Digital IC Design

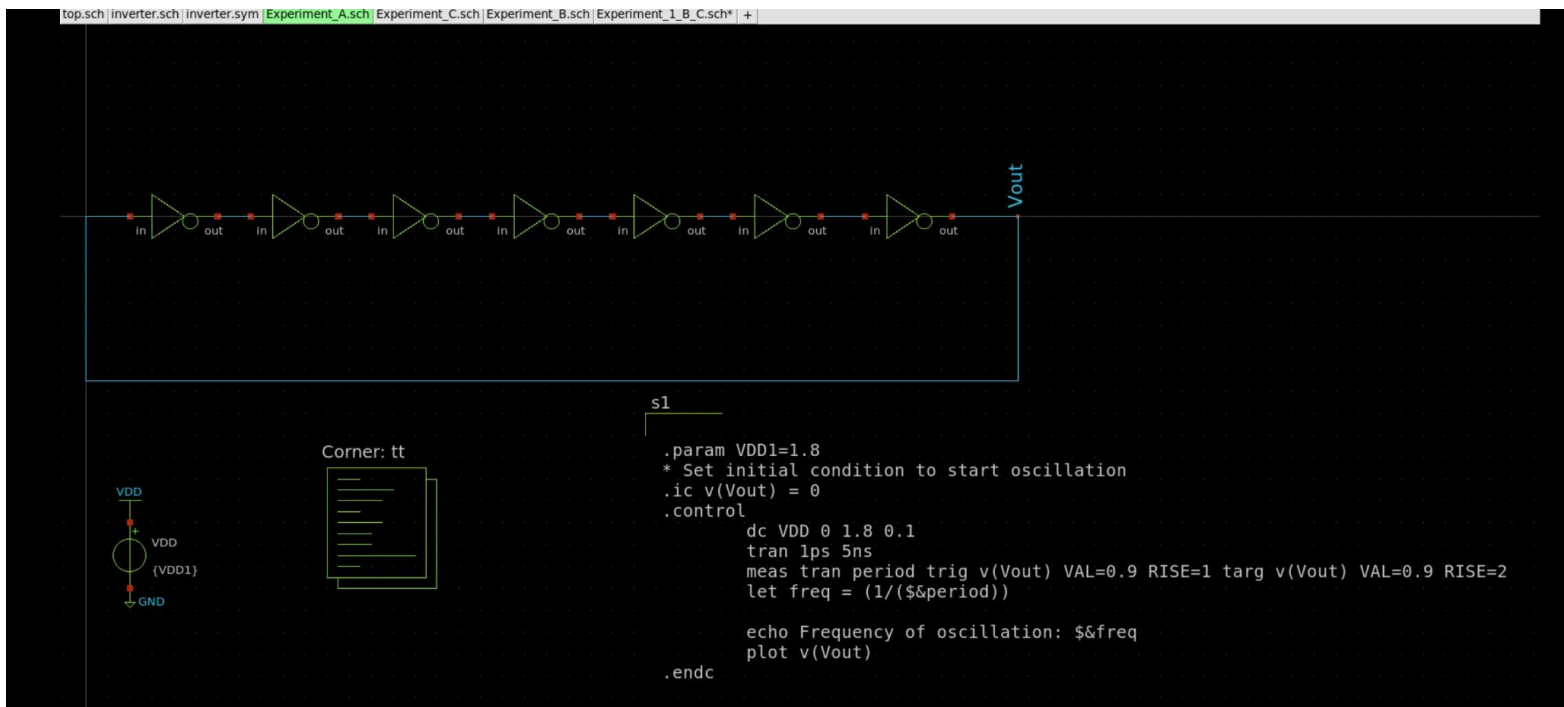## EE5311

