

# NCTU-CS Digital System Lab.

## LAB 02 - CONVCOR

### Design: Convolution and correlated sum

#### Data Preparation

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1. Extract LAB data from TA's directory.

```
% tar xvf ~2016dlabta05/Lab02.tar
```

#### Design Description and Examples

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Correlation and Convolution are basic operations that we will perform to extract information from images. In this practice, we need to compute convolution and correlation sum for A and B, which has three entries, respectively. Two calculation operates as following:

Input :

In\_a:   a<sub>0</sub>   a<sub>1</sub>   a<sub>2</sub>  
In\_b:   b<sub>0</sub>   b<sub>1</sub>   b<sub>2</sub>

for convolution operation

$$\text{In\_a} \circ \text{In\_b} = \sum_{k=-\infty}^{\infty} a_k * b_{n-k}$$

0 0 a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>	0 a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>	a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>	a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>	a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>
× × × × ×	× × × ×	× × ×	× ×	×
b <sub>2</sub> b <sub>1</sub> b <sub>0</sub> 0 0	b <sub>2</sub> b <sub>1</sub> b <sub>0</sub> 0	b <sub>2</sub> b <sub>1</sub> b <sub>0</sub>	b <sub>2</sub> b <sub>1</sub> b <sub>0</sub>	b <sub>2</sub> b <sub>1</sub> b <sub>0</sub>

Output :   a<sub>0</sub>b<sub>0</sub>   a<sub>0</sub>b<sub>1</sub>+ a<sub>1</sub>b<sub>0</sub>   a<sub>0</sub>b<sub>2</sub>+ a<sub>1</sub>b<sub>1</sub>+ a<sub>2</sub>b<sub>0</sub>   a<sub>1</sub>b<sub>2</sub>+ a<sub>2</sub>b<sub>1</sub>   a<sub>2</sub>b<sub>2</sub>

for correlation sum

a <sub>0</sub> a <sub>1</sub> a <sub>2</sub>
× × ×
$\overline{b_0} \ \overline{b_1} \ \overline{b_2}$

Output :   a<sub>0</sub> $\overline{b_0}$  + a<sub>1</sub> $\overline{b_1}$  + a<sub>2</sub> $\overline{b_2}$

These two different calculation modes are selected by the signal, MODE. MODE0 is the convolution of A and B. MODE1 is the correlation sum of two matrices.

Your goal is to compute matrices by above rules and output the correct answer.

Signal	Description
MODE	MODE=0 : convolution of A and B MODE=1 : correlation sum of A and B

### Inputs

1. Three input data for **in\_a[15:0]** and **in\_b[15:0]** each will be sequentially input in **3 continuous** cycles while **in\_valid** is high.
2. You will receive 3 inputs of 16-bits **signed complex numbers** for **in\_a[15:0]** and **in\_b[15:0]**, respectively. The former 8 bits are the real part of each number. Last 8 bits are the image part otherwise. Two parts of this complex number all are **twos-complement representation**.  
Ex: Bits format of  $in\_a0 = a_1a_2a_3a_4a_5a_6a_7a_8 + (a_9a_{10}a_{11}a_{12}a_{13}a_{14}a_{15}a_{16})i$
3. **in\_mode** define which calculation should be done at **first** cycle.
4. All inputs will be changed at clock **negative** edge.

### Outputs

1. Your answer should be output at **out[35:0]** for **only 5 cycle** when **MODE = 0**; Whereas, output at **out[35:0]** for **only 1 cycle** when **MODE = 1**.
2. **out[35:0]** is signed complex number, also. The former 18 bits are the real part, and last 18 bits are the image part otherwise.
3. **out\_valid** should be low and **out** should be set to zero after initial reset.
4. **out\_valid** is set to be high when output value is valid.
5. All outputs are synchronized at clock **positive** edge.
6. Test pattern will check whether your answer is correct or not at clock **negative edge** when **out\_valid** is high.

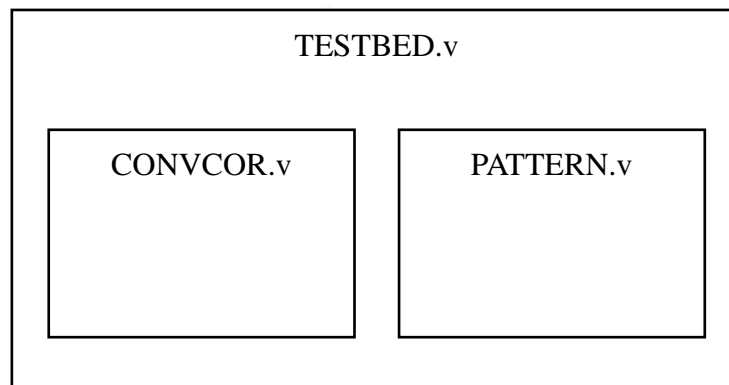
## Specifications

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1. Top module name : **CONVCOR** (File name : **CONVCOR.v**)
2. Input pins: **clk** , **rst\_n** , **in\_valid** , **in\_a[15:0]**, **in\_b[15:0]**, **in\_mode**.
3. Output pins: **out\_valid** , **out[35:0]**.
4. **out\_valid** should not be raised when **in\_valid** is high ( in\_a and in\_b is transferring).
5. It is **active-low synchronous** reset.
6. The latency of your design in each pattern should not be larger than 100 cycles.

## Block Diagram

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## Note

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1. Simulation step:
  - Put your design in 01\_RTL
  - Simulation to check design : ./01\_run.f
  - Show waveto debug: nWave&
  - Clear up : ./09\_clean\_up
2. Please add your student ID to the file name of .v file before upload file on e3 platform:  
CONVCOR\_0556123.v
3. Sample waveform:

