Full Custom Design

Warning!

While not mentioned explicitly, it is advised to ensure after every step that your design is free of errors. This will help you debug the problem at the initial stage. For schematic, the F8 shortcut will work. For layouts, you will have to select Verify > DRC ...

1 Introduction

In this lab, we will characterize an inverter and find its electrical characteristics. Specifically, we will find the following parameters

- V_{IL}, V_{IH}, V_{OL}, and V_{OH}
- Noise margin
- Siwtching Voltage
- Power Consumption
- Delays - t_{PHL} and t_{PLH}

2 Transfer Characteristics

Start virtuoso by typing the following commands

```
cd  /vlsi
virtuoso &
```

Using the Library Manager, copy the library we created for an inverter to a new library 'Inv_Char'

Open the schematic for the inv-sim cell.

Launch ADE L for simulation. (If lucky, you might resue the saved state by opting for Load State) Go to Analyses > Choose ...

Choose a dc sweep from 0 to 5V with 1mV increment (like we did before).

Choose 'Netlist and Run'

You will see something like below

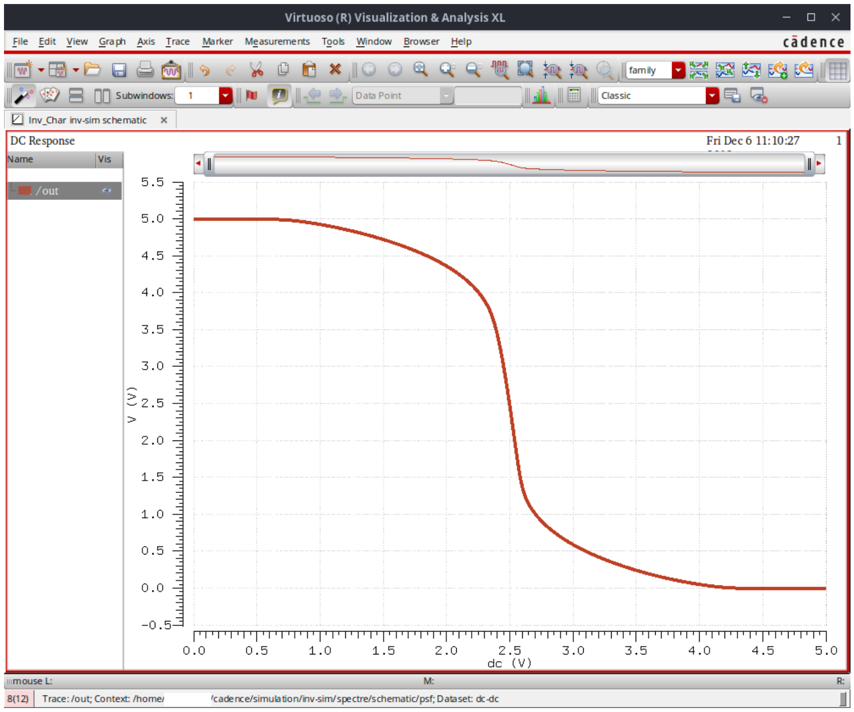

Figure 1: Transfer Curve of the Inverter

Launch calculator by going to Tools › Calculator ... Make sure the wave option is selected in the last toolbar

The window must show something like **v("/out" ?result "dc")**. If not, you need to select the waveform..

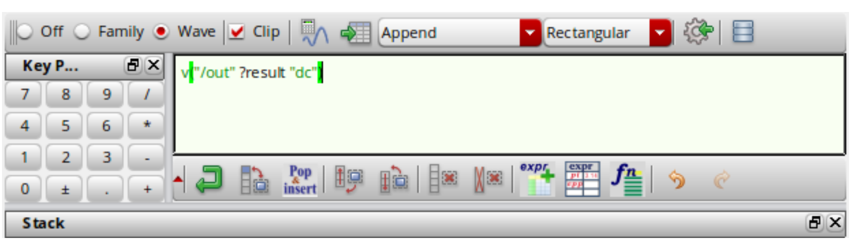

Figure 2: Buffer Windows - Output Curve

In the Function Panel, select Speical Functions and deriv. The window will update to **deriv(v("/out" ?re-**[redacted] **sult "dc"))**