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Tutorial - 4
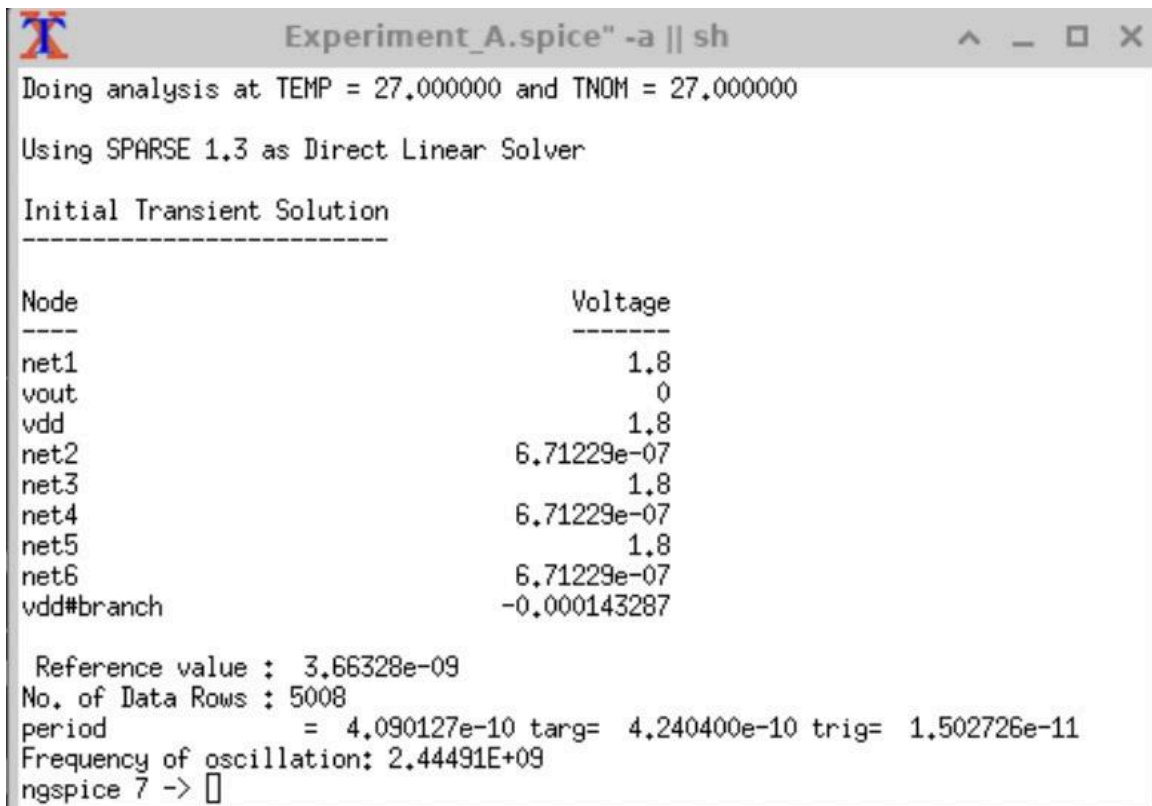Report

Experiment - 1

Schematic for (A):

```
                                                                              Vout
   in      out    in      out    in      out    in      out    in      out    in      out


                                                          s1

                      Corner: tt                          .param VDD1=1.8
                                                          * Set initial condition to start oscillation
   VDD                                                    .ic v(Vout) = 0
                                                          .control
        VDD                                                   dc VDD 0 1.8 0.1
        {VDD1}                                                tran 1ps 5ns
                                                              meas tran period trig v(Vout) VAL=0.9 RISE=1 targ v(Vout) VAL=0.9 RISE=2
   GND                                                        let freq = (1/($&period))

                                                              echo Frequency of oscillation: $&freq
                                                              plot v(Vout)
                                                          .endc
```
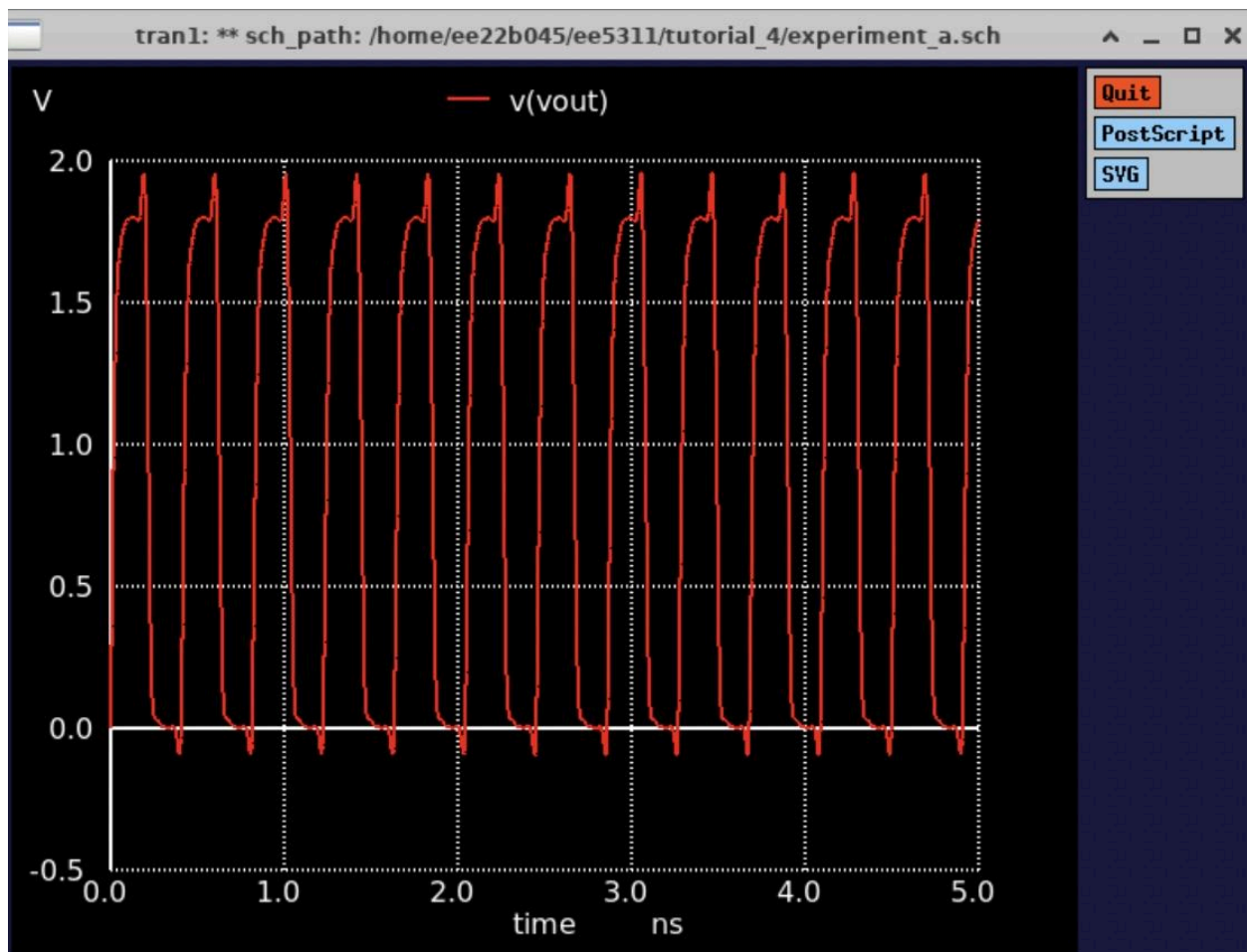
The CMOS inverter with Wp = 0.84um has the minimum delay

NgSpice response

```
                 Experiment_A.spice" -a || sh

Doing analysis at TEMP = 27.000000 and TNOM = 27.000000

Using SPARSE 1.3 as Direct Linear Solver

Initial Transient Solution
----------------------------

Node                              Voltage
----                              -------
net1                                  1.8
vout                                    0
vdd                                   1.8
net2                          6.71229e-07
net3                                  1.8
net4                          6.71229e-07
net5                                  1.8
net6                          6.71229e-07
vdd#branch                    -0.000143287


 Reference value :  3.66328e-09
No. of Data Rows : 5008
period             =  4.090127e-10 targ=  4.240400e-10 trig=  1.502726e-11
Frequency of oscillation: 2.44491E+09
ngspice 7 -> []
```

Frequency of Oscillations = 2.449GHz

The below graph Shows the Vout @7th inverter

tran1: ** sch_path: /home/ee22b045/ee5311/tutorial_4/experiment_a.sch

v(vout)

Schematic and code for 7-Inverters(B):

