Homework 4

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0 PMOS NMOS W/L Ratio

For detailed method, see hw2.

```
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

```
* HW4_0_op.sp
*-----------------------------------------------------------------------
* Assumption
* lib = cic018.1/tt/N_18 & P_18
* 1. temp 27
* 2. L=0.18um
*-----------------------------------------------------------------------

.lib 'cic018.l'  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
*-----------------------------------------------------------------------
.option captab=1        * nodal capacitance table
.op
.end
```

1.2 Capacitance

```
*-----------------------------------------------------------------------
* Result
*-----------------------------------------------------------------------
* HW4_1_0_op.lis
*
* nodal capacitance table
* node    =    cap
* d       =   1.2573f
* g       =   2.6345f
*
* element  mn1       mp1
* 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
```

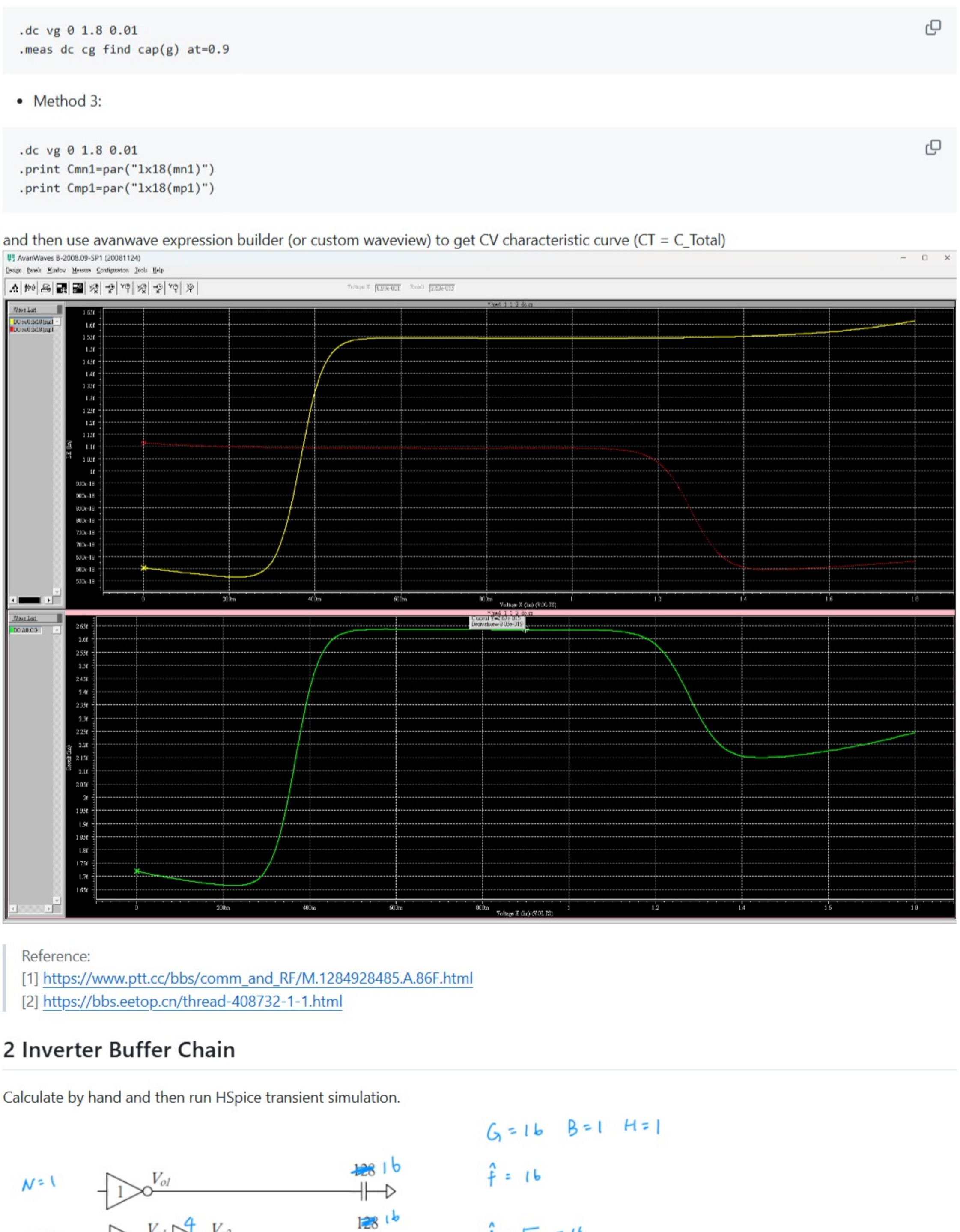
- Method 2:

```
.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)



> 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.