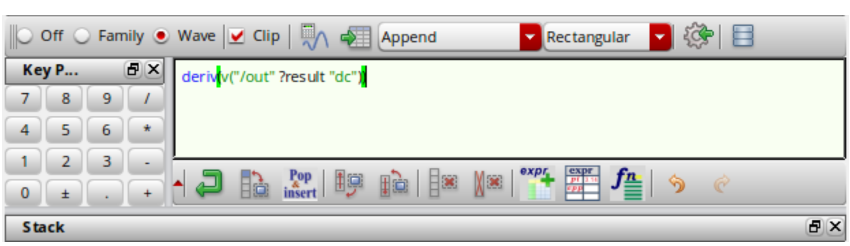

Figure 3: Buffer Windows -Derivative of Output Curve

Choose the 'Evaluate the buffer' icon to plot the derivative

Your plot window will update to something like below.

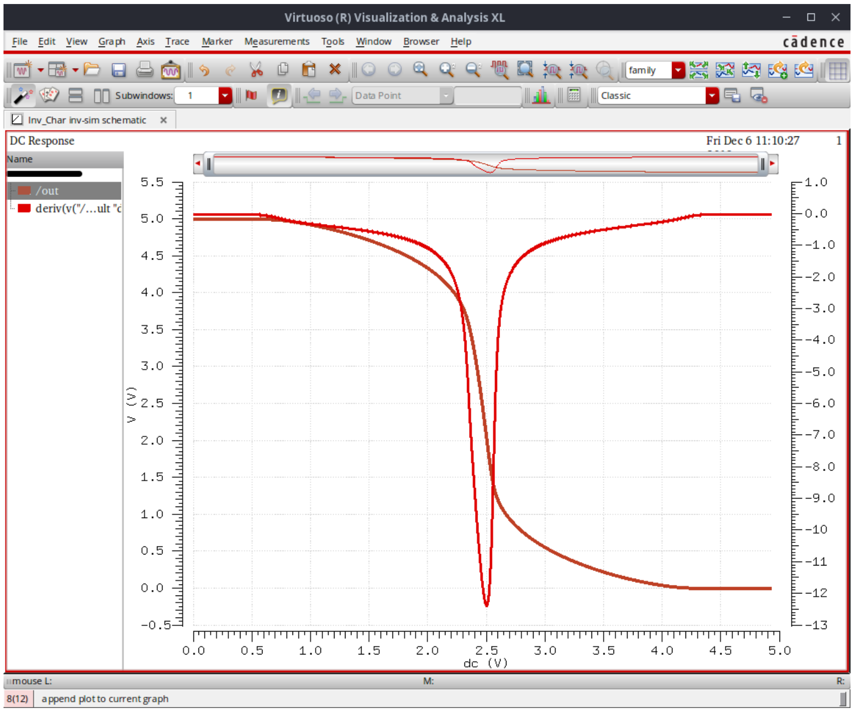

Figure 4: Plot of Voltage and its Derivative

2.1 V_{IL}

Go back to the calculator. This time choose the 'cross' function. Type as follows, and then click on Apply.

