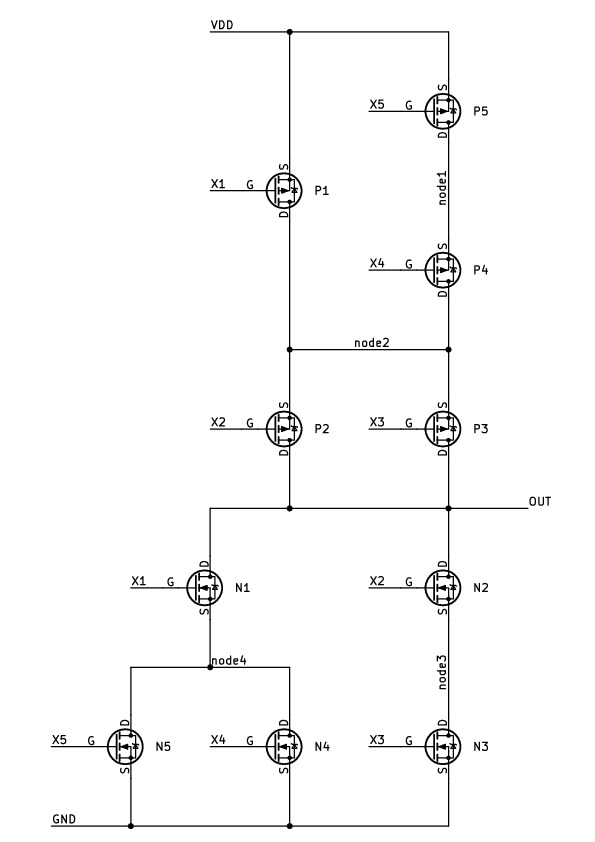
Midterm

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# Q1

## a)



Schematic of the five input function.

## b)

Output function is

## c)

Nodes are name in the code below.

.incl tsmc18.sp  
.param wp=0.3u  
.param wn=0.3u  
  
vdd vdd 0 dc 1.8  
Vx1 x1 0 PULSE(0 1.8 0n 1n 1n 5n 10n)  
Vx2 x2 0 PULSE(0 1.8 0n 1n 1n 10n 20n)  
Vx3 x3 0 PULSE(0 1.8 0n 1n 1n 20n 40n)  
Vx4 x4 0 PULSE(0 1.8 0n 1n 1n 40n 80n)  
Vx5 x5 0 PULSE(0 1.8 0n 1n 1n 80n 160n)  
  
MP1 node2 X1 VDD VDD CMOSP W=0.5u L=0.2u  
MP2 OUT X2 node2 VDD CMOSP W=0.5u L=0.2u  
MP3 OUT X3 node2 VDD CMOSP W=0.5u L=0.2u  
MP4 node2 X4 node1 VDD CMOSP W=0.5u L=0.2u  
MP5 node1 X5 VDD VDD CMOSP W=0.5u L=0.2u  
  
MN1 OUT X1 node4 0 CMOSN W=0.5u L=0.2u  
MN2 OUT X2 node3 0 CMOSN W=0.5u L=0.2u  
MN3 node3 X3 0 0 CMOSN W=0.5u L=0.2u  
MN4 node4 X4 0 0 CMOSN W=0.5u L=0.2u  
MN5 node4 X5 0 0 CMOSN W=0.5u L=0.2u  
  
.control  
tran 0.5n 160n  
plot v(x1) v(x2)+2 v(x3)+4 v(x4)+6 v(x5)+8 v(y)+10  
.endc  
.end

# Q2

Before starting calculations, I determine all necessary values are shown in below table, units are given in square brackets. , , , , and given in the tech file. is a value from mosfet model. can be calculated usign where is approximately , and is from the mosfet model.

## Calculation of chain number

Since n is given as 3, I will use it as 3.

## Calculation of tapering factor

Then I need to calculate which is calculated by following formula.

And when I put the values to formula:

And results is . So .

## a)

| Inverter | Wn | Wp |
| --- | --- | --- |
| 1 | 500n | 750n |
| 2 | 5425n | 8137n |
| 3 | 58861n | 88291n |

