Lecture 2: LTspice

Digital CMOS VLSI Design

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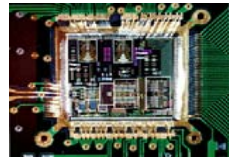
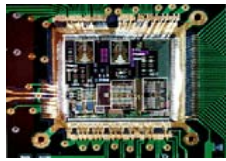
NOTE: The figures, text etc included in slides are borrowed from various books, websites, authors pages, and other sources for academic purpose only. The instructor does not claim any originality.

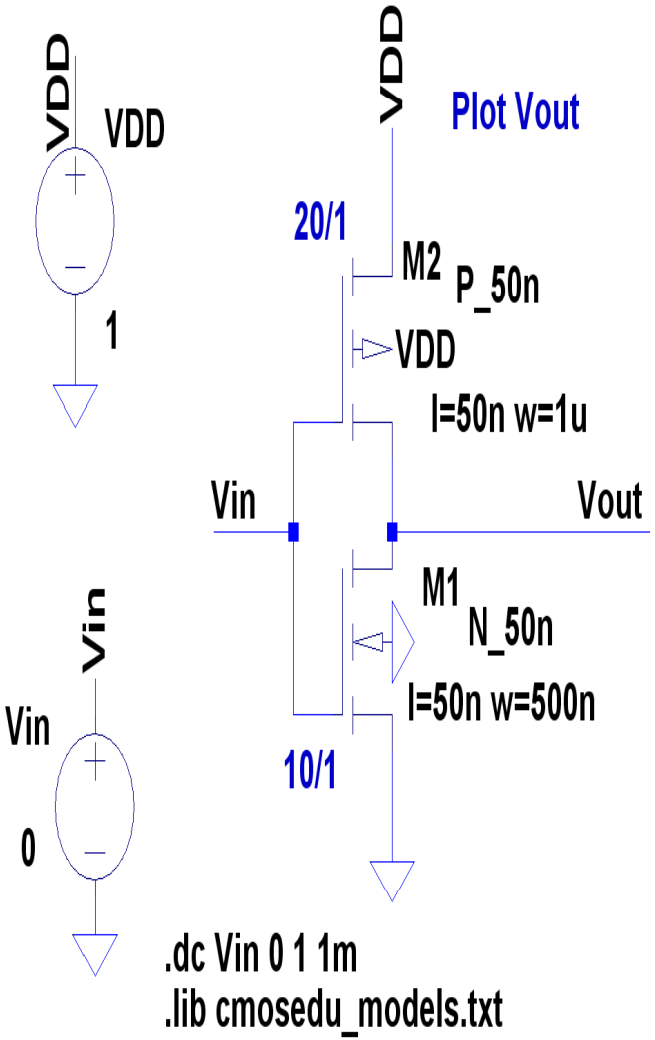


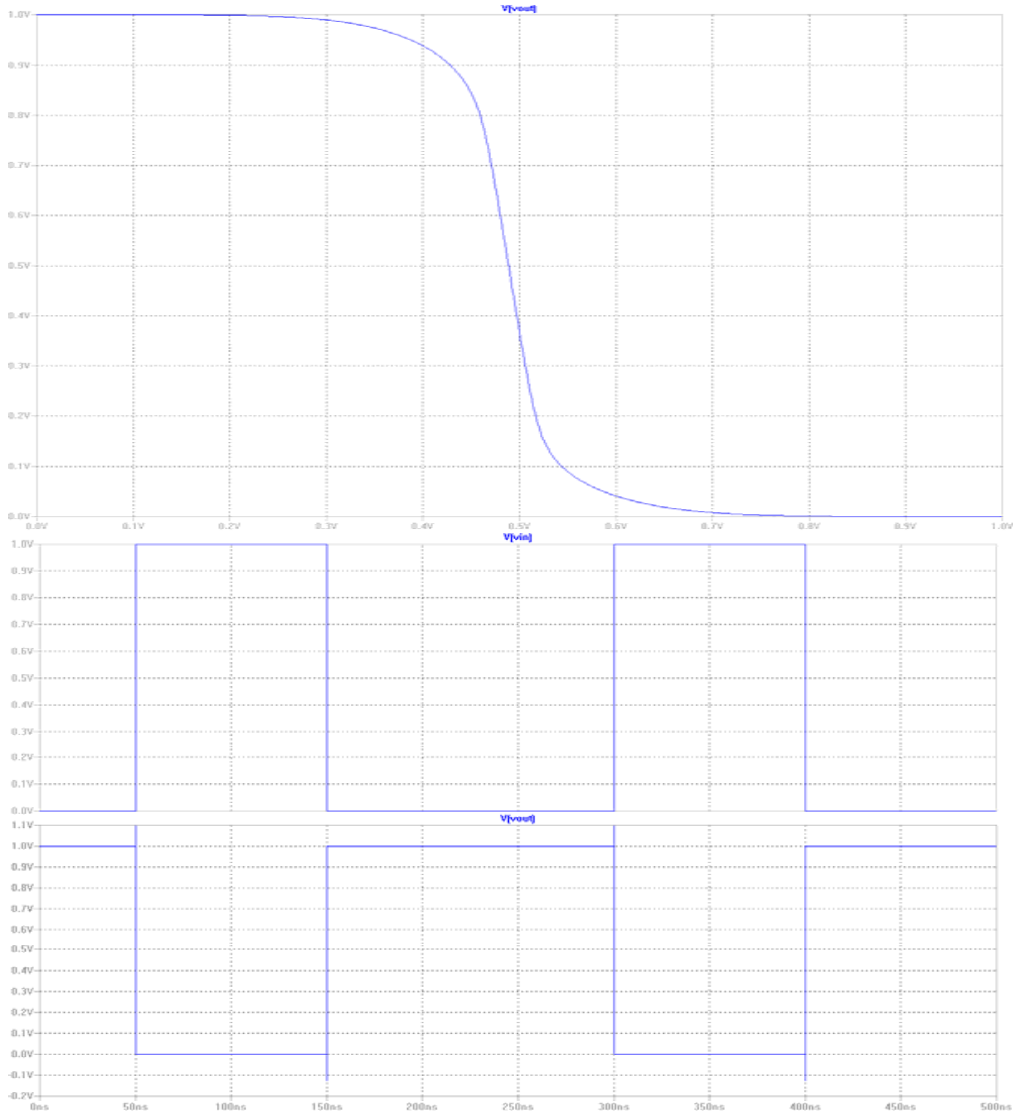
USEFUL LINKS

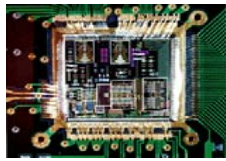
- LTPSICE software available at: http://www.linear.com/designtools/software/switchercad.jsp
- 50nm model file available at: http://www.cmosedu.com/cmos1/book.htm
- More model files available at: http://www.eas.asu.edu/~ptm/



CMOS Inverter

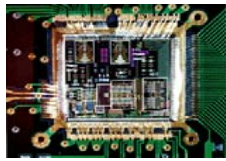






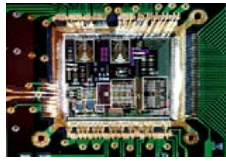
Construct an Inverter using LTSPICE

- Discussion at Nano-CMOS: 50nm technology.
- PMOS: 20/1 (L = 50nm/ W = 1µm)
- NMOS: 10/1 (L = 50nm/ W = 500nm)
- V_{DD}: Supply voltage (V_{dc} = 1V).
- V_{in}: changes depending upon analysis:
- DC analysis: DC voltage (1V).
- Transient analysis: Pulsed voltage (vpulse).
- Wire to connect components.
- Model file (cmosedu_models.txt).