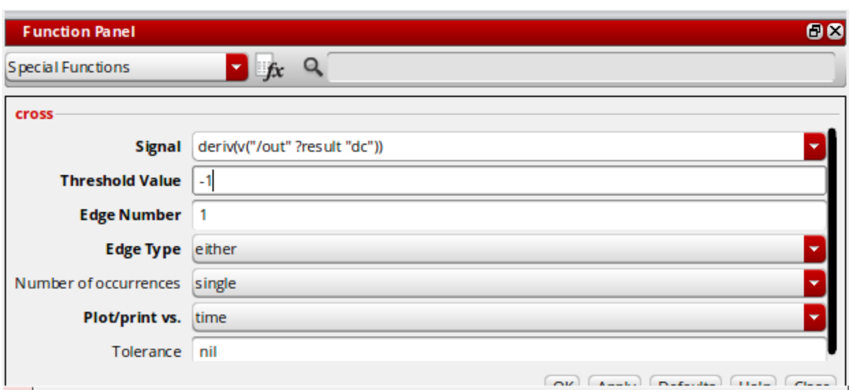

Figure 5: Cross Function for VIL

In the expression editor, click on the Add buffer expresion so it can be used later.

Double click on the name to change from E0 to VIL. Click on the 'Evaluate the buffer' icon to find the value.

(My answer was 1.992)

2.2 V_{IH}

Similarly, for VIH type as follows

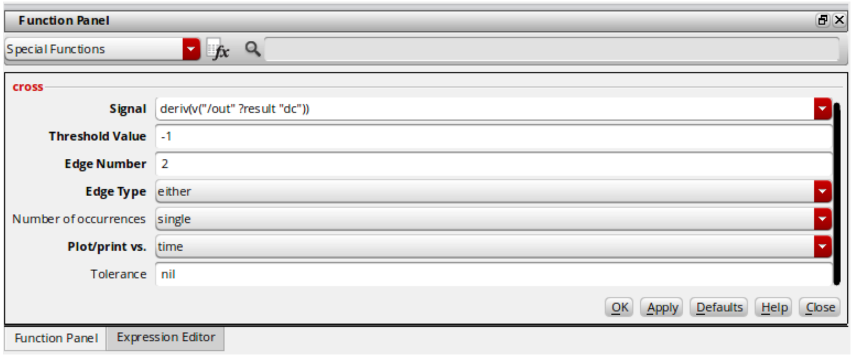

Figure 6: Cross Function for VIH

(My answer was 2.982)

2.3 V_{OH}

For VOH, use the value function and the original signal, not the derivative.

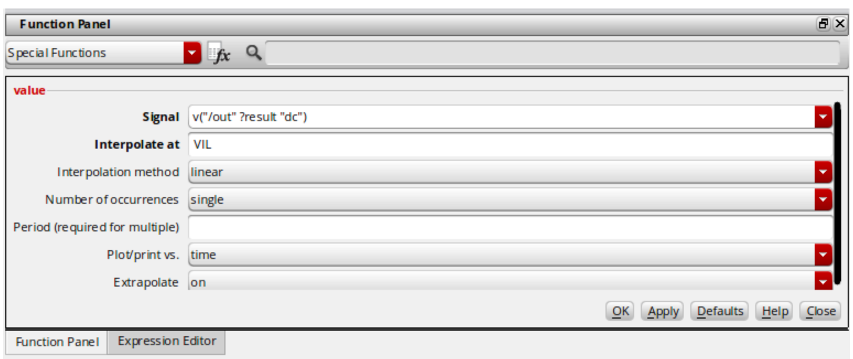

Figure 7: Value Function for VOH

(My answer was 4.373)

2.4 V_{OL}

For VOL, use the value function and the original signal, not the derivative.

