EE5311: Digital IC Design

Tutorial 3

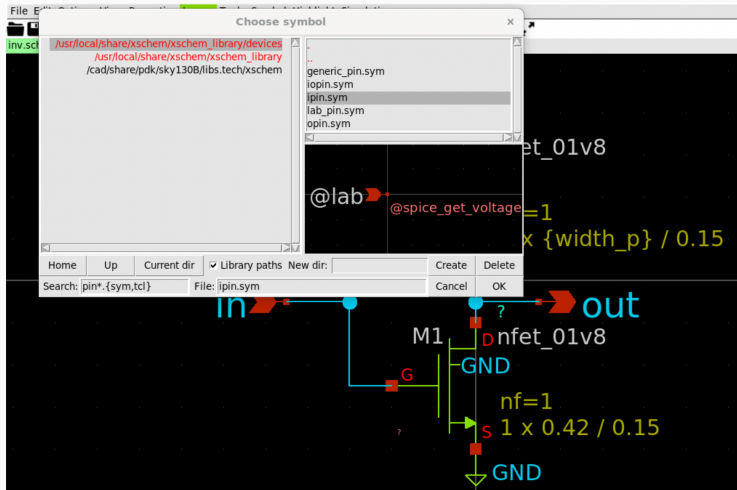1a) Obtain the delay for $W_p = 0.42\,\mu m$, $0.84\,\mu m$, $1.26\,\mu m$
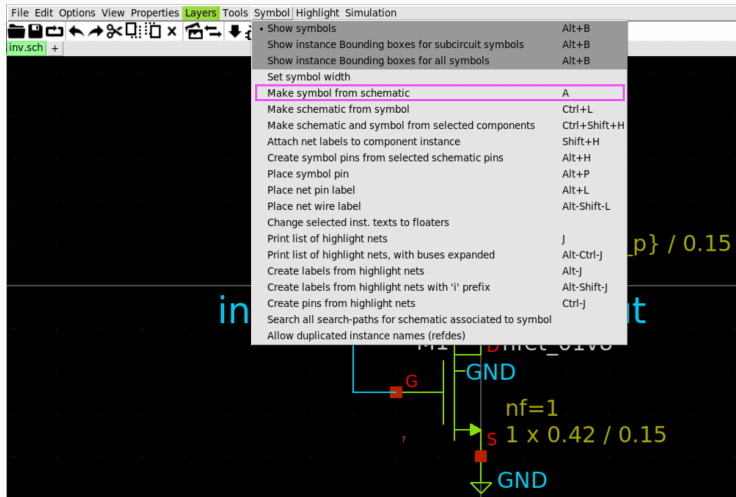
Create inverter schematic as below:
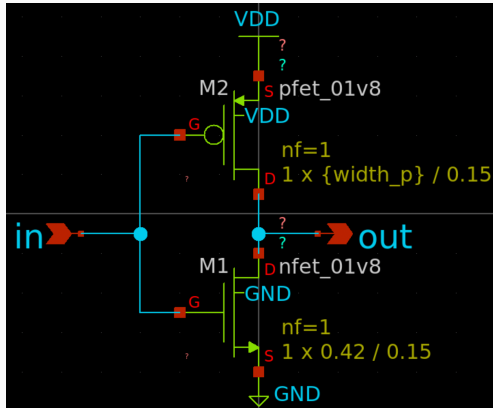
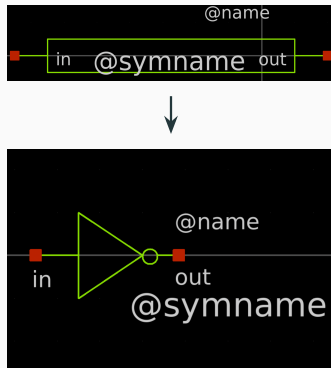Input and output pins are in

`xschem_library` ► `devices` ► `ipin/opin`
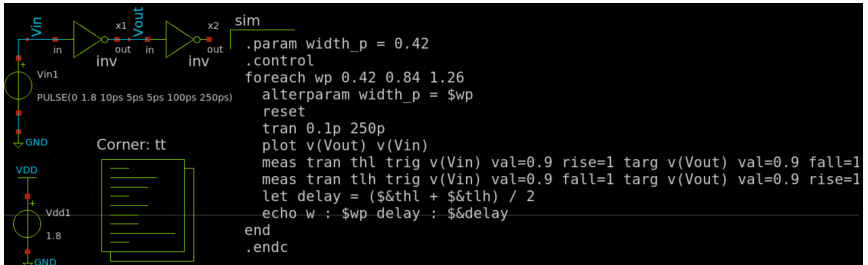
Make symbol for inverter using:

Experiment 1

Edit the default symbol to that of an inverter:

- Delete the unnecessary lines in the symbol editor by selecting them using mouse and pressing delete key
- Use the shortcut key l to draw lines in the symbol editor
- To create the circle, use the circle shortcut key on the menu bar

Sweep the pMOS widths and obtain the delays:


```
sim
.param width_p = 0.42
.control
foreach wp 0.42 0.84 1.26
    alterparam width_p = $wp
    reset
    tran 0.1p 250p
    plot v(Vout) v(Vin)
    meas tran thl trig v(Vin) val=0.9 rise=1 targ v(Vout) val=0.9 fall=1
    meas tran tlh trig v(Vin) val=0.9 fall=1 targ v(Vout) val=0.9 rise=1
    let delay = ($&thl + $&tlh) / 2
    echo w : $wp delay : $&delay
end
.endc
```
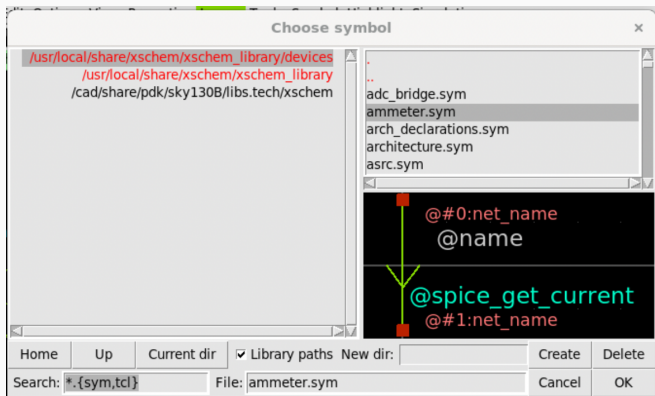
- Experiment 1c requires measurement of current through either the pMOS or nMOS to calculate the energy
- To attach an ammeter to the source pin of nMOS, create a new nMOS schematic and symbol **without** the gnd connection as below:
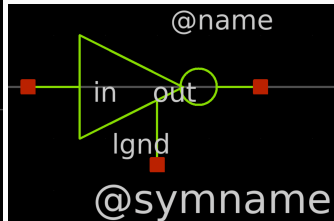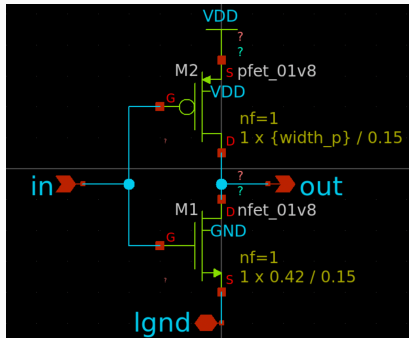
Insert an ammeter using: `xschem_library` ▶ `devices` ▶ `ammeter`

Find the delay and energy-delay product as a function of V_{DD} using:


```
sim
.param VDDval = 1.8
.param width_p = 0.84
.control
let Nsim = 9
let delayvec = vector(Nsim)
let vddvec = vector(Nsim)
let edpvec = vector(Nsim)
let index = 0
while index < Nsim
  let vddv = 1.0 + (index * 0.1)
  let vby2 = vddv / 2
  alterparam VDDval = $&vddv
  reset
  tran 1p 600p
  meas tran thl trig v(Vin) val=$&vby2 rise=1 targ v(Vout) val=$&vby2 fall=1
  meas tran tlh trig v(vin) val=$&vby2 fall=1 targ v(vout) val=$&vby2 rise=1
  meas tran iinteg integ i(vmeas)
  let delayvec[index] = ($&thl + $&tlh) / 2
  let vddvec[index] = vddv
  let edpvec[index] = $&iinteg * vddv * delayvec[index]
  let index = index + 1
end
plot delayvec vs vddvec
plot edpvec vs vddvec
.endc
```