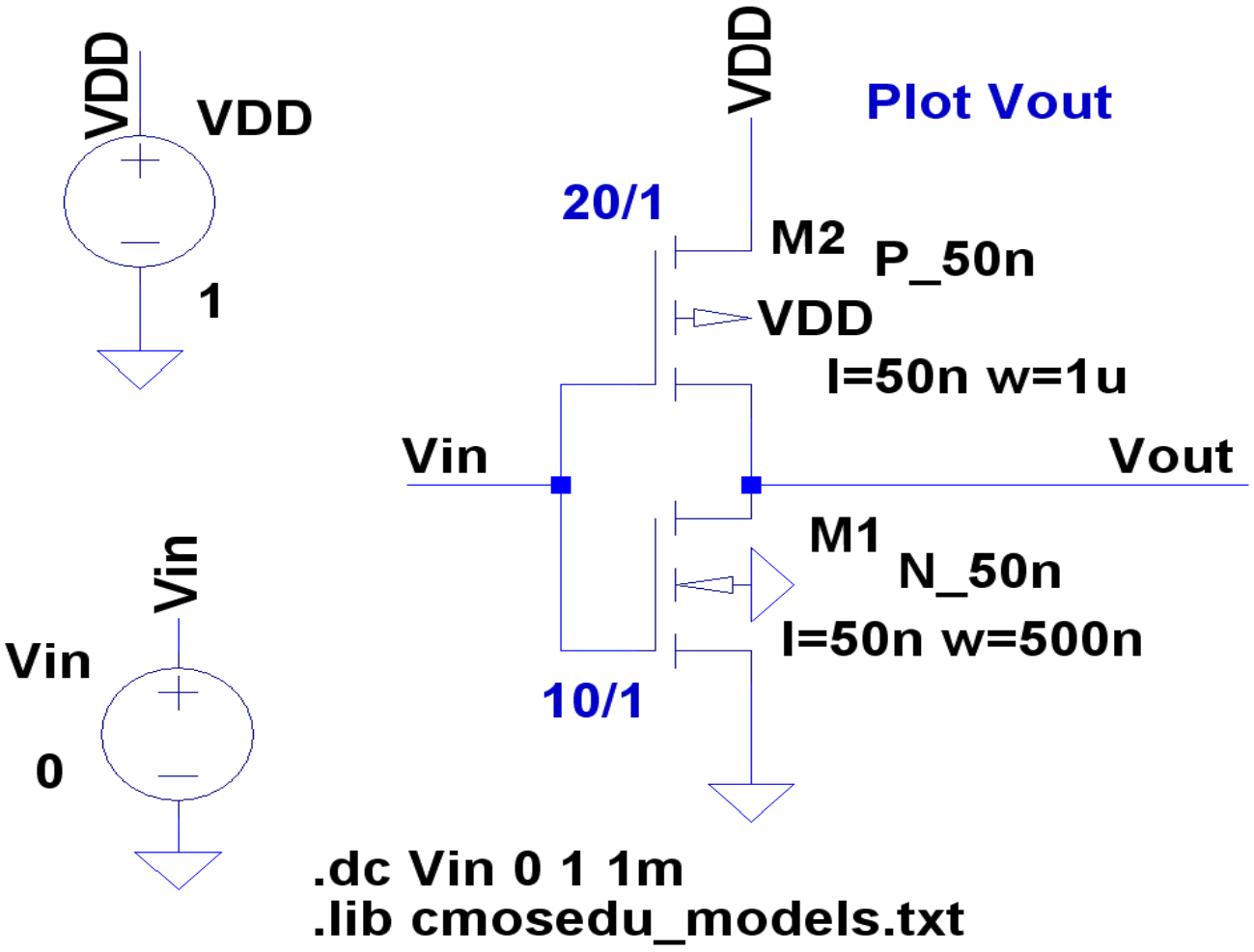


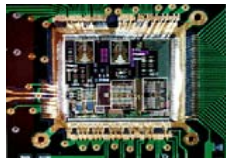
What does a model file look like ?

```
*** Short channel models from CMOS Circuit Design, Layout, and Simulation, 2e
* 50nm BSIM4 models Vdd=1V

.model   N_50n   nmos   level = 14

+binunit  = 1              paramchk= 1              mobmod   = 0
+capmod   = 2              igcmod  = 1              igbmod   = 1              geomod   = 1
+diomod   = 1              rdsmod  = 0              rbodymod= 1               rgatemod= 1
+permod   = 1              acnqsmod= 0              trnqsmod= 0

+tnom     = 27             toxe     = 1.4e-009      toxp     = 7e-010         toxm     = 1.4e-009
+epsrox   = 3.9            wint     = 5e-009        lint     = 1.2e-008
+ll       = 0              wl       = 0             lln      = 1              wln      = 1
+lw       = 0              ww       = 0             lwn      = 1              wwn      = 1
+lwl      = 0              wwl      = 0             xpart    = 0              toxref   = 1.4e-009

+vth0     = 0.22           k1       = 0.35          k2       = 0.05           k3       = 0
+k3b      = 0              w0       = 2.5e-006      dvt0     = 2.8            dvt1     = 0.52
+dvt2     = -0.032         dvt0w    = 0             dvt1w    = 0              dvt2w    = 0
+dsub     = 2              minv     = 0.05          voffl    = 0              dvtp0    = 1e-007
+dvtp1    = 0.05           lpe0     = 5.75e-008     lpeb     = 2.3e-010       xj       = 2e-008
+ngate    = 5e+020         ndep     = 2.8e+018      nsd      = 1e+020         phin     = 0
+cdsc     = 0.0002         cdscb    = 0             cdscd    = 0              cit      = 0
+voff     = -0.15          nfactor  = 1.2           eta0     = 0.15           etab     = 0
+vfb      = -0.55          u0       = 0.032         ua       = 1.6e-010       ub       = 1.1e-017
+uc       = -3e-011        vsat     = 1.1e+005      a0       = 2              ags      = 1e-020
+a1       = 0              a2       = 1             b0       = -1e-020        b1       = 0
+keta     = 0.04           dwg      = 0             dwb      = 0              pclm     = 0.18
+pdiblc1  = 0.028          pdiblc2  = 0.022         pdiblcb  = -0.005         drout    = 0.45
+pvag     = 1e-020         delta    = 0.01          pscbe1   = 8.14e+008      pscbe2   = 1e-007
+fprout   = 0.2            pdits    = 0.2           pditsd   = 0.23           pditsl   = 2.3e+006
+rsh      = 3              rdsw     = 150           rsw      = 150            rdw      = 150
+rdswmin  = 0              rdwmin   = 0             rswmin   = 0              prwg     = 0
+prwb     = 6.8e-011       wr       = 1             alpha0   = 0.074          alpha1   = 0.005
+beta0    = 30             agidl    = 0.0002        bgidl    = 2.1e+009       cgidl    = 0.0002
+egidl    = 0.8

+aigbacc  = 0.012          bigbacc  = 0.0028        cigbacc  = 0.002
+nigbacc  = 1              aigbinv  = 0.014         bigbinv  = 0.004          cigbinv  = 0.004
+eigbinv  = 1.1            nigbinv  = 3             aigc     = 0.017          bigc     = 0.0028
+cigc     = 0.002          aigsd    = 0.017         bigsd    = 0.0028         cigsd    = 0.002
+nigc     = 1              poxedge  = 1             pigcd    = 1              ntox     = 1

+xrcrg1   = 12             xrcrg2   = 5
+cgso     = 6.238e-010     cgdo     = 6.238e-010    cgbo     = 2.56e-011      cgdl     = 2.495e-10
+cgsl     = 2.495e-10      ckappas  = 0.02          ckappad  = 0.02           acde     = 1
+moin     = 15             noff     = 0.9           voffcv   = 0.02

+kt1      = -0.21          kt11     = 0.0           kt2      = -0.042         ute      = -1.5
+ua1      = 1e-009         ub1      = -3.5e-019     uc1      = 0              prt      = 0
+at       = 53000

+fnoimod  = 1              tnoimod  = 0

+jss      = 0.0001         jsws     = 1e-011        jswgs    = 1e-010         njs      = 1
+ijthsfwd= 0.01            ijthsrev= 0.001          bvs      = 10             xjbvs    = 1
+jsd      = 0.0001         jswd     = 1e-011        jswgd    = 1e-010         njd      = 1
```

