

NCTU-EE IC LAB – Fall 2024

Lab01 Exercise

Design: Code Calculator

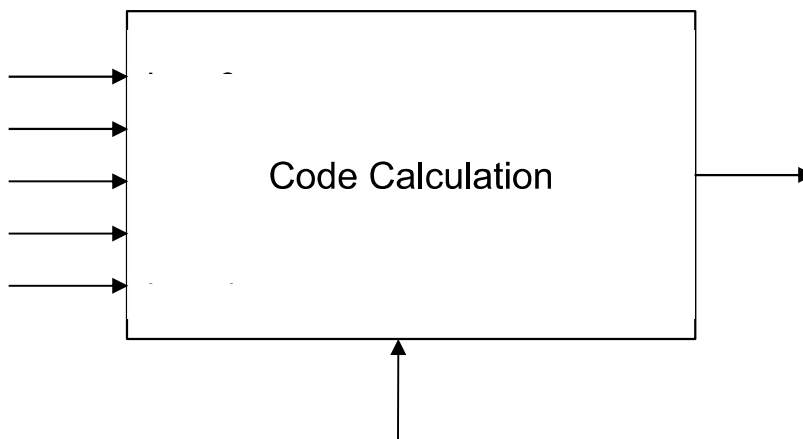
Data Preparation

1. Extract files from TA's directory:
% tar xvf ~iclabTA01/Lab01.tar
2. The extracted LAB directory contains:
 - a. Exercise/
 - b. Practice/

Design Description and Examples

At the final stage of NYCU Millionaire, you are asked to answer a question based on a series of simple mathematical operations. The only challenge is the remaining time, 20 ns. If you answer it in time correctly, you will win a prize of a million dollars. “Ready... Start...”.

You will receive a sequence with 5 numbers {**in_n0**, **in_n1**, **in_n2**, **in_n3**, **in_n4**} and a **3-bit opt** signal. Then you should calculate the result in the following order:



First, please do the 3 possible operations indicated by **opt** signal in the following order:

1. Sort	<p>If opt[1] is 1, sort the sequence from the largest to the smallest.</p> <p>For example, {-1, 3, 5, 4, -3} becomes {5, 4, 3, -1, -3}.</p> <p>If opt[1] is 0, sort the sequence from the smallest to the largest.</p> <p>For example, {-1, 3, 5, 4, -3} becomes {-3, -1, 3, 4, 5}.</p>
2. Normalization	<p>If opt[0] is 1, subtract the average of the largest number</p>

	<p>and the smallest number from every element in sequence.</p> <p>For example, the original sequence is {1, 2, 4, 6, 9}. The value $(1+9)/2$ should be subtracted from each element in the sequence, and the sequence will become {-4, -3, -1, 1, 4}.</p> <p>If opt[0] is 0, don't normalize.</p> <p>For example, the original sequence {1, 2, 4, 6, 9} remains {1, 2, 4, 6, 9}.</p> <p>(round-down the average first if it is not an integer)</p>
3. Calculation	<p>After the two operations, you will get a sequence {n0, n1, n2, n3, n4}. Finally, the output answer can be obtained by one of the following equations</p> <p>If opt[2] is 1, Eq : $n3 * 3 - n0 * n4$</p> <p>If opt[2] is 0, Eq : $((n0 + n1 * n2 + \text{avg} * n3) / 3)$</p> <p>About avg:</p> <p>Based on the normalization result to calculate the average.</p> <p>For example, the sequence after normalization is {-4, -3, -1, 1, 4}, and you will get the average result, avg = $(-4 + -3 + -1 + 1 + 4)/5$.</p> <p>(round-down both the answer of Eq and avg if it is not integer)</p>

The summary of the description and specifications are as follows:

Input Signal	Bit Width	Description
in_n0	4	The first number of code, which ranged from 0~15 .
in_n1	4	The second number of code, which ranged from 0~15 .
in_n2	4	The third number of code, which ranged from 0~15 .
in_n3	4	The fourth number of code, which ranged from 0~15 .
in_n4	4	The fifth number of code, which ranged from 0~15 .

opt	3	Operator for different modes. The operation will be encoded as follows: opt[0]: 1: Normalize 0: Don't normalize opt[1]: 1: Sort from largest to smallest. 0: Sort from smallest to largest. opt[2]: 1: Eq : $ n3 * 3 - n0 * n4 $ 0: Eq : $((n0 + n1 * n2 + avg * n3) / 3)$
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Output Signal	Bit Width	Description
out_n	10	The answer. Ranged from -512~511

Inputs

1. The input signals in_n0, in_n1, in_n2, in_n3 and in_n4 are 4-bit inputs
2. The input signal opt is a 3-bit input indicating whether to do the operations and which equation to use for the final result.

