Lab 3 – Buffer Insertion

- Due: 23:59pm, May 6 (Thu)

- How to submit
  - **Zip all the files and upload it in the blackboard "Lab 3" page.**
  - **Email submission will not be accepted.**

Lab 3

- Download the following file.
  - wget https://eecs.wsu.edu/~ee434/Labs/lab3.tar.gz

- Unzip it.
  - tar xvfz lab3.tar.gz

- Source
  - ictools_generic.sh
 - cadence_innovus17.sh

- Run Innovus
  - innovus

Lab 3

- Click "File" → "Import Design...".

- In the "Design Import" window, click "Load..." and select "bi.globals". This will fill up the "Design Import" window. Click "OK".

- Now, you have imported the netlist. Let's also import a layout. In the terminal window, run the following command.
  - defIn bi.def

```
innovus 1>
innovus 1> defIn bi.def
```

- Press "f" to refresh the window.

Lab 3

- You can see this window.
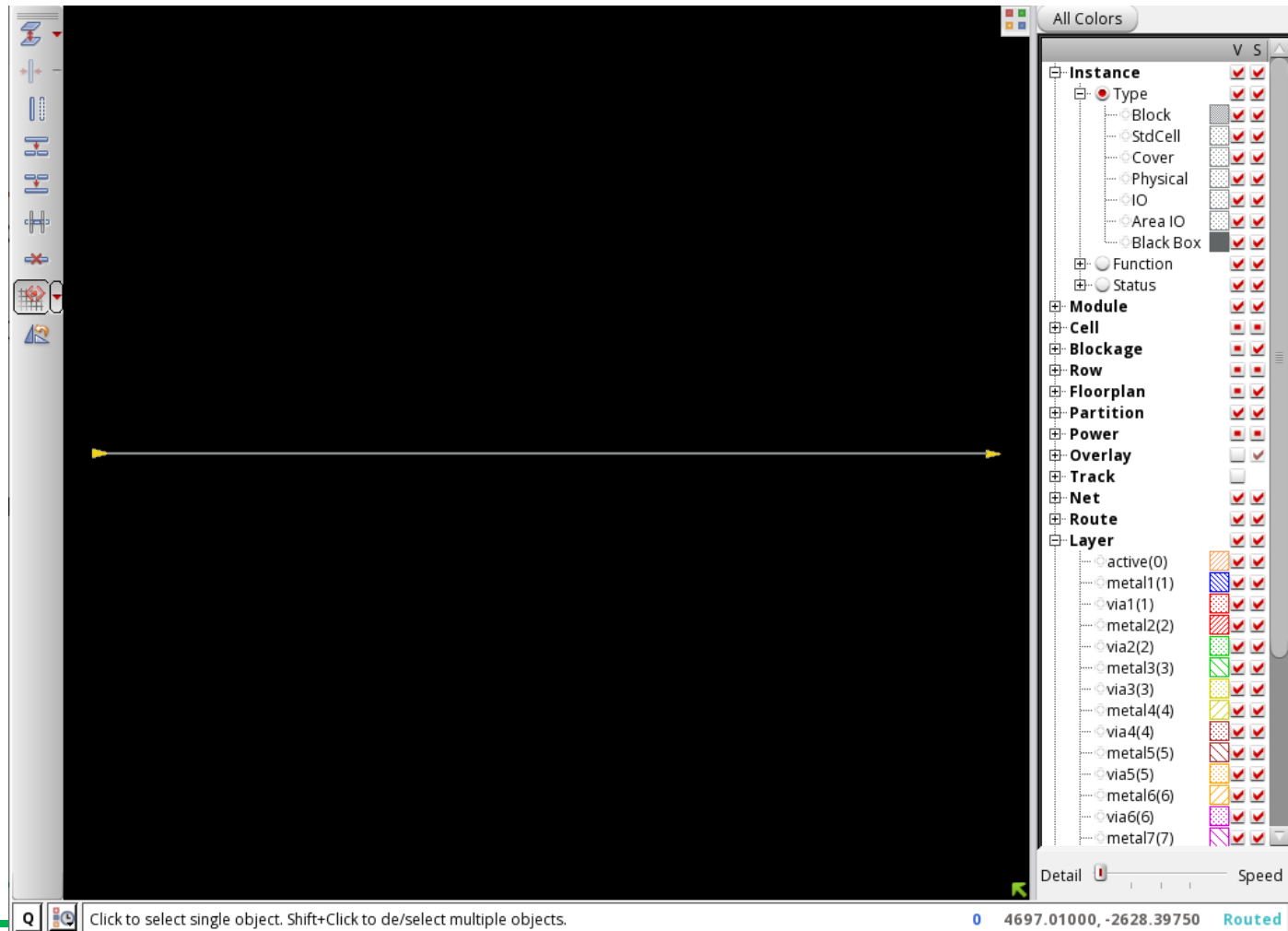
User Interface

- Mouse left button: select an object.

- Mouse right button: click → hold → drag → release (zoom-in)

Timing

- The design has a two-input NAND gate.

- g_out = ~(g_in[0] AND g_in[1])

- Timing constraint: 500ps

- Layout width: 5,000um
  - The two input pins are on the left side of the layout.
  - The output pin is on the right side.
  - The NAND gate is on the left side.
  - Thus, the distance between the output of the NAND gate and the output pin g_out is almost 5,000um.
  - You are supposed to minimize the delay.