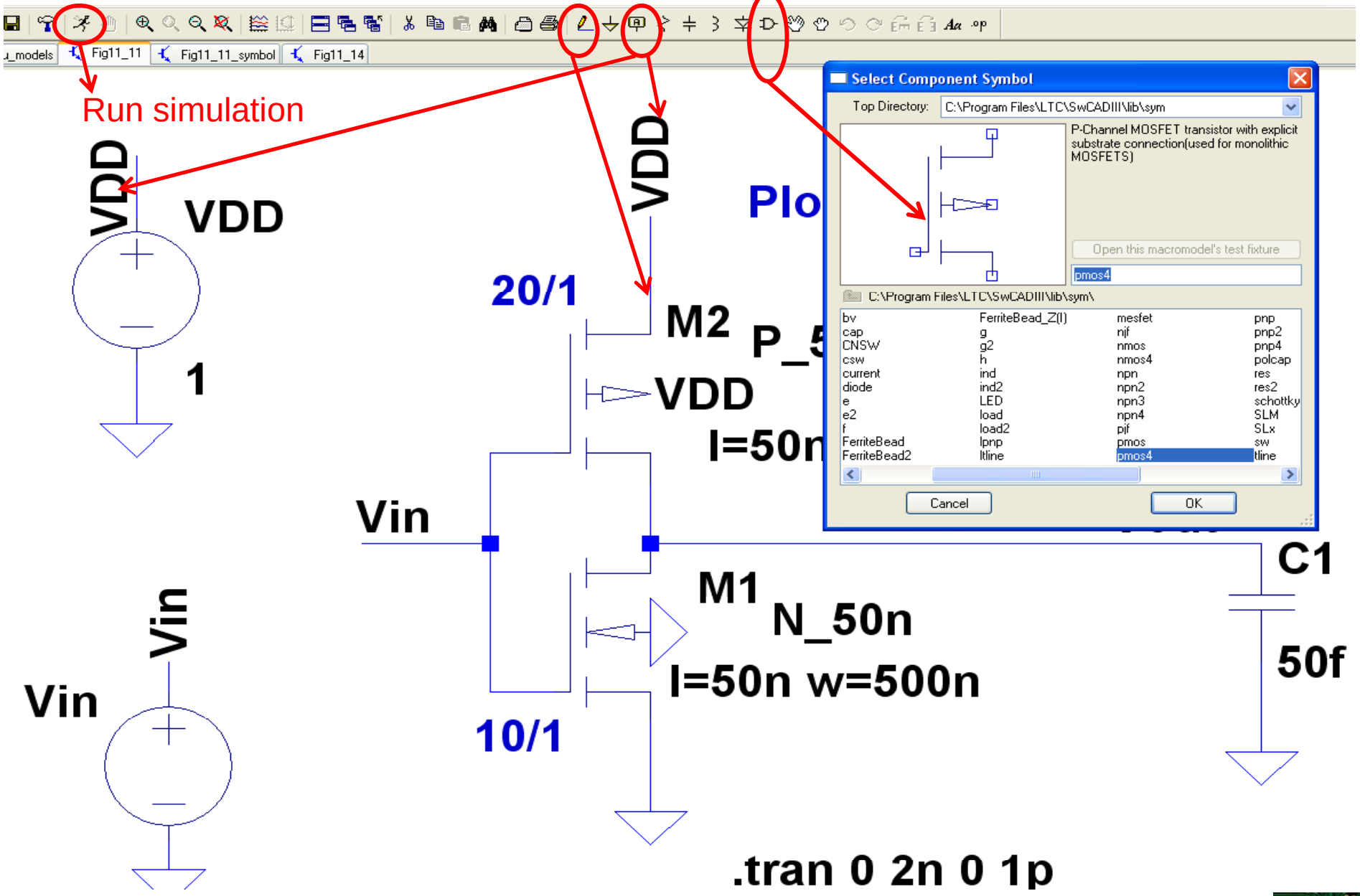



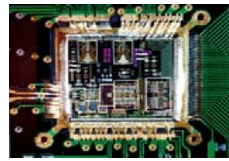
Placing and connecting components



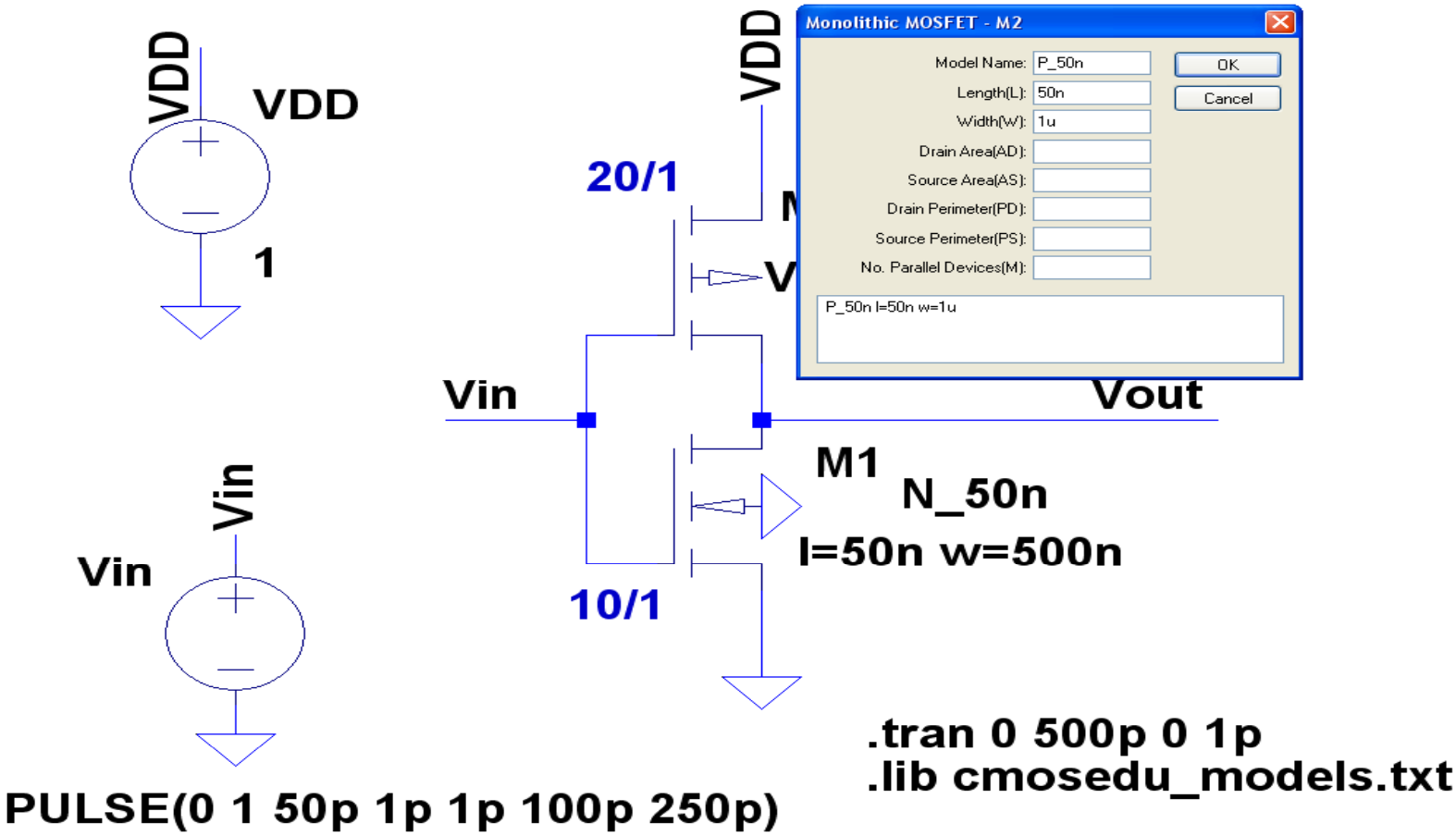