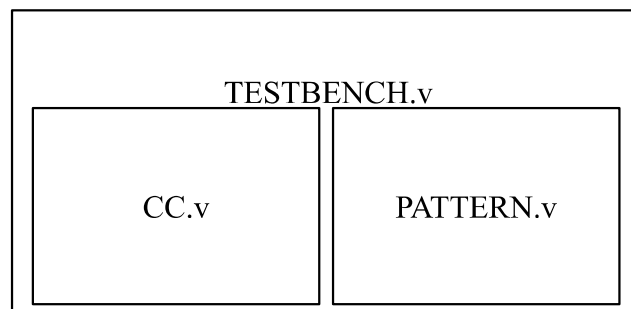
Outputs

The output signal **out_n** is a signed number ranging from **-512~511**. This represents the correct result.

Specifications

1. Top module name : CC (File name: CC.v)
2. Input pins : in_n0, in_n1, in_n2, in_n3, in_n4, opt
3. Output pins : out_n
4. After synthesis, check the "CC.area" and "CC.timing" in the folder "Report". **The area report is valid only when the slack at the end of "CC.timing" is "MET".**
5. The synthesis result **cannot** contain any **latch**.
Note: You can check if there is a latch by searching the keyword "**Latch**" in 02_SYN/syn.log

Block Diagram



Grading Policy

The performance is determined by the area of your design. The less area your design has, the higher grade you get.

Function Validity: 70%

Performance: area 30%

Note

1. Please upload the following file on e3 platform before **12:00 at noon on Mar. 4:**
CC_iclab??.v (?? is your account no.)

Ex: CC_iclab99.v

First demo deadline: 12:00 at noon on Mar. 4

Second demo deadline: 12:00 at noon on Mar. 6

2. Template folders and reference commands:

In RTL simulation, the name of template folder and reference commands is:

01_RTL:

./01_run

02_SYN/ (Synthesis):

./01_run_dc

./08_check

(Check **latch** by searching the keyword “**Latch**” in 02_SYN/syn.log)

(Check the design’s timing in /Report/CC.timing)

(Check the design’s area in /Report/CC.area)

03_GATE/:

./01_run

09_SUBMIT:

./00_tar:

After ./00_tar, you should add your cycle time.

For example: ./00_tar 20

Since in this lab performance is only based on area, changing cycle time by yourself is forbidden.

./01_submit

You can only do this after ./00_tar, or maybe you will upload the wrong file.

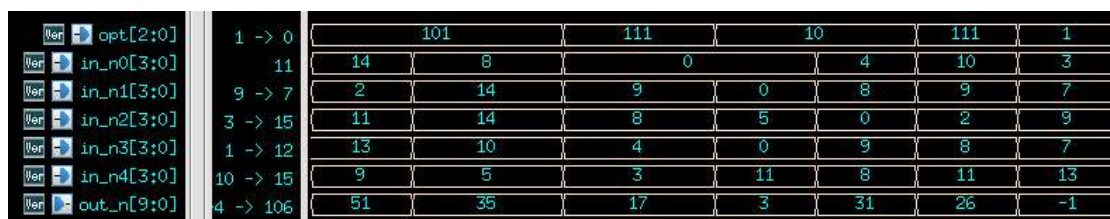
./02_check

Always run ./02_check after ./01_submit to make sure you upload the correct file.

You can key in **./09_clean_up** to clear all log files and dump files in each folder

Example Waveform

Input and output signal:



Signal	1 -> 0	11	9 -> 7	3 -> 15	1 -> 12	10 -> 15	4 -> 106
opt[2:0]	101	111	10	111	1		
in_n0[3:0]	14	8	0	4	10	3	
in_n1[3:0]	2	14	9	0	8	9	7
in_n2[3:0]	11	14	8	5	0	2	9
in_n3[3:0]	13	10	4	0	9	8	7
in_n4[3:0]	9	5	3	11	8	11	13
out_n[9:0]	51	35	17	3	31	26	-1