Vout

Corner: tt

VDD

VDD
{VDD1}

GND

s2

```
.param VDD1 = 1.8
.ic v(Vout) = 0
.control
let Nsim = 9
let periodvec = vector(Nsim)
let vddvec = vector(Nsim)
let freqvec = vector(Nsim)
let index = 0
let vdd = 1.0
while index < Nsim
        let vdd = 1.0 + (index * 0.1)
        alterparam VDD1 = $&vdd
        reset
        tran 1ps 5ns
        meas tran period trig v(Vout) val=0.5 rise=1 targ v(Vout) val=0.5 rise=2
        let freq = 1/$&period
        let periodvec[index] = $&period
        let vddvec[index] = vdd
        let freqvec[index] = freq
        let index = index + 1
        echo Vdd = $&vdd Period = $&period Frequency = $&freq

end
plot periodvec vs vddvec
plot freqvec vs vddvec
.endc
```

VDD vs Frequency:

```
1. VDD = 1.0V    ;Frequency = 0.484GHz ;Period = 2.064ns
2. VDD = 1.1V    ;Frequency = 0.734GHz ;Period = 1.362ns
3. VDD = 1.2V    ;Frequency = 0.996GHz ;Period = 1.003ns
4. VDD = 1.3V    ;Frequency = 1.259GHz ;Period = 0.793ns
