```
Homework 4
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0 PMOS NMOS W/L Ratio
For detailed method, see hw2.
                                                                                                                                9
  MN1 d g gnd gnd N_18 W=250n L=900n M=1
  MP1 d g ndd ndd p_18 W=250n L=270n M=2
1 Unit Inverter (with V_d = 1.8V, I_d = 10\mu A, V_i = V_o = 0.9V)
1.1 Design
                                                                                                                                9
  * HW4_0_op.sp
  * Assumption
  * lib = cic018.1/tt/N_18 & P_18
  * 1. temp 27
  * 2. L=0.18um
  .lib 'cic018.1' tt
  .temp 27
  .option post
  * Simulation netlist
  Vg g gnd 0.9
  Vd d gnd 0.9
  Vdd ndd gnd 1.8
  MN1 d g gnd gnd N_18 W=250n L=900n M=1
  MP1 d g ndd ndd p_18 W=250n L=270n M=2
  * Stimulus
                       * nodal capacitance table
  .option captab=1
  .op
  .end
1.2 Capacitance
                                                                                                                                9
  * HW4_1_0_op.lis
  * nodal capacitance table
  * node
                cap
            = 1.2573f
            = 2.6345f
  * element mn1
  * model
            n_18.1 p_18.1
  * id
            10.0246u -10.1859u
Remark: There are 3 ways to measure capacitance
  Method 1:
  .option captab=1
  .op

    Method 2:

                                                                                                                                9
  .dc vg 0 1.8 0.01
  .meas dc cg find cap(g) at=0.9

 Method 3:

  .dc vg 0 1.8 0.01
  .print Cmn1=par("lx18(mn1)")
  .print Cmp1=par("lx18(mp1)")
and then use avanwave expression builder (or custom waveview) to get CV characteristic curve (CT = C_Total)
# AvanWaves B-2008.09-SP1 (20081124)
Design Penels Mindow Measure Configuration Isols Help
 A PO B 图 图 双 少 中 双 少 中 平
                                                Voltage X 8,996-001 Read 2,036-013
 D0:se0:bd8(mm) =
D0:se0:bd8(mp)
           1.61
           1.50
           1.4f -
           1.30
           1.25f -
           1.05f -
          9306-18
          850e-19
          800e-18
          7506-18
                                                                  Nobage X (in) (VOL II)
  Reference:
  [1] https://www.ptt.cc/bbs/comm_and_RF/M.1284928485.A.86F.html
  [2] https://bbs.eetop.cn/thread-408732-1-1.html
2 Inverter Buffer Chain
Calculate by hand and then run HSpice transient simulation.
                                                                   G=16 B=1 H=1
  N=1
                             Fig.2
2.1 Single Stage Buffer Chain
                                                                                                                                O
  * HW4_2_1.sp
  * Assumption
  * lib = cic018.1/tt/N_18 & P_18
  * 1. temp 27
  * 2. L=0.18um
  .lib 'cic018.1' tt
  .temp 27
  .option post
  * Simulation netlist
  * Trapezoidal Pulse Source, Page 189, HSPICE® User Guide: Simulation and Analysis
  * Vxxx n+ n- PU[LSE] [(]v1 v2 [td [tr [tf [pw [per]]]]] [)]
  Vdd ndd gnd 1.8
  Vin in gnd PULSE(0v 1.8v 10ns 0.01ns 0.01ns 19.99ns 40ns)
  MN1 o1 in gnd gnd N_18 W=250n L=900n M=1
  MP1 o1 in ndd ndd p_18 W=250n L=270n M=2
  * 16x invertor load
  MNL nd o1 gnd gnd N_18 W=250n L=900n M=16
  MPL nd o1 ndd ndd p_18 W=250n L=270n M=32
  *_____
  * Stimulus 25Mhz/40ns
  * Performing Basic Cell Measurements, Page 648, HSPICE® User Guide: Simulation and Analysis
  *_____
  .tran 1ps 60ns
                   TRIG V(o1) val=0.18 TD=10n RISE=1 TARG V(o1) val=1.62 RISE=1
  .MEAS TRAN Trise
  .MEAS TRAN Tfall
                    TRIG V(o1) val=1.62 TD=10n FALL=1 TARG V(o1) val=0.18 FALL=1
  .MEAS TRAN Tdelay TRIG V(in) val=0.9 TD=10n RISE=1 TARG V(o1) val=0.9 FALL=1
  .print tran v(in) v(o1)
  .end
  * Result
  * trise= 1.2633E-09
  * tfall= 1.7268E-09
  * tdelay= 7.9930E-10
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Design Penelt Mindow Measure Configuration Isola Help
Voltage X 8.996-001 Result [2.036-013
           17 -
           1.65
2.2 Two Stage Buffer Chain
                                                                                                                                9
  * HW4_2_2.sp
  * Assumption
  * lib = cic018.1/tt/N_18 & P_18
  * 1. temp 27
  * 2. L=0.18um
  .lib 'cic018.1' tt
  .temp 27
  .option post
  * Simulation netlist
  * Trapezoidal Pulse Source, Page 189, HSPICE® User Guide: Simulation and Analysis
  * Vxxx n+ n- PU[LSE] [(]v1 v2 [td [tr [tf [pw [per]]]]] [)]
  Vdd ndd gnd 1.8
  Vin in gnd PULSE(0v 1.8v 10ns 0.01ns 0.01ns 19.99ns 40ns)
  MN1 o1 in gnd gnd N_18 W=250n L=900n M=1
  MP1 o1 in ndd ndd p_18 W=250n L=270n M=2
  MN2 o2 o1 gnd gnd N_18 W=250n L=900n M=4
  MP2 o2 o1 ndd ndd p_18 W=250n L=270n M=8
  * 16x invertor load
  MNL nd o2 gnd gnd N_18 W=250n L=900n M=16
  MPL nd o2 ndd ndd p_18 W=250n L=270n M=32
  * Stimulus 25Mhz/40ns
  * Performing Basic Cell Measurements, Page 648, HSPICE® User Guide: Simulation and Analysis
  *-----
  .tran 1ps 60ns
  .MEAS TRAN Trise
                    TRIG V(o2) val=0.18 TD=10n RISE=1 TARG V(o2) val=1.62 RISE=1
  .MEAS TRAN Tfall TRIG V(o2) val=1.62 TD=10n FALL=1 TARG V(o2) val=0.18 FALL=1
  .MEAS TRAN Tdelay TRIG V(in) val=0.9 TD=10n RISE=1 TARG V(o2) val=0.9 RISE=1
  .print tran v(in) v(o2)
  .end
  * Result
  * trise= 4.8475E-10
  * tfall= 5.5330E-10
  * tdelay= 5.1425E-10
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Design Penelt Mindow Measure Configuration Isola Help
A 한 은 및 및 정 수 연 정 수 연 요
                                                Voltage X 8.99e-001 Result 2.53e-015
           12 -
          700m -
          650m
                                    10a 12a 14a 16a 10a 20a
2.3 Three Stage Buffer Chain
                                                                                                                                9
  * HW4_2_3.sp
  * lib = cic018.1/tt/N_18 & P_18
  * 1. temp 27
  * 2. L=0.18um
  .lib 'cic018.1' tt
  .temp 27
  .option post
  * Simulation netlist
  * Trapezoidal Pulse Source, Page 189, HSPICE® User Guide: Simulation and Analysis
  * Vxxx n+ n- PU[LSE] [(]v1 v2 [td [tr [tf [pw [per]]]]] [)]
  Vdd ndd gnd 1.8
  Vin in gnd PULSE(0v 1.8v 10ns 0.01ns 0.01ns 19.99ns 40ns)
  * W/L from HW2
  MN1 o1 in gnd gnd N_18 W=250n L=900n M=1
  MP1 o1 in ndd ndd p_18 W=250n L=270n M=2
  MN2 o2 o1 gnd gnd N_18 W=630n L=900n M=1 * x2.52
  MP2 o2 o1 ndd ndd p_18 W=630n L=270n M=2 * \times 2.52
  MN3 o3 o2 gnd gnd N_18 W=1590n L=900n M=1 * x2.52
  MP3 o3 o2 ndd ndd p_18 W=1590n L=270n M=2 * \times 2.52
  * 16x invertor load
  MNL nd o2 gnd gnd N_18 W=250n L=900n M=16
  MPL nd o2 ndd ndd p_18 W=250n L=270n M=16
  * Stimulus 25Mhz/40ns
  * Performing Basic Cell Measurements, Page 648, HSPICE® User Guide: Simulation and Analysis
  .tran 1ps 60ns
                   TRIG V(o3) val=0.18 TD=10n RISE=1 TARG V(o3) val=1.62 RISE=1
  .MEAS TRAN Trise
                    TRIG V(o3) val=1.62 TD=10n FALL=1 TARG V(o3) val=0.18 FALL=1
  .MEAS TRAN Tfall
  .MEAS TRAN Tdelay TRIG V(in) val=0.9 TD=10n RISE=1 TARG V(o3) val=0.9 FALL=1
  .print tran v(in) v(o3)
  .end
  * Result
  * trise= 1.8406E-10
  * tfall= 1.8491E-10
  * tdelay= 6.1823E-10
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Design Panels Mindow Measure Configuration Iools Help
Voltage X 8.99e-001 Read [2.53e-013
           18
           1.75
           1.45
2.4 Four Stage Buffer Chain
                                                                                                                                9
  * HW4 2 4.sp
  * Assumption
  * lib = cic018.1/tt/N_18 & P_18
  * 1. temp 27
  * 2. L=0.18um
  .lib 'cic018.1' tt
  .temp 27
  .option post
  * Simulation netlist
  * Trapezoidal Pulse Source, Page 189, HSPICE® User Guide: Simulation and Analysis
  * Vxxx n+ n- PU[LSE] [(]v1 v2 [td [tr [tf [pw [per]]]]] [)]
  *_____
  Vdd ndd gnd 1.8
  Vin in gnd PULSE(0v 1.8v 10ns 0.01ns 0.01ns 19.99ns 40ns)
  * W/L from HW2
  MN1 o1 in gnd gnd N_18 W=250n L=900n M=1
  MP1 o1 in ndd ndd p_18 W=250n L=270n M=2
  MN2 o2 o1 gnd gnd N_18 W=250n L=900n M=2
  MP2 o2 o1 ndd ndd p_18 W=250n L=270n M=4
  MN3 o3 o2 gnd gnd N_18 W=250n L=900n M=4
  MP3 o3 o2 ndd ndd p_18 W=250n L=270n M=8
  MN4 o4 o3 gnd gnd N_18 W=250n L=900n M=8
  MP4 o4 o3 ndd ndd p_18 W=250n L=270n M=16
  * 16x invertor load
  MNL nd o4 gnd gnd N_18 W=250n L=900n M=16
  MPL nd o4 ndd ndd p_18 W=250n L=270n M=32
  * Stimulus 25Mhz/40ns
  * Performing Basic Cell Measurements, Page 648, HSPICE® User Guide: Simulation and Analysis
  *_____
  .tran 1ps 60ns
  .MEAS TRAN Trise TRIG V(o4) val=0.18 TD=10n RISE=1 TARG V(o4) val=1.62 RISE=1
  .MEAS TRAN Tfall TRIG V(o4) val=1.62 TD=10n FALL=1 TARG V(o4) val=0.18 FALL=1
  .MEAS TRAN Tdelay TRIG V(in) val=0.9 TD=10n RISE=1 TARG V(o4) val=0.9 RISE=1
  .print tran v(in) v(o4)
  .end
  * Result
  * trise= 2.6542E-10
  * tfall= 3.2837E-10
  * tdelay= 6.6552E-10
# AvanWaves B-2008.09-SP1 (20081124)
                                                                                                                          - 0 X
Design Panels Window Measure Configuration Icols Help
 × N/A y N/A
 D0:tr0:v(m)
D0:tr0:v(o4)
             1.85
             1.75
             1.45
             800m
             650m
```

550m 550m 500m 450m 400m 350m 300m

2n 4n 6n 8n 10n 12n 14n 16n 18n 20n 22n 24n 26n 28n 30n 32n 34n 36n 38n 40n 42n 44n 46n 48n 50n 52n 54n 56n 56n 60n