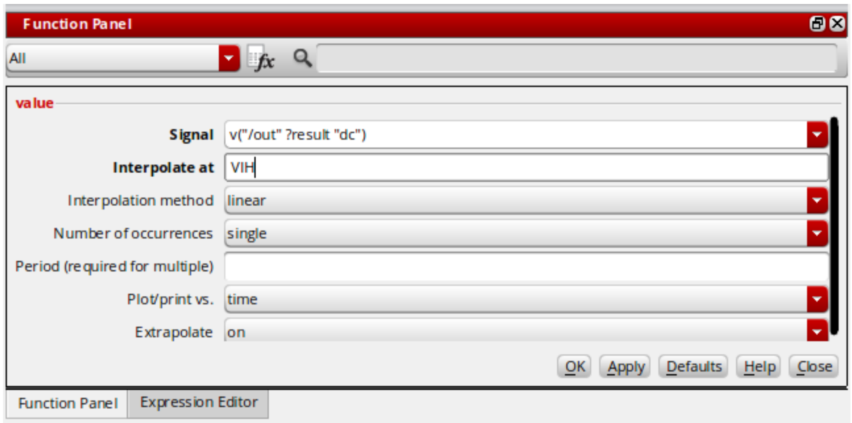

Figure 8: Value Function for VOL

(My answer was 0.613)

3 Noise Margins

To find NM_L, type V_{IL} - V_{OL} in the buffer window and evaluate. Then save it to a expression NML

(My answer was 1.378)

To find NM_H, type V_{OH} - V_{IH} in the buffer window and evaluate. Then save it to a expression NMH

(My answer was 1.392)

As a task, let's see how changing the width of a transistor affects the noise margin.

For the PMOS, in the schematic, change width to W1 (use descend and edit).

Define the variable by going to Variables ⟩ Edit ...

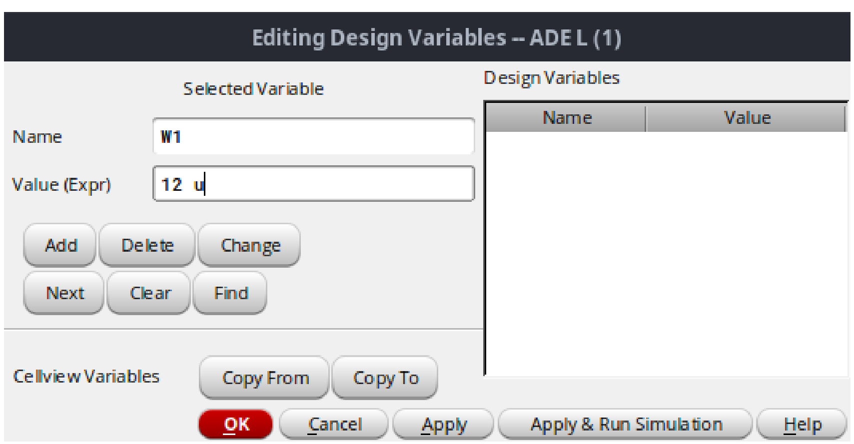

Figure 9: Design Variable

Go to Tools ⟩ Parametric Analysis ... . Set variable to W1, and sweep from 10μ to 14μ in 5 steps. Clikc Run Selected Sweeps.

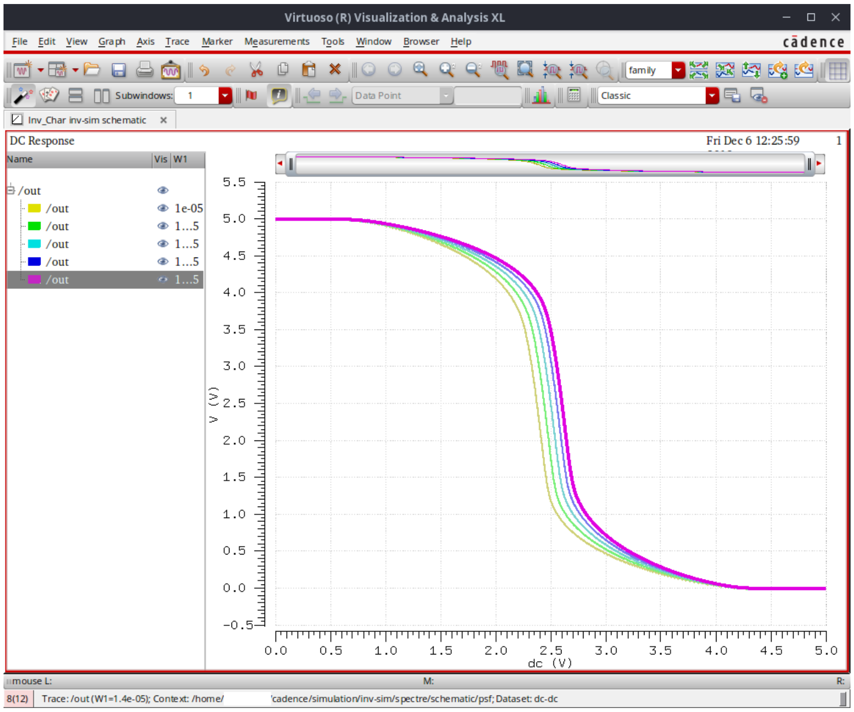

Figure 10: parametric Sweep for Different Widths

Click on the NML expression and select "Copy expression name to calculator buffer".

Figure 11: Copy Expression

Click on "Evaluate the buffer and display the results in a table"

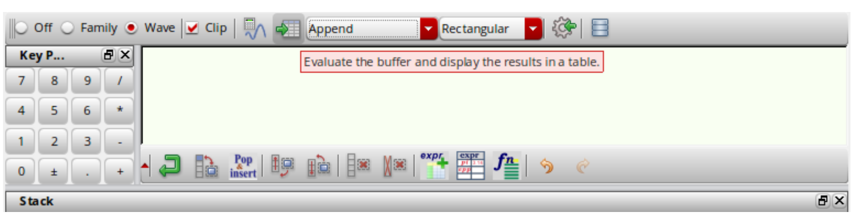

Figure 12: Evaluate Buffer

A table will pop up showing the result. Do the same for NMH.

4 Switching Voltage

To find the switching voltage, go back to your design, and plot both the input and the output voltages

Select the cross function and enter as following

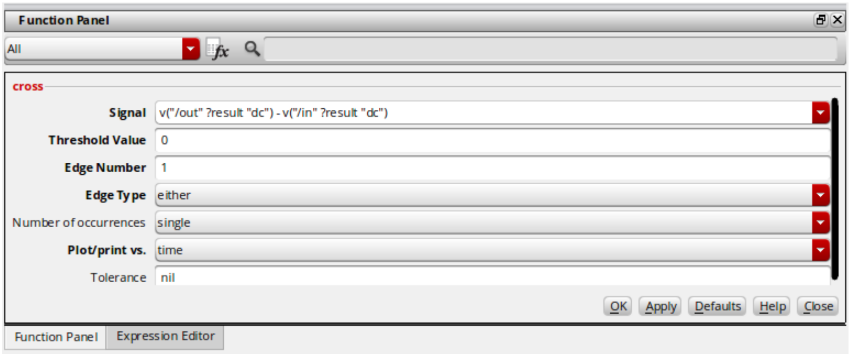

Figure 13: Cross Function for Switching Voltage

In the buffer windows type **v("/out" ?result "dc") - v("/in" ?result "dc")** . Evaluate and plot. Save it to an expression **dif**

Click on the 'Evaluate the buffer' icon to find the value.

(My answer was 2.498)

5 Delays

First, duplicate the inv-sim cell (because we will slightly modify the circuit). Name it **inv-sim-del**.

Delete the dc source for innput and replace it with a pulse source.

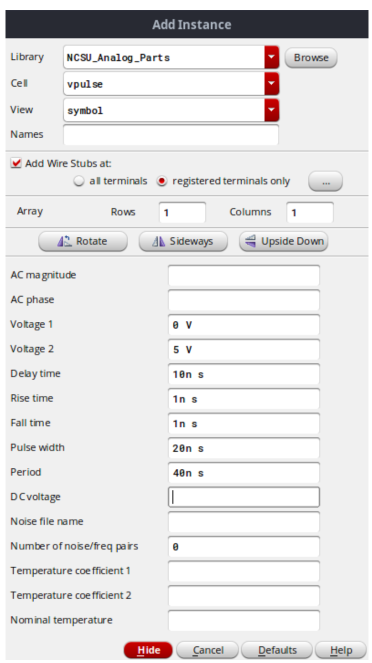

Figure 14: Values for Pulse Voltage

Also, add a 100fF capacitor at the output node.

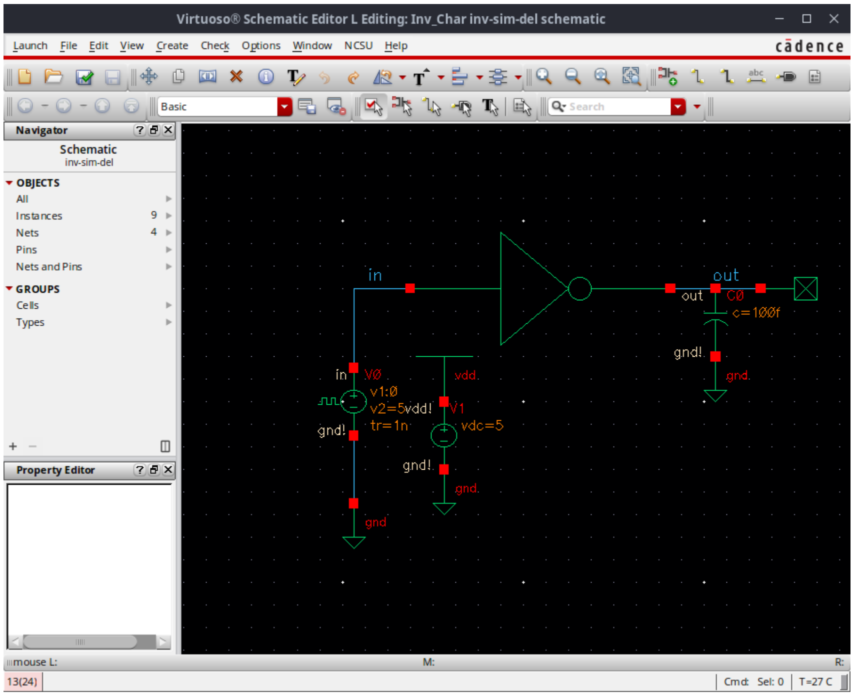

Figure 15: Circuit for Delay Measurement

Choose transient analysis for 40ns. Plot both the input voltage andthe output voltage.

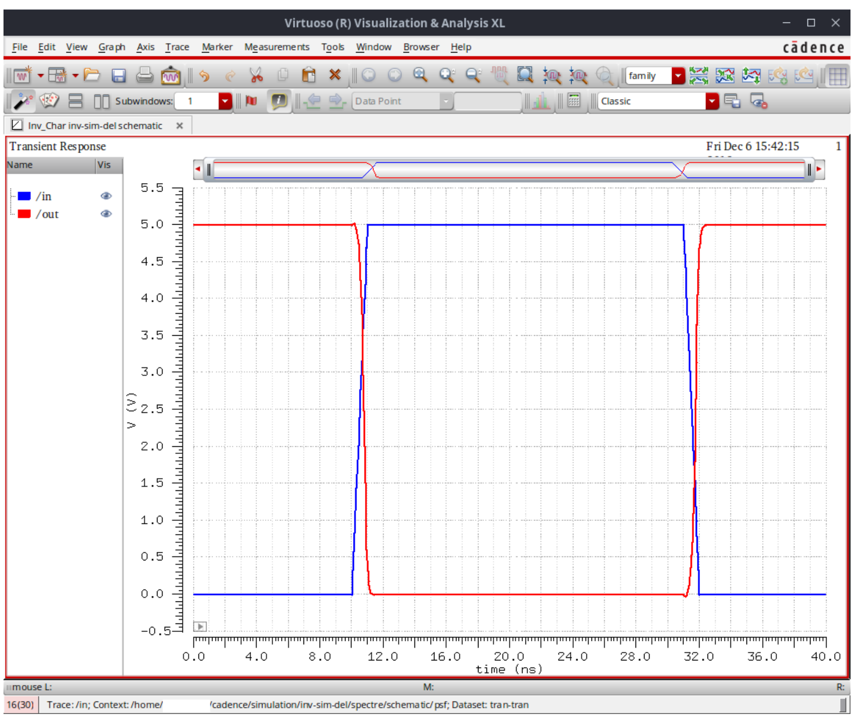

Figure 16: Transient Plot

Launch calculator.

