if($T2_0 == 0$) then +1 → ALU_B else $T1_{5-0}$ → SE_6 → ALU_B ALU_CND ← 11 ALU_S → PC	ALU_J ← 00 PC_E

S_8 **(Storing PC into REG_A)**

Data Transfer	Commands
$T1_{11-9}$ → RF_A3 PC → RF_D3	RF_WR

S_9 **(Branching PC to the address PC + immediate)**

Data Transfer	Commands
PC → ALU_A $T1_{8-0}$ → SE_9 → ALU_B ALU_CND ← 11 ALU_S → PC	ALU_J ← 00 PC_E

S_{10} **(Branching PC to the address in REG_B)**

Data Transfer	Commands
$T1_{8-6}$ → RF_A1 RF_D1 → PC	PC_E

S_{11} **(Executing Load Higher Immediate)**

Data Transfer	Commands
$T1_{11-9}$ → RF_A3 $T1_{8-0}$ → PZ_7 → RF_D3	RF_WR

S_{12} **(Computing address of the memory destination)**

Data Transfer	Commands
T3 → ALU_A $T1_{5-0}$ → SE_6 → ALU_B ALU_S → T3	ALU_J ← 00 ALU_CND ← 11 T3_E

S_{13} **(Writing to the memory)**

Data Transfer	Commands
T3 → M_add T2 → M_data	MWR

S_{14} **(Reading from memory)**

Data Transfer	Commands
T3 → M_add	MDR
M_data → T2	T2_E

S_{15} **(Writing to the register)**

Data Transfer	Commands
$T1_{11-9}$ → RF_A3	RF_WR
T2 → RF_D3	

S_{16} **(Initial step of SM and LM)**

Data Transfer	Commands
(0000000000000000) → T2	T2_E
$T1_{11-9}$ → RF_A2	T3_E
RF_D2 → T3	
counter := int($T2_{2-0}$)	

S_{17} **(Looping step 1 of SM)**

Data Transfer	Commands
T3 → ALU_A	T3_E
+1 → ALU_B	ALU_J ← 00
if($T1_{counter}$==1) then	ALU_CND ← 11
{T3 → M_add	MWR
$T2_{2-0}$ → RF_A1	
RF_D1 → M_data	
ALU_S → T3 }	

S_{18} **(Updating counter variable (Looping step 2 of SM and LM))**

Data Transfer	Commands
counter (converted to 16 bit) → ALU_A	ALU_J ← 00
1 bit → ALU_B	ALU_CND ← 11
ALU_S → counter	

S_{19} **(Looping step 1 of LM)**

Data Transfer	Commands
$T1_{counter}$ → RF_WR	T3_E
T3 → M_add	ALU_J ← 00
M_data → RF_D3	ALU_CND ← 11
$T2_{2-0}$ → RF_A3	MDR
T3 → ALU_A	
+1 → ALU_B	
if($T1_{counter}$==1) then ALU_S → T3	

Instructions with their State Diagrams and Control Signals

Instruction	State flow
ADD	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
ADC	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
ADZ	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
ADI	$S_0 \rightarrow S_1 \rightarrow S_5 \rightarrow S_3 \rightarrow S_4$
NDU	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
NDC	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
NDZ	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow S_4$
LHI	$S_0 \rightarrow S_1 \rightarrow S_{11}$
LW	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_{12} \rightarrow S_{14} \rightarrow S_{15}$
SW	$S_0 \rightarrow S_1 \rightarrow S_2 \rightarrow S_{12} \rightarrow S_{13}$
SM	$S_0 \rightarrow S_1 \rightarrow S_{16} \rightarrow S_{17}\ S_{18}$
LM	$S_0 \rightarrow S_1 \rightarrow S_{16} \rightarrow S_{19}\ S_{18}$
BEQ	$S_0 \rightarrow S_2 \rightarrow S_6 \rightarrow S_7$
JAL	$S_0 \rightarrow S_8 \rightarrow S_9$
JLR	$S_0 \rightarrow S_8 \rightarrow S_{10}$

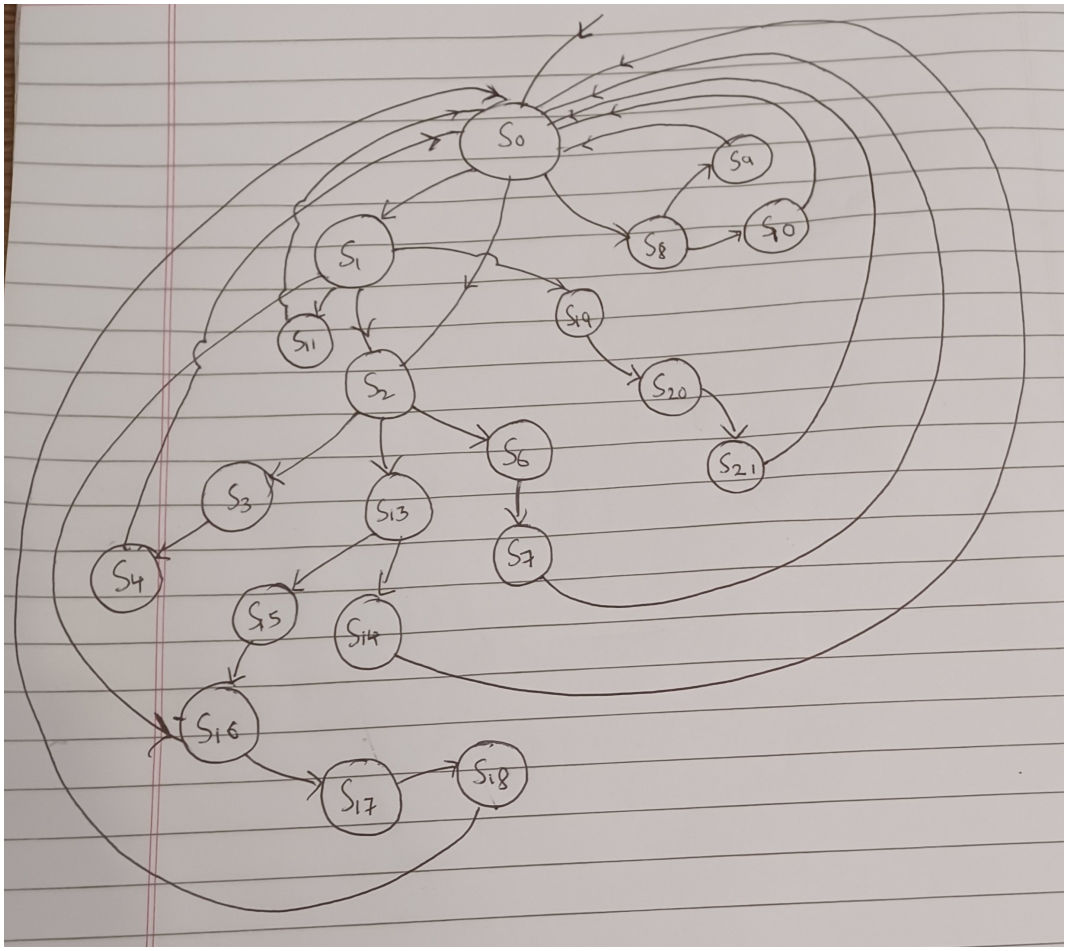


Figure 1: State Transition Diagram