Timing

- Use "report_timing -net" to get a timing report.

```
Path 1: VIOLATED Path Delay Check
Endpoint:   g_out   (^)
Beginpoint: g_in[1] (v) triggered by  leading edge of '@'
Path Groups: {default}
Analysis View: NG_view_typ
- External Delay                  0.000
+ Path Delay                      0.500
= Required Time                   0.500
- Arrival Time                    2.323
= Slack Time                     -1.823
    Clock Rise Edge                       0.000
    + Input Delay                         0.000
    = Beginpoint Arrival Time             0.000
+------------------------------------------------------------------------+
|  Pin    | Edge |   Net   |   Cell   | Delay | Arrival | Required |
|         |      |         |          |       |  Time   |  Time    |
|---------+------+---------+----------+-------+---------+----------|
| g_in[1] |  v   | g_in[1] |          |       |  0.000  |  -1.823  |
| U1/A2   |  v   | g_in[1] | NAND2_X1 | 0.000 |  0.000  |  -1.823  |
| U1/ZN   |  ^   | g_out   | NAND2_X1 | 0.475 |  0.475  |  -1.348  |
| g_out   |  ^   | g_out   | VBI      | 1.848 |  2.323  |   0.500  |
+------------------------------------------------------------------------+
```

Gate internal delay

Net delay

U1
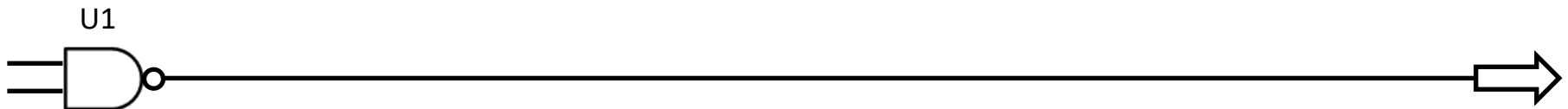
Buffer Types

- BUF_X1
- BUF_X2
- BUF_X4
- BUF_X8
- BUF_X16
- BUF_X32

How to Insert a Buffer

- Click "ECO" → "Interactive ECO..."

- Click the "Add Repeater" tab.

- Type the name of the target net ("g_out" in this example) or click the net in the GUI window with your mouse left button and click "get selected" in the ECO window.

- In the "New Cell" box, select "BUF_X8".

- Click the "Location" bullet.

- You can enter the target coordinate or click the icon beside the "First Buf/Inv" coordinates and click a target buffer insertion location in the layout.

Interactive ECO

| Add Repeater | Add Instance | Change Cell | Del Repeater | Display Buffer Tree |

Net: g_out ❌ | Get Selected |

Terminals:

- ● All Terminals
- ○ Listed Terminals

New Cell: BUF_X8 ▼

Place Mode

- ○ Default
- ○ Don't Place Cells
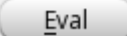- ● Location: First Buf/Inv   X: 2740.499   Y: 1.5515
  - ☐ Second Inv   X: Y:
- ○ Relative distance wire cut to the sink (%):   0.5
- ○ Offload:
  - ● By Slack (ns):
  - ○ By Location: X: Y:
- ☐ Radius (um):
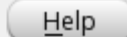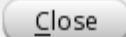
| Apply | Eval | Eval All | Add to WhatIf List |

| **Mode** | Close | Help |

How to Insert a Buffer

- Click "Apply". This will insert a buffer into the target location.

- In the Innovus terminal, reroute the design (you should reroute the design after you insert a buffer.)
    - globalDetailRoute

- Then, run "report_timing -net".

- The slack increased from -1.823ns to -0.851ns.

```
Path 1: VIOLATED Path Delay Check
Endpoint:   g_out    (v)
Beginpoint: g_in[1] (^) triggered by  leading edge of '@'
Path Groups: {default}
Analysis View: NG_view_typ
- External Delay              0.000
+ Path Delay                  0.500
= Required Time               0.500
- Arrival Time                1.351
= Slack Time                 -0.851
    Clock Rise Edge                 0.000
    + Input Delay                   0.000
    = Beginpoint Arrival Time       0.000
```

Pin	Edge	Net	Cell	Delay	Arrival Time	Required Time
g_in[1]	^	g_in[1]			0.000	-0.851
U1/A2	^	g_in[1]	NAND2_X1	0.000	0.000	-0.851
U1/ZN	v	FE_ECON0_g_out	NAND2_X1	0.234	0.234	-0.618
FE_ECOC0_g_out/A	v	FE_ECON0_g_out	BUF_X8	0.620	0.854	0.002
FE_ECOC0_g_out/Z	v	g_out	BUF_X8	0.185	1.039	0.187
g_out	v	g_out	VBI	0.313	1.351	0.500

Note

- If you insert a buffer into a net, it splits the net into two nets. The names of the nets will change, so it would be better to select a net and click "Get Selected" in the "Add Repeater" window.

Goal

- Satisfy the given timing constraint.

- Minimize the total buffer size (the sum of BUF_X#).

- Submit
  - Final DEF file (see the next slide)
  - Final timing report (a screenshot or copy&paste)
  - Total buffer size
  - A brief description of the optimization methodology you used.

How to Generate DEF

- In the Innovus terminal, type
  - defOut -floorplan -netlist -routing <filename>
  - For example
    - defOut -floorplan -netlist -routing Kim.def

Play with Buffers

- If you want to delete a buffer, go to the "Del Repeater" tab.
  - Select the target buffer in the layout.
  - Click "Get Selected".
  - Click "Apply".

- If you want to replace a buffer with a different buffer, go to the "Change Cell" tab.
  - Select the target buffer in the layout.
  - Click "Get Selected".
  - Select the new buffer type (e.g., BUF_X16) in the "specified cell".
  - Click "Apply".

- Don't forget to reroute the design whenever you modify the layout.
  - globalDetailRoute