## b)

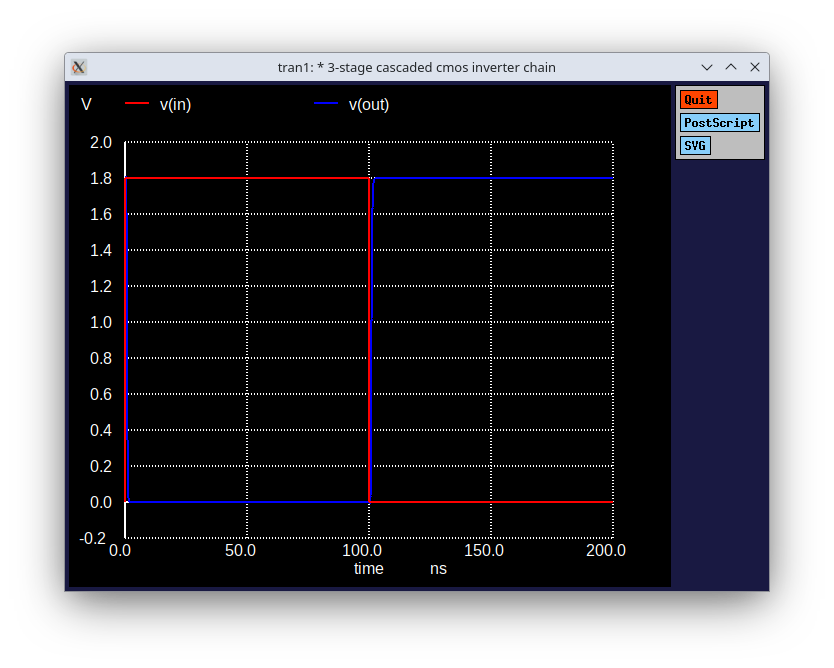
I need to calculate which is calculated by following formula.

And when I put the values to formula:

And results is . So

## c)

According to simulation, , and and it creates 798.5[ps] delay.



Output waveform of Vin and Vout for 3stage cascaded inverter.

# Q3

## a)

Let’s write for inverter, 3 input NAND and 3 input NOR gates in general form.  
Assume that and beacuse we are using minimum dimensions.  
Assume that .  
N is 3 for NAND and NOR.

### Delay of Inverter

### Delay of NAND

### Delay of NOR

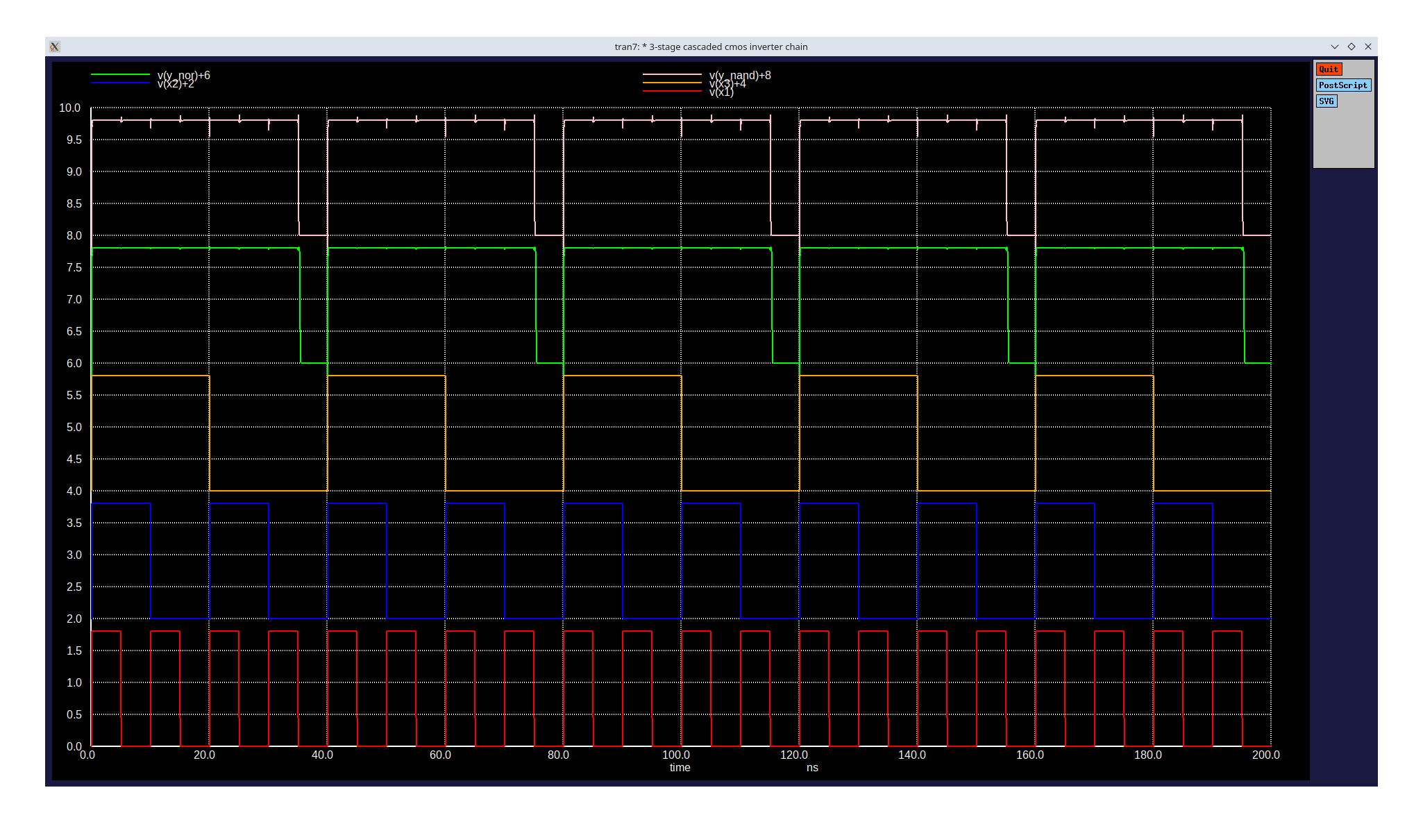
### Delay of NOR + Inverter

### Delay of Inverters + NAND

## b)

Results of simulation in terms of and

|  |  |  |  |
| --- | --- | --- | --- |
| Start Point | End Point | Delay Type | Value |
| X1 | NOR Circuit |  | 35.34 ps |
| X1 | NOR Circuit |  | 4.97 ps |
| X2 | NOR Circuit |  | 35.34 ps |
| X2 | NOR Circuit |  | 9.97 ps |
| X3 | NOR Circuit |  | 35.34 ps |
| X3 | NOR Circuit |  | 19.97 ps |
| X1 | NAND Circuit |  | 35.10 ps |
| X1 | NAND Circuit |  | 4.96 ps |
| X2 | NAND Circuit |  | 35.10 ps |
| X2 | NAND Circuit |  | 9.96 ps |
| X3 | NAND Circuit |  | 35.10 ps |
| X3 | NAND Circuit |  | 19.96 ps |



Waveform of all inputs and both outputs.

\* 3-Stage Cascaded CMOS Inverter Chain  
  
.incl tsmc18.sp  
  
\* Parameters  
.param Wp=0.3u  
.param Lp=0.2u  
.param Ln=0.2u  
.param Wn=0.3u  
  
\* Power supply  
VDD vdd 0 1.8  
  
\* Input pulse  
Vx1 x1 0 PULSE(0 1.8 100p 10p 10p 5n 10n)  
Vx2 x2 0 PULSE(0 1.8 100p 10p 10p 10n 20n)  
Vx3 x3 0 PULSE(0 1.8 100p 10p 10p 20n 40n)  
  
  
\* Inverter 1  
M1\_1 n1 in vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M2\_1 n1 in 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
M1 n1 x1 vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M2 n2 x2 n1 n1 cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M3 n3 x3 n2 n2 cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
  
M4 n3 x1 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
M5 n3 x2 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
M6 n3 x3 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
M7 Y\_nor n3 vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M8 Y\_nor n3 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
  
M9 x1\_not x1 vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M10 x1\_not x1 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
M11 x2\_not x2 vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M12 x2\_not x2 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
M13 x3\_not x3 vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M14 x3\_not x3 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
M15 Y\_nand x1\_not vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M16 Y\_nand x2\_not vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
M17 Y\_nand x3\_not vdd vdd cmosp W='Wp' L='Lp' ad='Wp\*0.55u' as='Wp\*0.55u' pd='2\*(Wp+0.55u)' ps='2\*(Wp+0.55u)'  
  
M18 Y\_nand x1\_not n4 n4 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
M19 n4 x2\_not n5 n5 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
M20 n5 x3\_not 0 0 cmosn w='wn' l=0.2u ad='wn\*0.55u' as='wn\*0.55u' pd='2\*(wn+0.55u)' ps='2\*(wn+0.55u)'  
  
  
.control  
tran 5p 200n  
\* plot v(in) v(out)  
plot v(x1) v(x2)+2 v(x3)+4 v(Y\_nor)+6 v(Y\_nand)+8  
  
meas tran tphl TRIG v(x1) VAL=0.9 RISE=1 TARG v(Y\_nor) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x1) VAL=0.9 FALL=1 TARG v(Y\_nor) VAL=0.9 RISE=1  
  
meas tran tphl TRIG v(x2) VAL=0.9 RISE=1 TARG v(Y\_nor) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x2) VAL=0.9 FALL=1 TARG v(Y\_nor) VAL=0.9 RISE=1  
  
meas tran tphl TRIG v(x3) VAL=0.9 RISE=1 TARG v(Y\_nor) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x3) VAL=0.9 FALL=1 TARG v(Y\_nor) VAL=0.9 RISE=1  
  
meas tran tphl TRIG v(x1) VAL=0.9 RISE=1 TARG v(Y\_nand) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x1) VAL=0.9 FALL=1 TARG v(Y\_nand) VAL=0.9 RISE=1  
  
meas tran tphl TRIG v(x2) VAL=0.9 RISE=1 TARG v(Y\_nand) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x2) VAL=0.9 FALL=1 TARG v(Y\_nand) VAL=0.9 RISE=1  
  
meas tran tphl TRIG v(x3) VAL=0.9 RISE=1 TARG v(Y\_nand) VAL=0.9 FALL=1  
meas tran tplh TRIG v(x3) VAL=0.9 FALL=1 TARG v(Y\_nand) VAL=0.9 RISE=1  
  
.endc  
.end