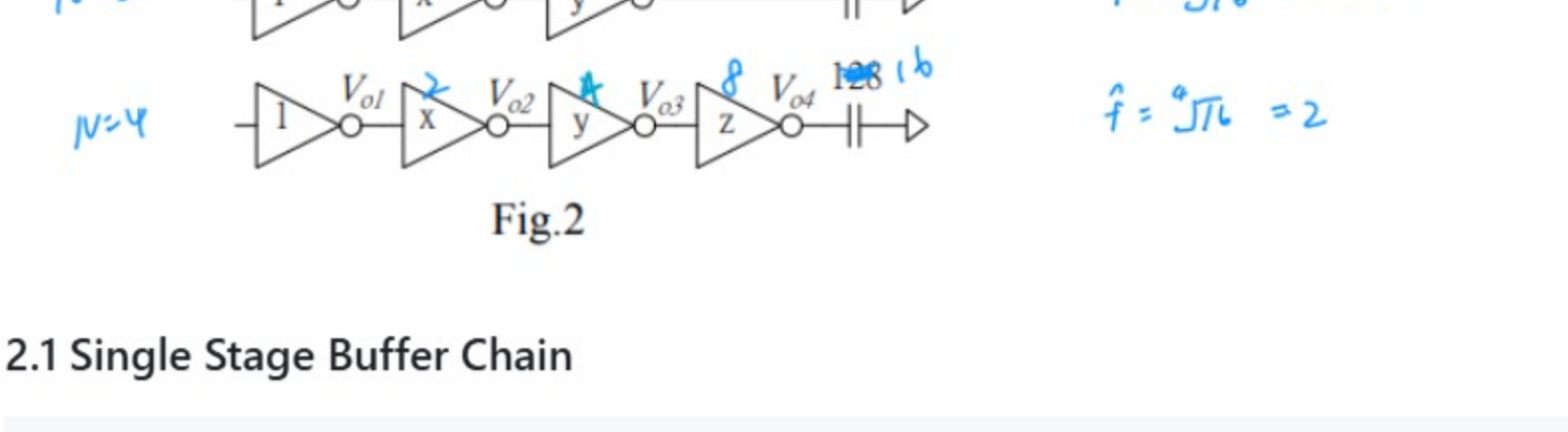
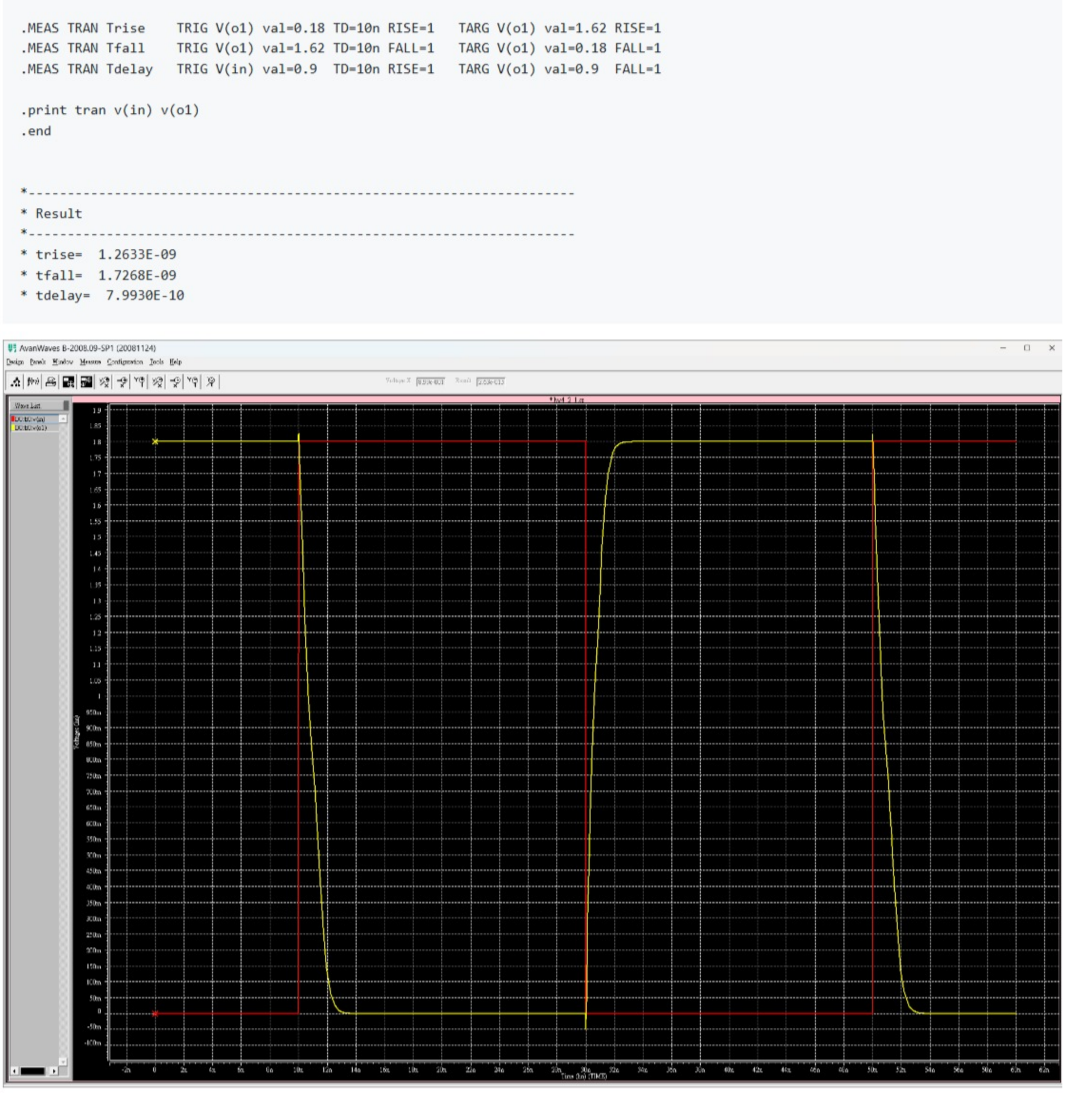


Fig.2

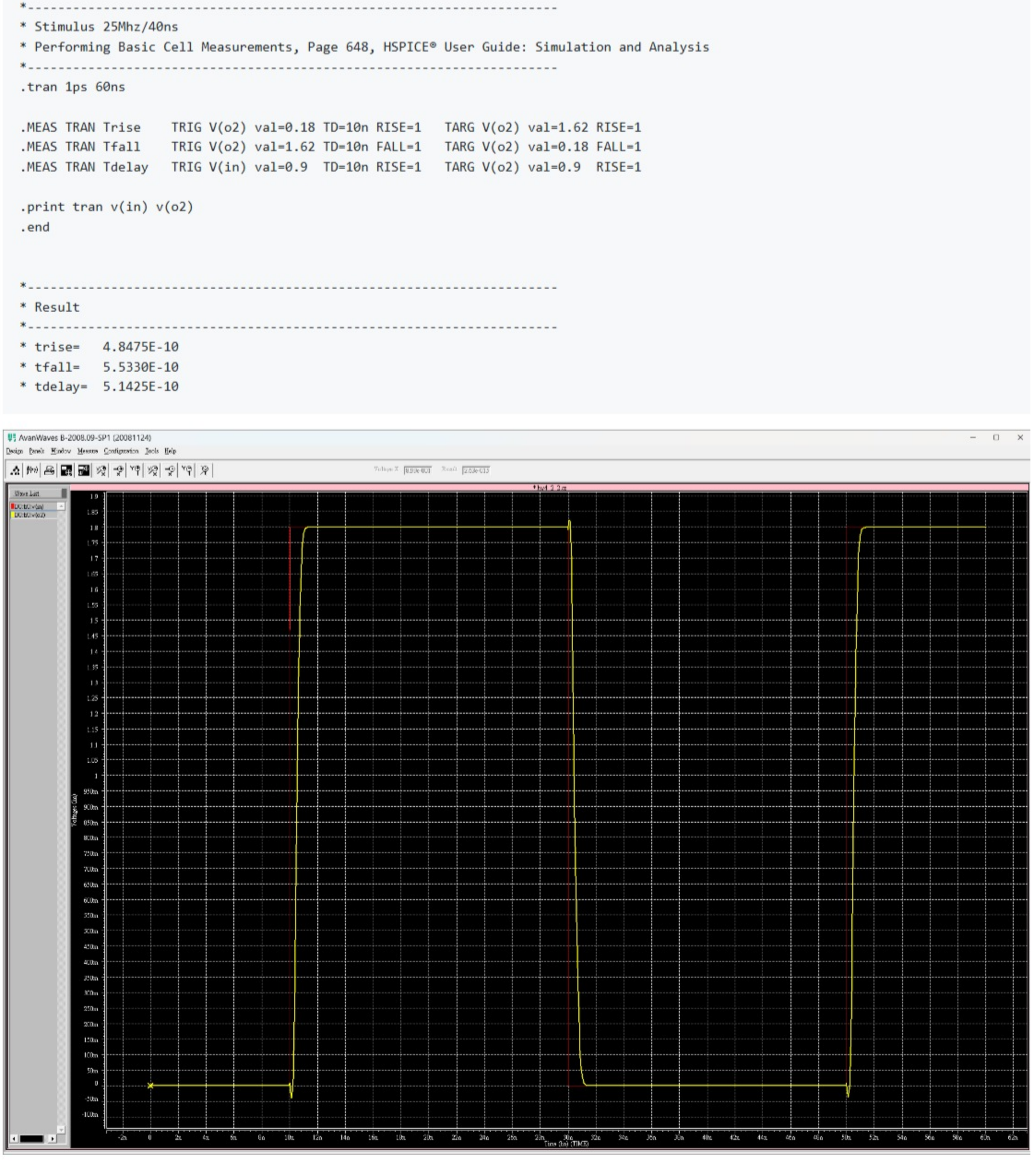
2.1 Single Stage Buffer Chain

```
* HW4_2_1.sp
*-----------------------------------------------------------------------
* Assumption
* lib = cic018.1/tt/N_18 & P_18
* 1. temp 27
* 2. L=0.18um
*-----------------------------------------------------------------------

.lib 'cic018.l'  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

.MEAS TRAN Trise    TRIG V(o1) val=0.18 TD=10n RISE=1   TARG V(o1) val=1.62 RISE=1
.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
```