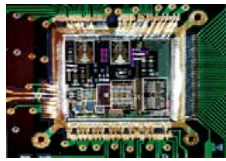
Where to get components from ?



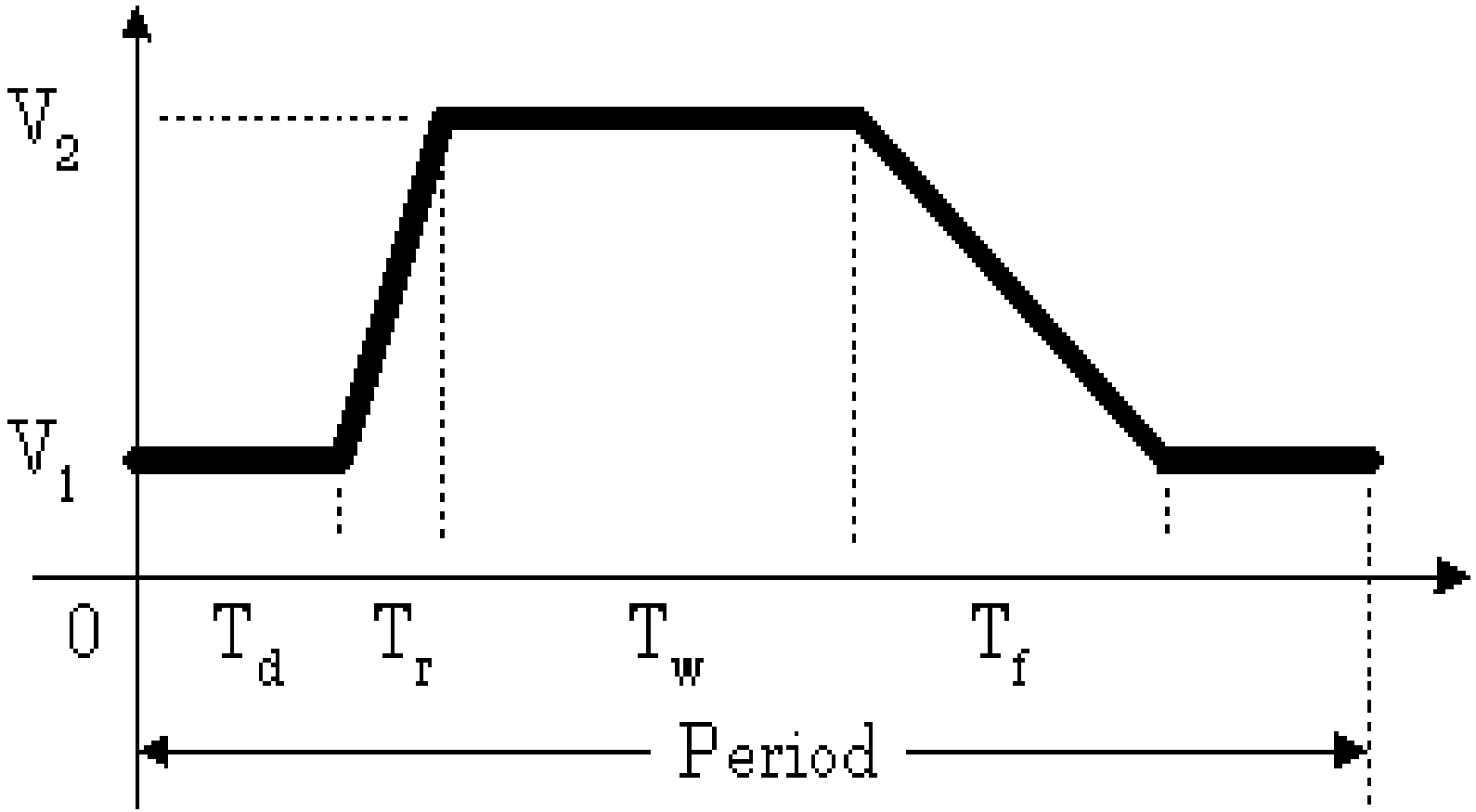


How to assign W/L ?