5.1 T_{PHL}

(output goes from high to low)

Choose the delay function. Type as follows.

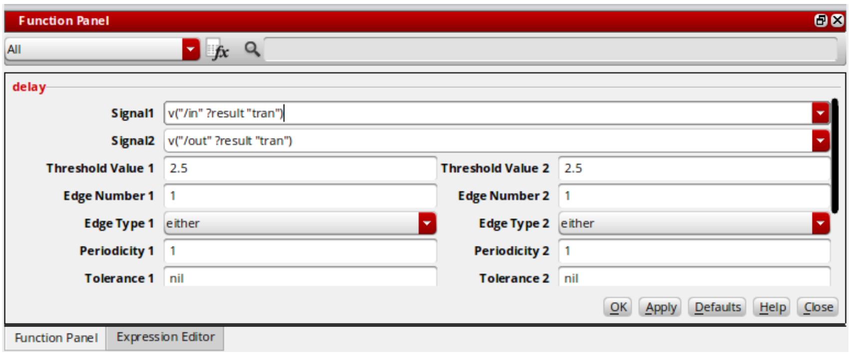

Figure 17: Delay Function for T_{PHL}

Then click apply. Click on the 'Evaluate the buffer' icon to find the value. (My answer was 259.8ps)

5.2 T_{PLH}

(output goes from low to high)

Choose the delay function. Type as follows.

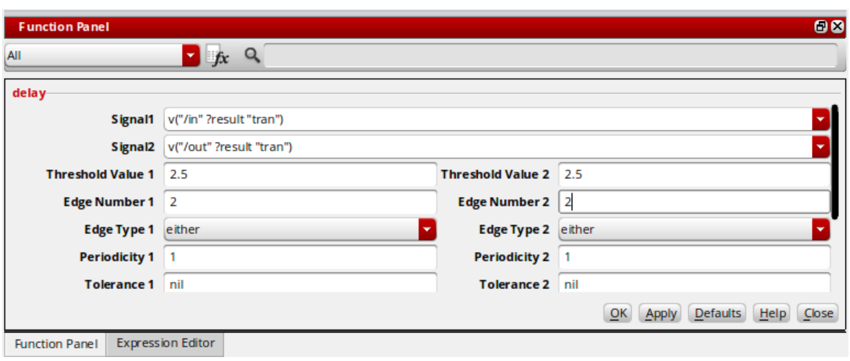

Figure 18: Delay Function for T_{PLH}

Then click apply. Click on the 'Evaluate the buffer' icon to find the value. (My answer was 249.5ps)

To find rise time of the output voltage, chose the riseTime function. Type as follows

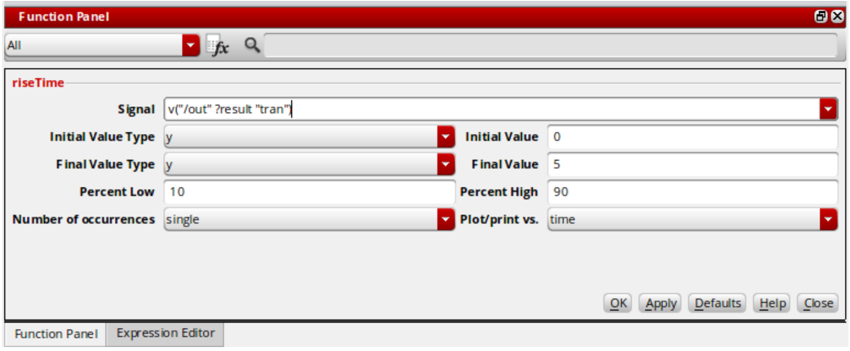

Figure 19: Rise Function for Output Voltage

Then click apply. Click on the 'Evaluate the buffer' icon to find the value. (My answer was 471.5ps)