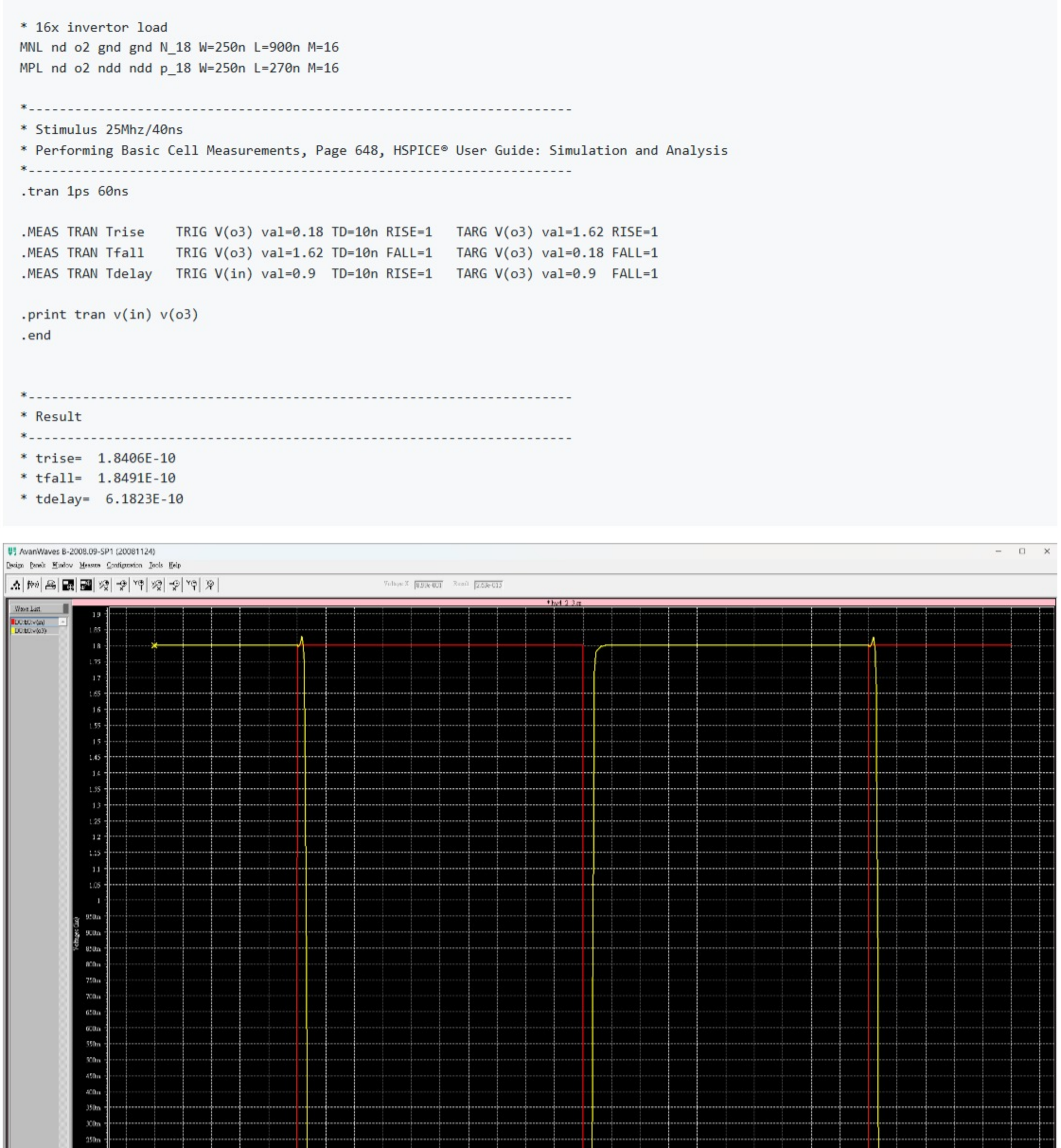
2.2 Two Stage Buffer Chain

```
* HW4_2_2.sp
*-----------------------------------------------------------------------
* Assumption
* lib = cic018.1/tt/N_18 & P_18
* 1. temp 27
* 2. L=0.18um
*-----------------------------------------------------------------------

.lib 'cic018.l'  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
```



2.3 Three Stage Buffer Chain

```
* HW4_2_3.sp
*-----------------------------------------------------------------------
* Assumption
* lib = cic018.1/tt/N_18 & P_18
* 1. temp 27
* 2. L=0.18um
*-----------------------------------------------------------------------

.lib 'cic018.l'  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 * x2.52

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 * x2.52

* 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

.MEAS TRAN Trise    TRIG V(o3) val=0.18 TD=10n RISE=1   TARG V(o3) val=1.62 RISE=1
.MEAS TRAN Tfall    TRIG V(o3) val=1.62 TD=10n FALL=1   TARG V(o3) val=0.18 FALL=1
.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
```



2.4 Four Stage Buffer Chain

```
* HW4_2_4.sp
*-----------------------------------------------------------------------
* Assumption
* lib = cic018.1/tt/N_18 & P_18
* 1. temp 27
* 2. L=0.18um
*-----------------------------------------------------------------------

.lib 'cic018.l'  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
```