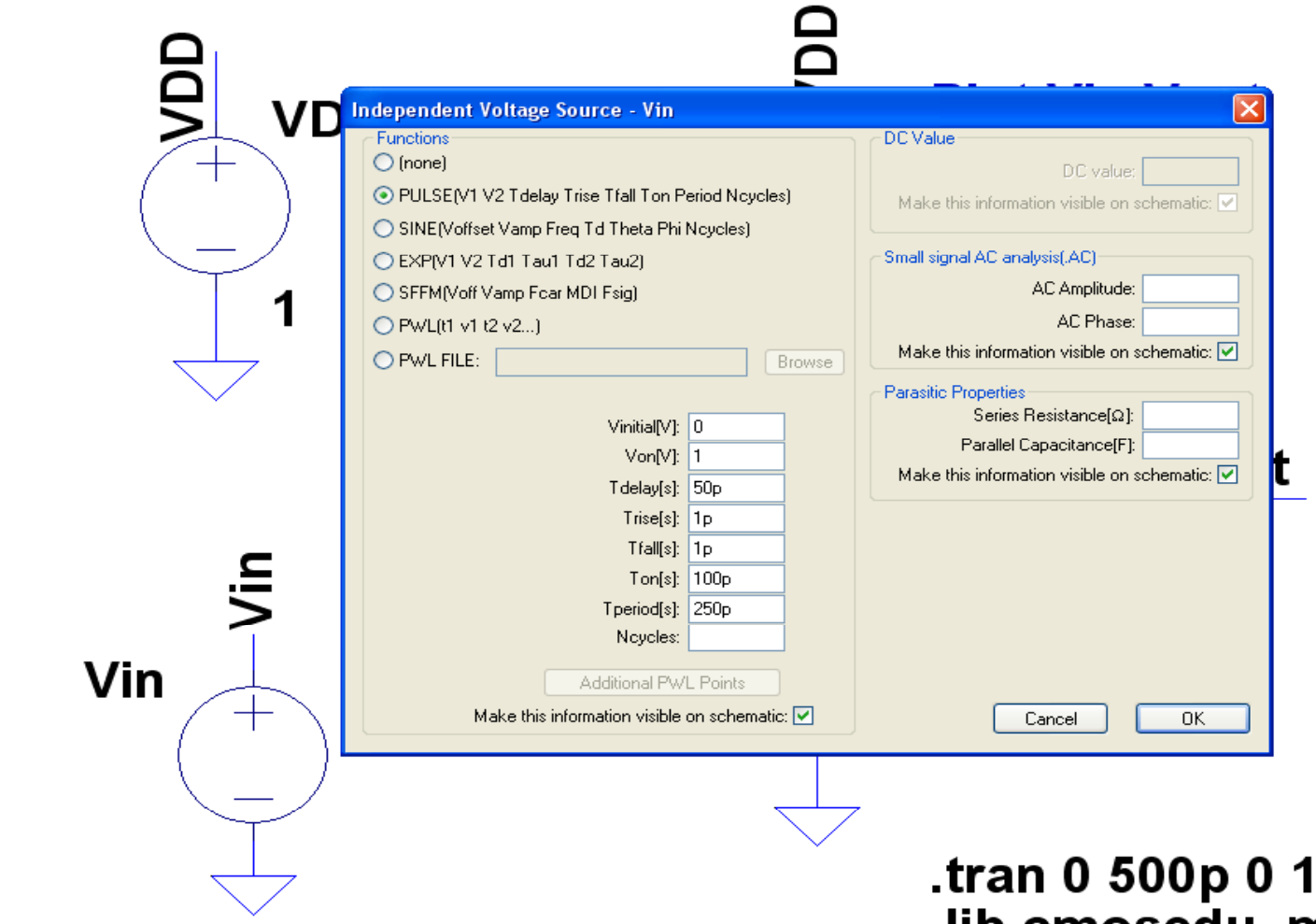




Interpreting a pulsed waveform

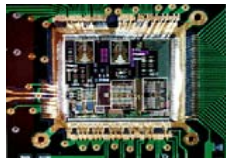


How to assign Vin ?

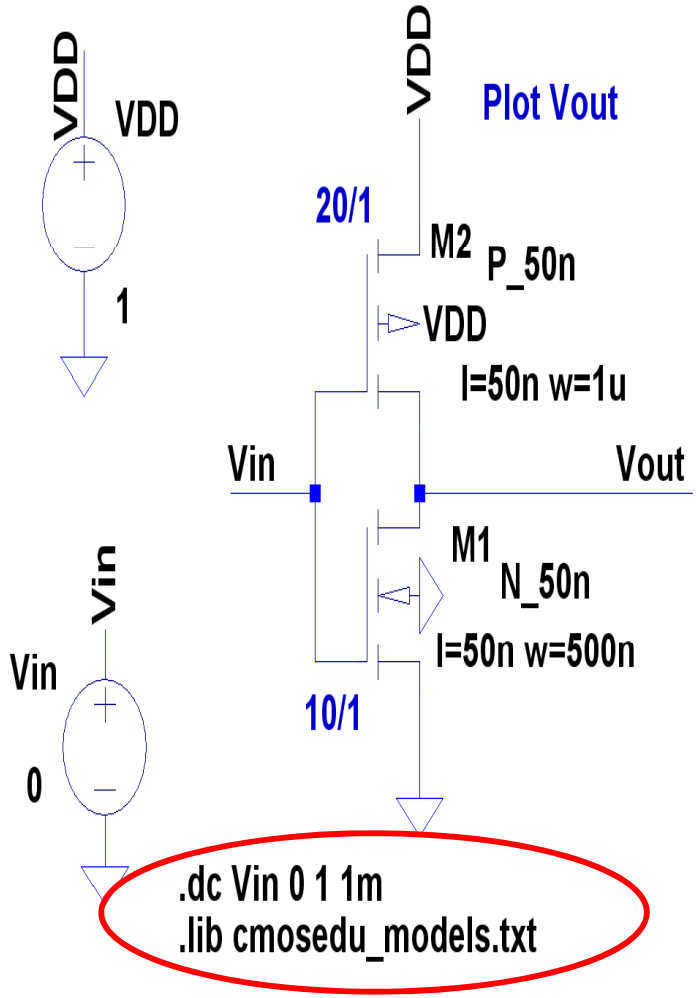


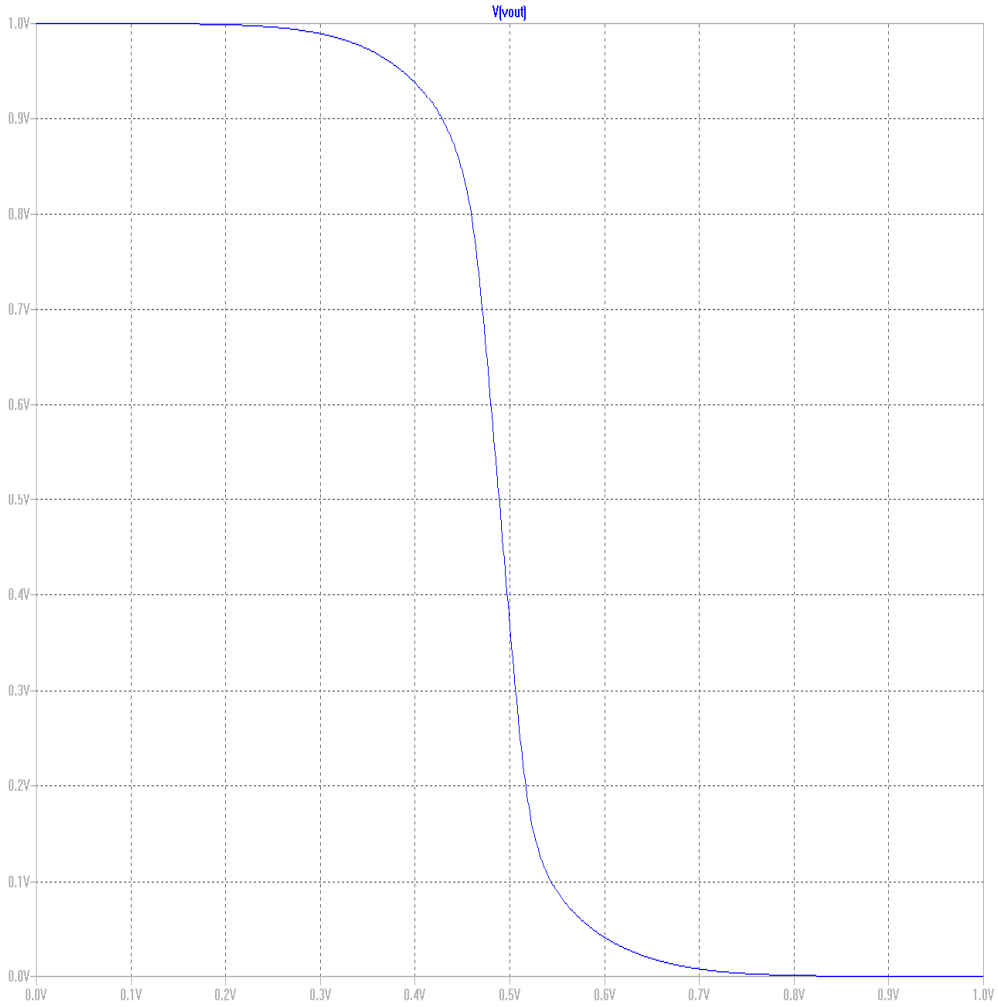
PULSE(0 1 50p 1p 1p 100p 250p)

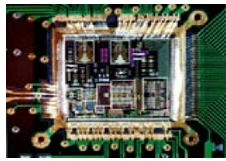
.tran 0 500p 0 1p
.lib cmosedu_models.txt



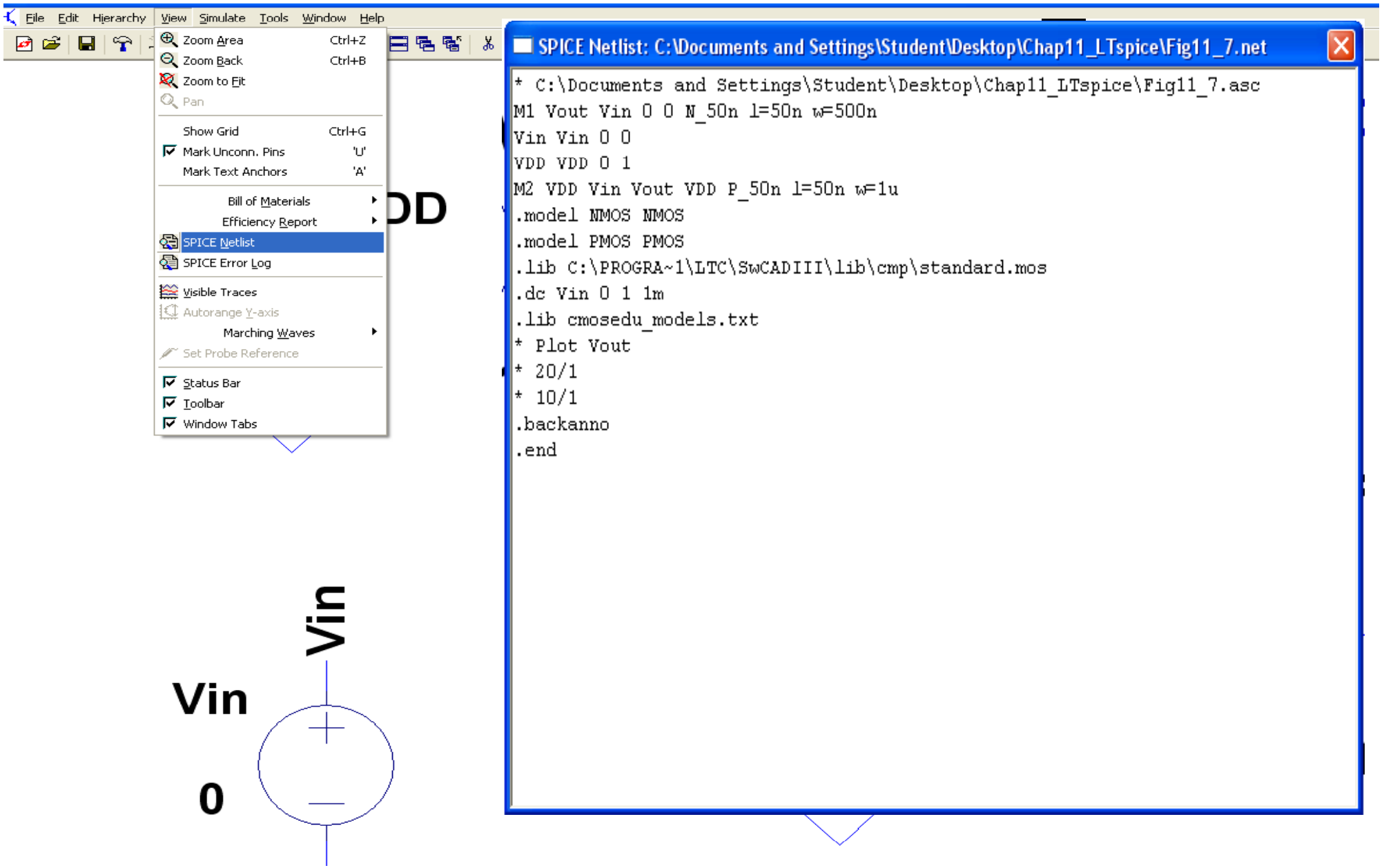
DC Analysis

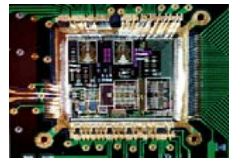

VDD
VDD
1
VDD
Plot Vout
20/1
M2
P_50n
VDD
l=50n w=1u
Vin
Vout
M1
N_50n
l=50n w=500n
10/1
Vin
Vin
0
.dc Vin 0 1 1m
.lib cmosedu_models.txt


V(vout)
1.0V
0.9V
0.8V
0.7V
0.6V
0.5V
0.4V
0.3V
0.2V
0.1V
0.0V
0.0V
0.1V
0.2V
0.3V
0.4V
0.5V
0.6V
0.7V
0.8V
0.9V
1.0V

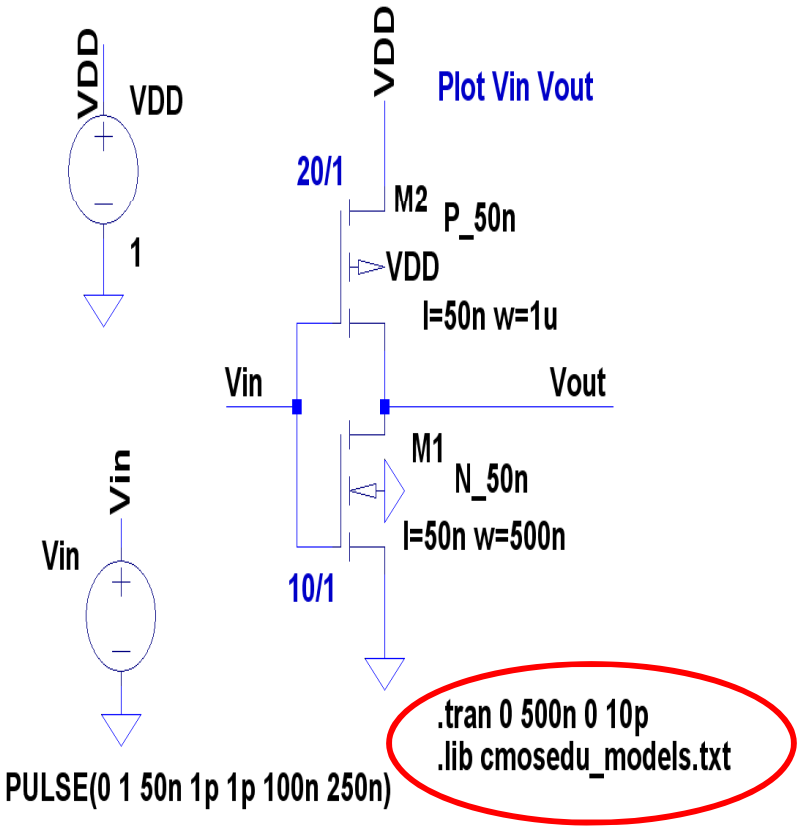


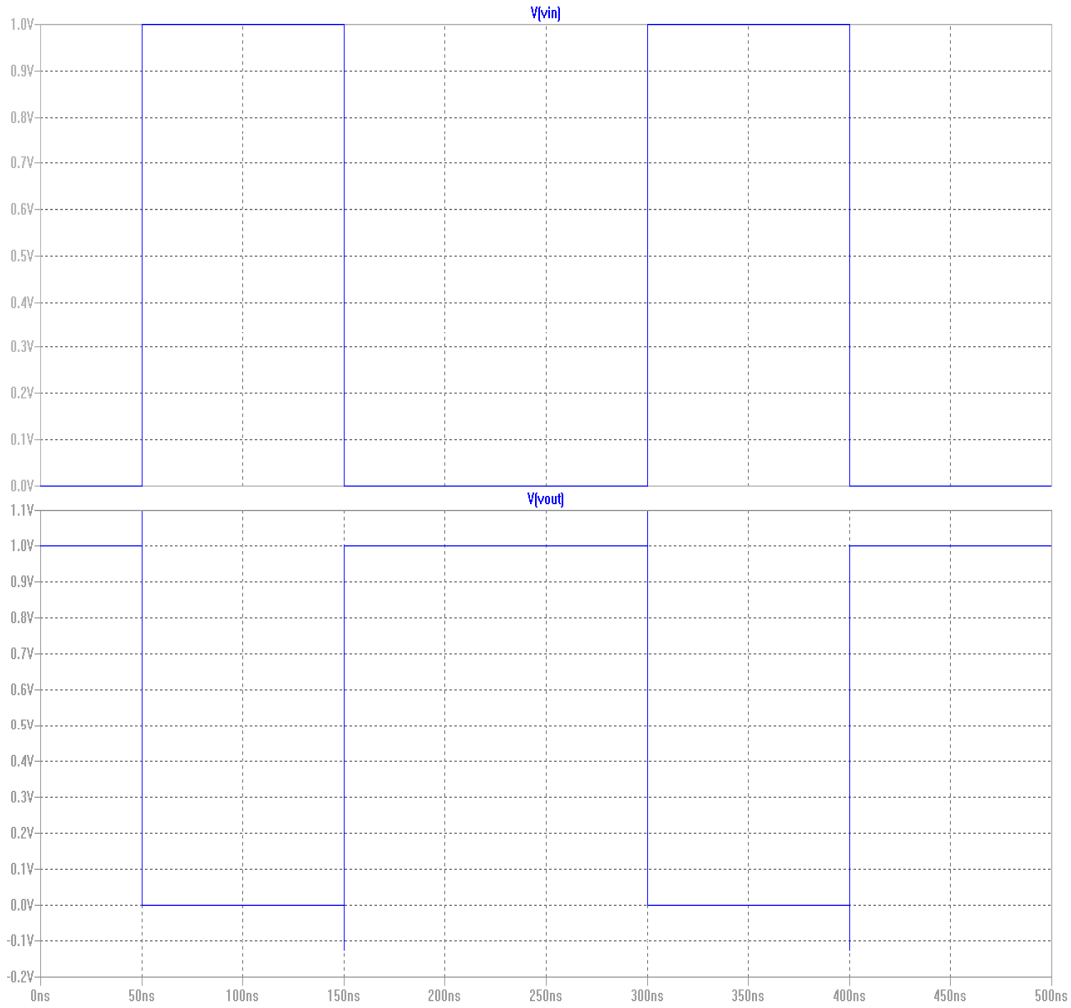
View netlist

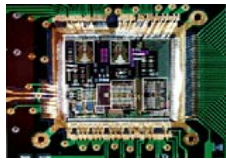




Transient (time) Analysis

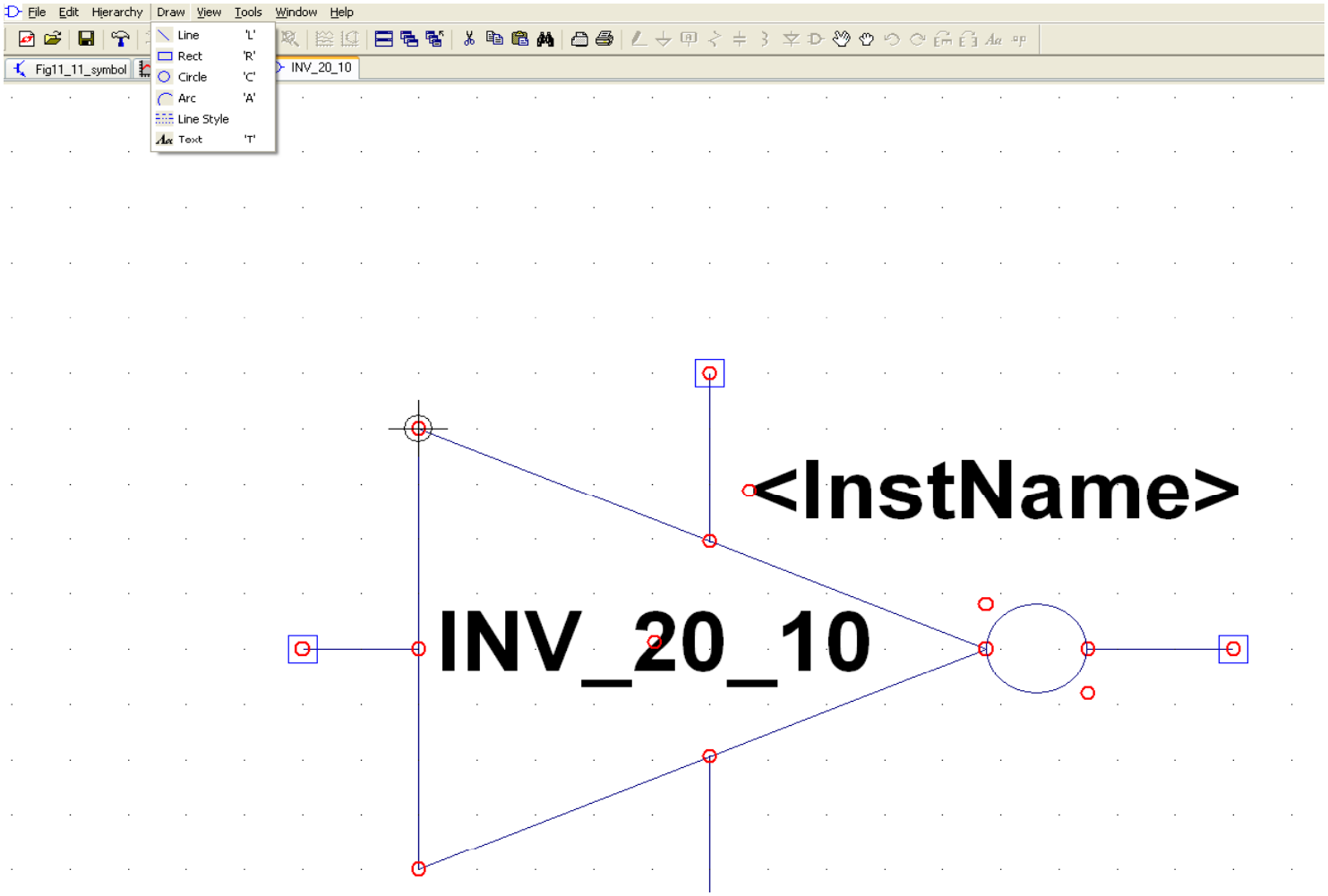