5. VDD = 1.4V    ;Frequency = 1.518GHz ;Period = 0.658ns
6. VDD = 1.5V    ;Frequency = 1.768GHz ;Period = 0.565ns
7. VDD = 1.6V    ;Frequency = 2.008GHz ;Period = 0.498ns
8. VDD = 1.7V    ;Frequency = 2.235GHz ;Period = 0.474ns
9. VDD = 1.8V    ;Frequency = 2.448GHz ;Period = 0.408ns
```
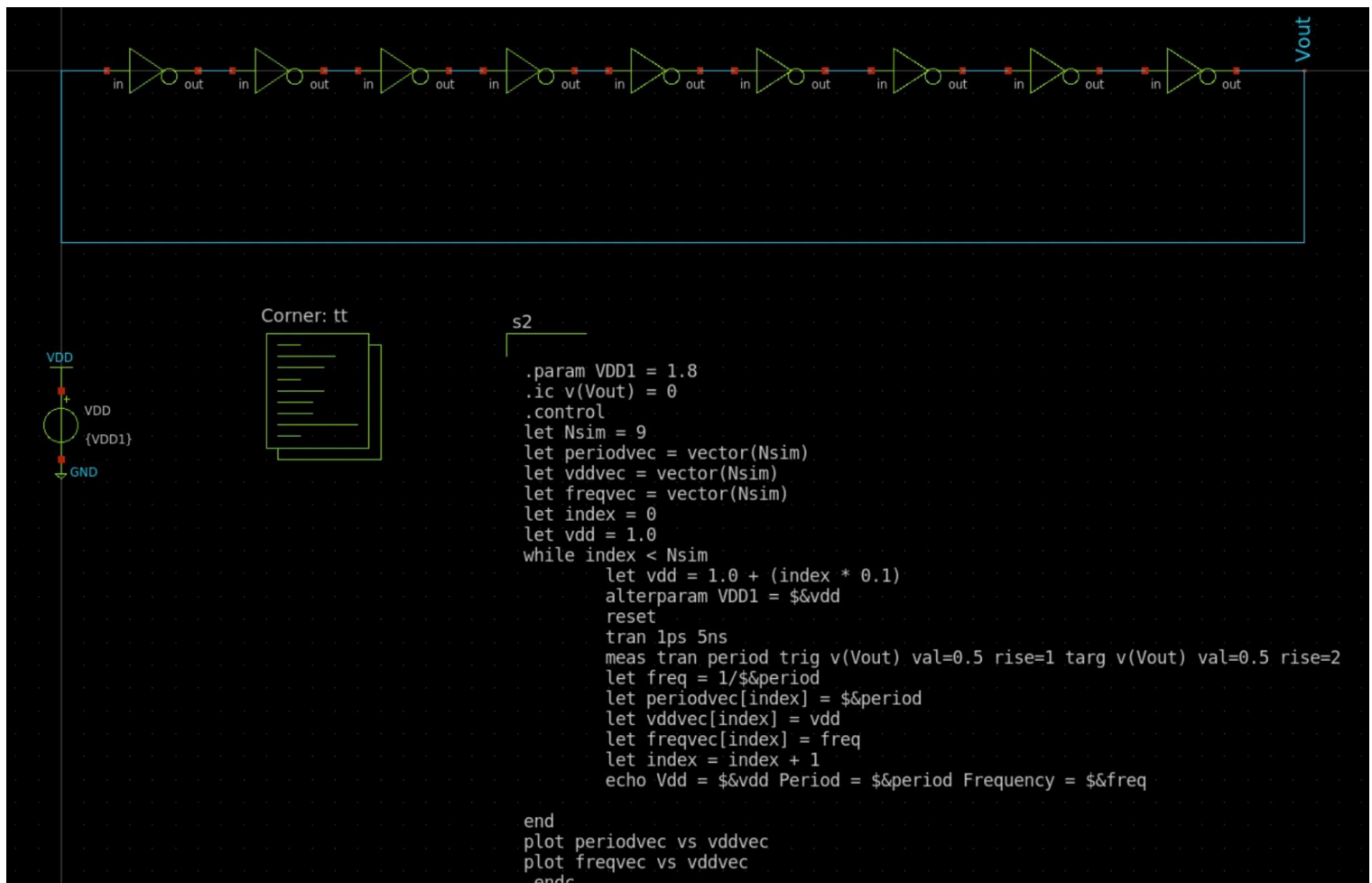
Period vs VDD (from 1.0V to 1.8V)
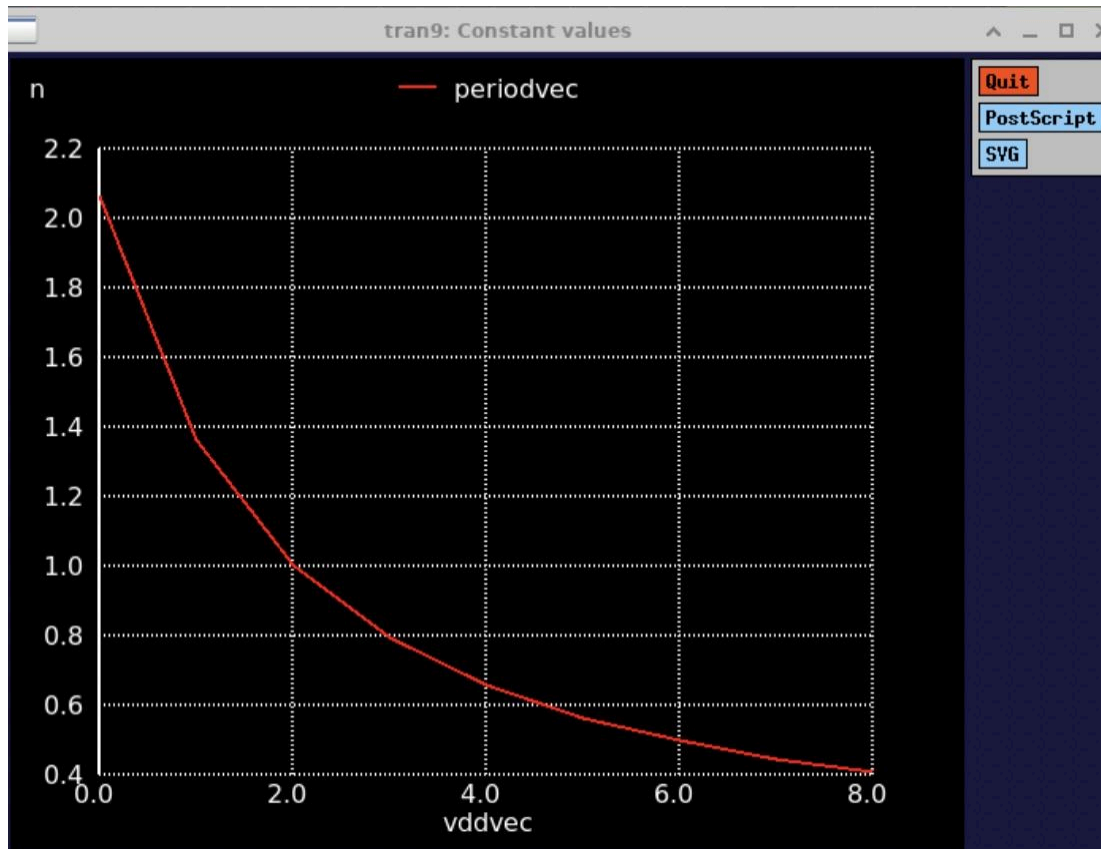
Frequency vs VDD (from 1.0V to 1.8V)
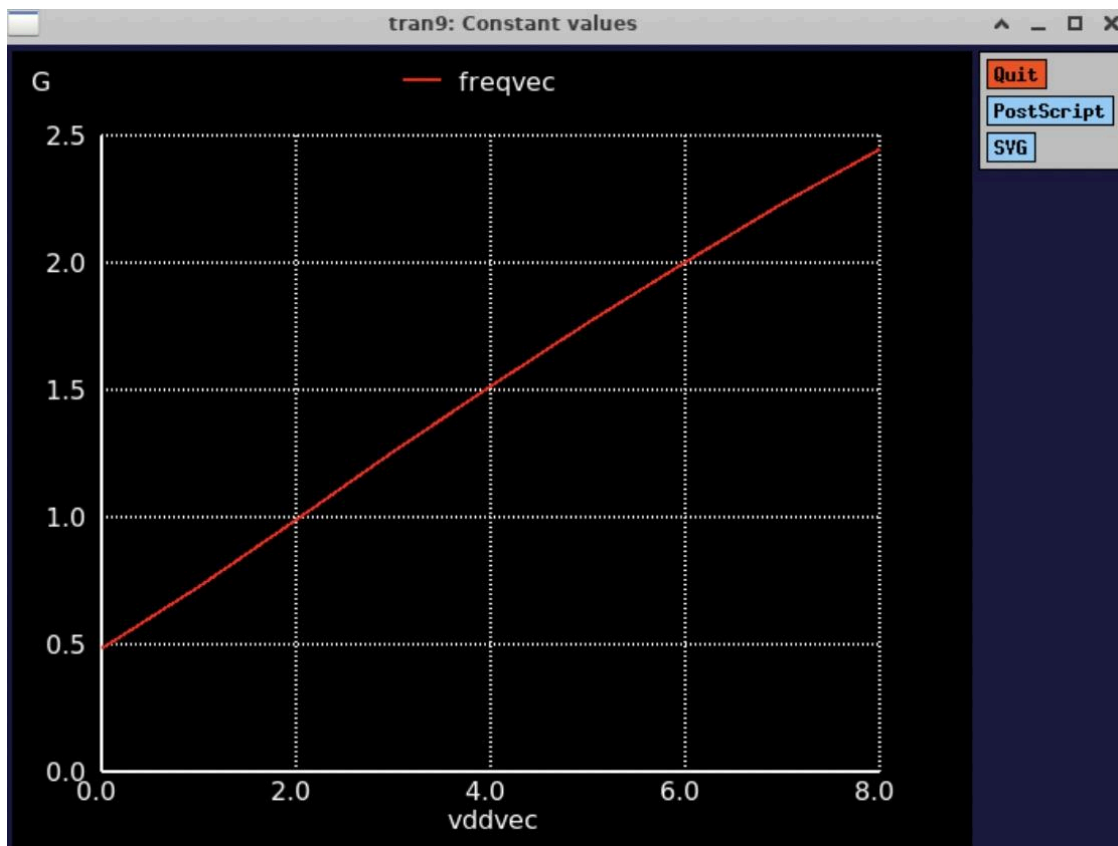
Schematic and code for 9-Inverters(C):