To find fall time of the output voltage, chose the fallTime function. Type as follows

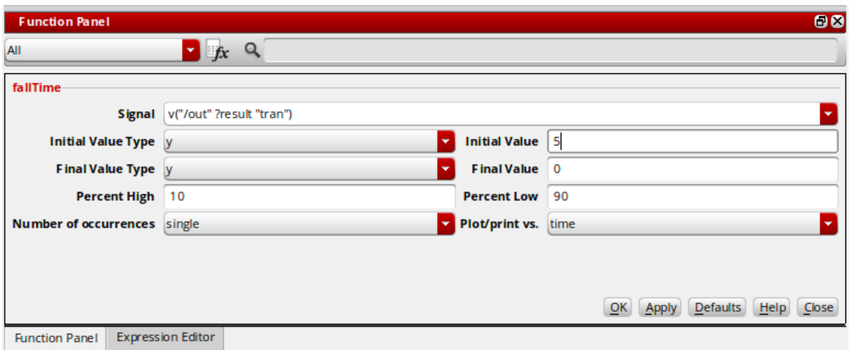

Figure 20: Fall Function for Output Voltage

Then click apply. Click on the 'Evaluate the buffer' icon to find the value. (My answer was 480.4ps)

6 Power Consumption

While chosing the outputs, right-click on the terminal of vdd to get the following

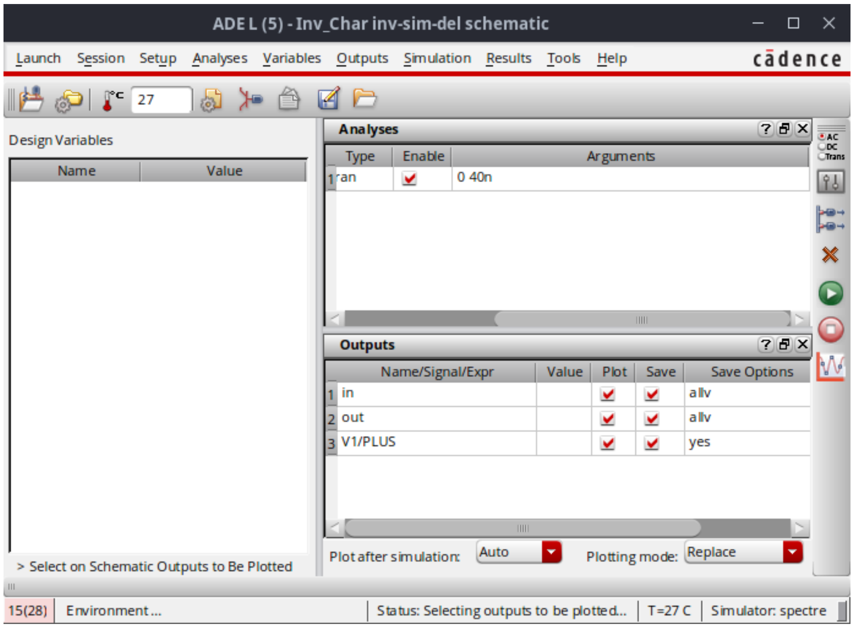

Figure 21: Choosing Current as an Output to be Plotted

In the calculator, choose the integ function, and type as follows.

Now, in the buffer windows, multiply with $(\frac{-5}{40n})$. (Multiplying by -5 to get the instantaneous power; the integration and divsion with 40n will average.)

Click on the 'Evaluate the buffer' icon to find the value. (My answer was 124.9μJ)