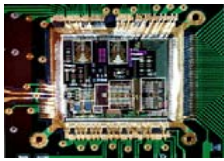




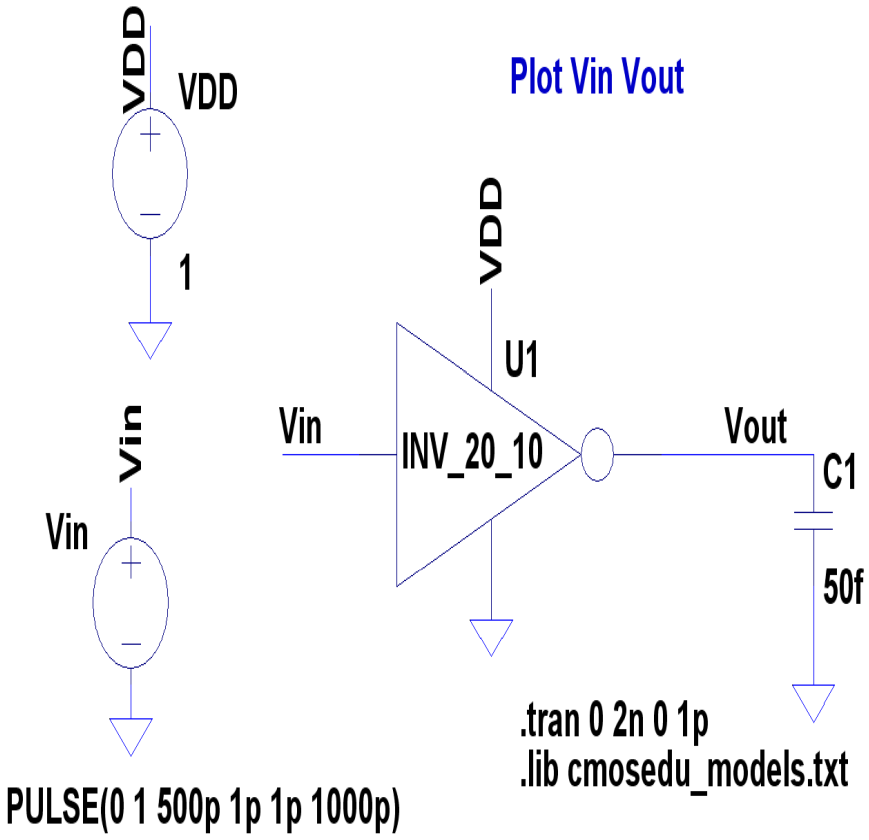
Creating a symbol for Inverter

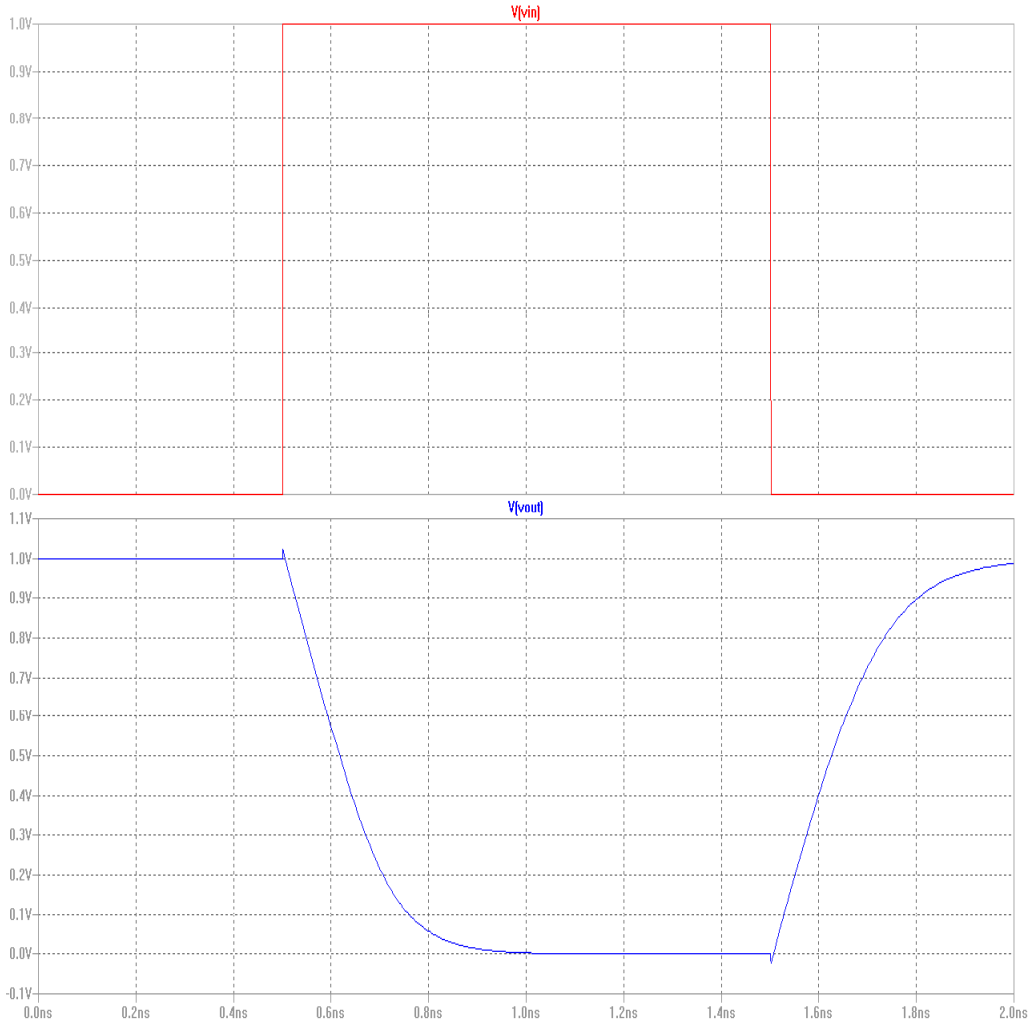
- Schematic files saved as *.asc
- Symbol files saved as *.asy

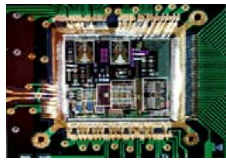




Simulation using symbol: workspace much cleaner!







One more example: NAND gate