Corner: tt

s2

```
.param VDD1 = 1.8
.ic v(Vout) = 0
.control
let Nsim = 9
let periodvec = vector(Nsim)
let vddvec = vector(Nsim)
let freqvec = vector(Nsim)
let index = 0
let vdd = 1.0
while index < Nsim
        let vdd = 1.0 + (index * 0.1)
        alterparam VDD1 = $&vdd
        reset
        tran 1ps 5ns
        meas tran period trig v(Vout) val=0.5 rise=1 targ v(Vout) val=0.5 rise=2
        let freq = 1/$&period
        let periodvec[index] = $&period
        let vddvec[index] = vdd
        let freqvec[index] = freq
        let index = index + 1
        echo Vdd = $&vdd Period = $&period Frequency = $&freq

end
plot periodvec vs vddvec
plot freqvec vs vddvec
.endc
```

Frequency @VDD = 1.8V is **1.903GHz**

VDD vs Frequency:

1. VDD = 1.0V   ;Frequency = 0.376GHz ;Period = 2.654ns
2. VDD = 1.1V   ;Frequency = 0.570GHz ;Period = 1.751ns
3. VDD = 1.2V   ;Frequency = 0.774GHz ;Period = 1.290ns
4. VDD = 1.3V   ;Frequency = 0.979GHz ;Period = 1.020ns
5. VDD = 1.4V   ;Frequency = 1.180GHz ;Period = 0.469ns
6. VDD = 1.5V   ;Frequency = 1.375GHz ;Period = 0.727ns
7. VDD = 1.6V   ;Frequency = 1.561GHz ;Period = 0.640ns
8. VDD = 1.7V   ;Frequency = 1.737GHz ;Period = 0.575ns
9. VDD = 1.8V   ;Frequency = **1.903GHz** ;Period = 0.525ns

Period vs VDD (from 1.0V to 1.8V)
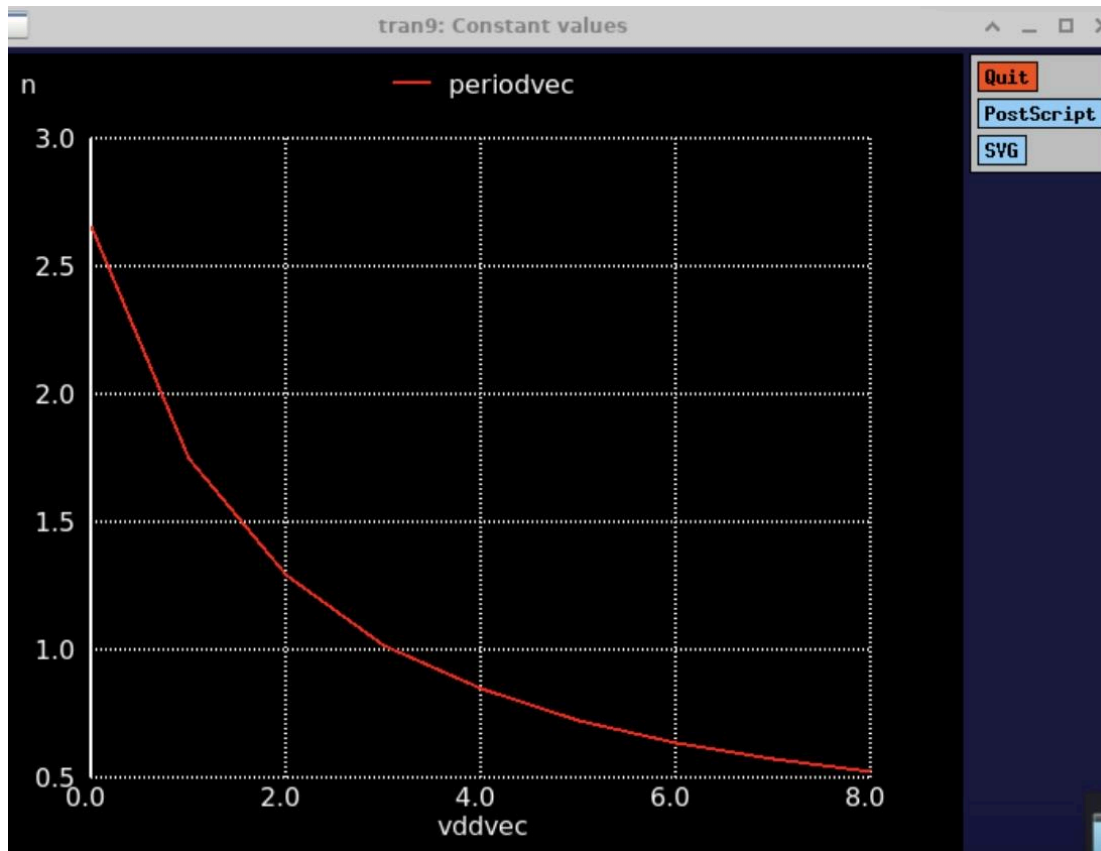
Frequency vs VDD (from 1.0V to 1.8V)

- The End -