# EE5311 Tutorial 4 Report - EE22B070

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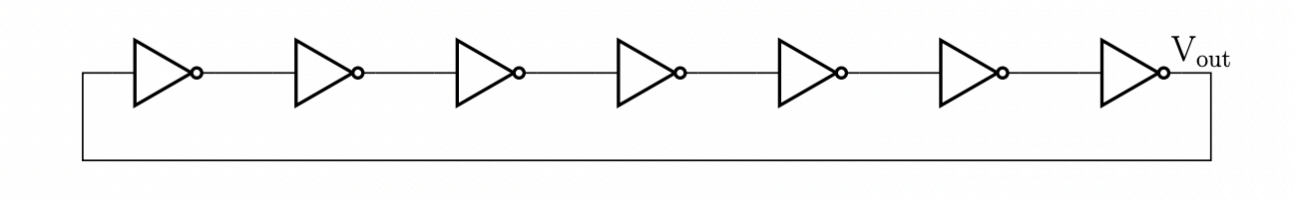
1. Construct a seven-stage ring oscillator as shown below and find the oscillating frequency.



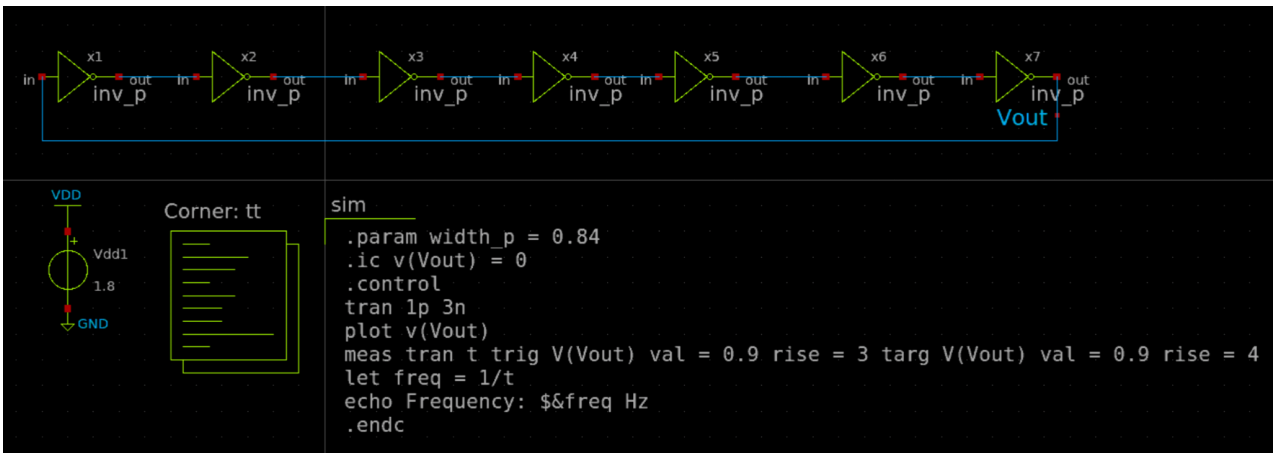

1(a) Measure the oscillating frequency for $V_{DD}$ = 1.8 V

## Calculations:

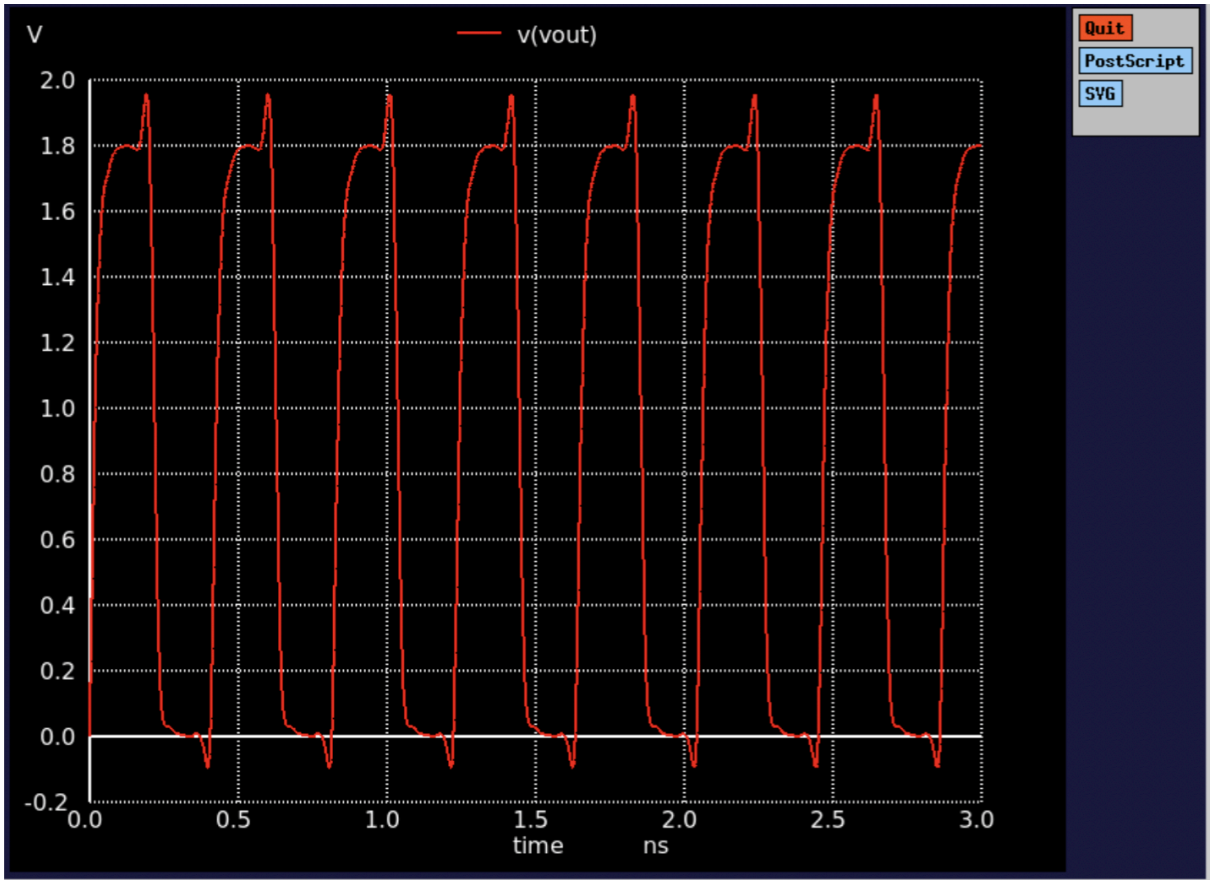
### Frequency calculations:

We take the difference of the adjacent rise times when the the $V_{out}$ = $V_{DD}/2$ to get the time period of the waveform, and then reciprocate it to get the waveform's frequency.

## Schematic & Code:



# Measurements:




**$V_{out}$ vs time gives us a pulse like waveform with spikes**

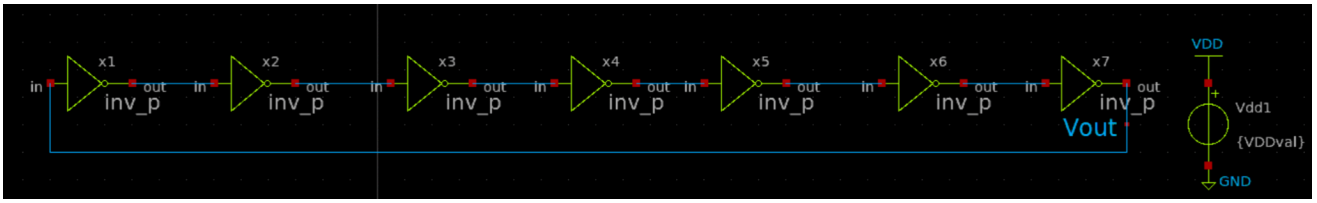
```
Frequency: 2.44432E+09 Hz
ngspice 2 ->
```

From above, we get the frequency to be **2.44 GHz**.

1(b) Plot the oscillating frequency and time period as a function of $V_{DD}$ for $V_{DD}$ = 1 V to 1.8 V in steps of 0.1 V.

# Schematic:

Same as 1(a)

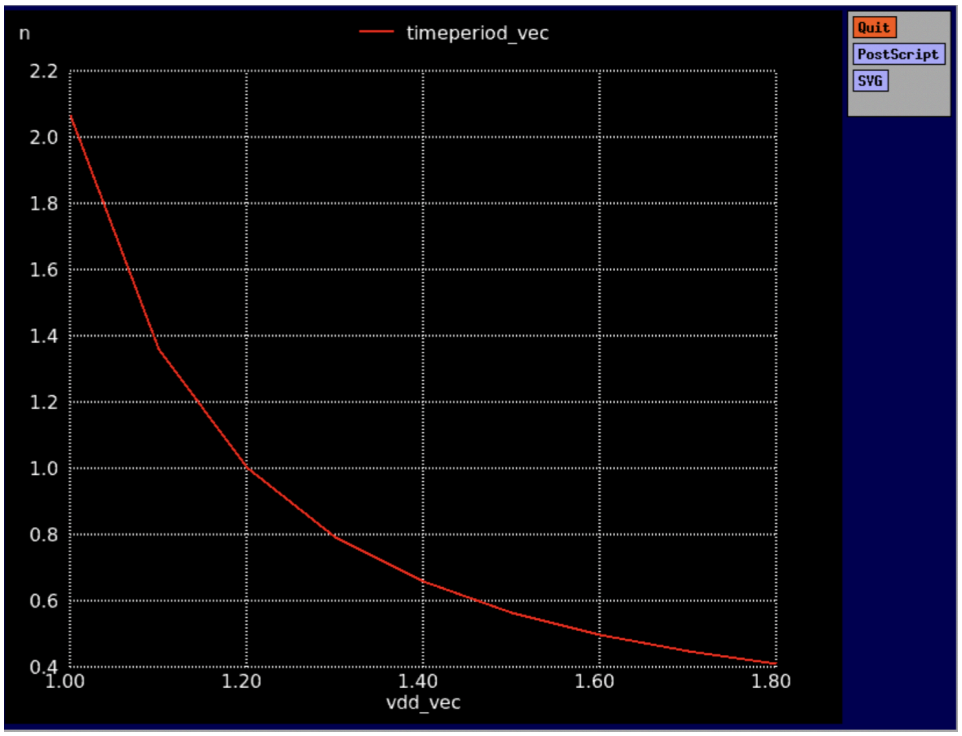



# Code:

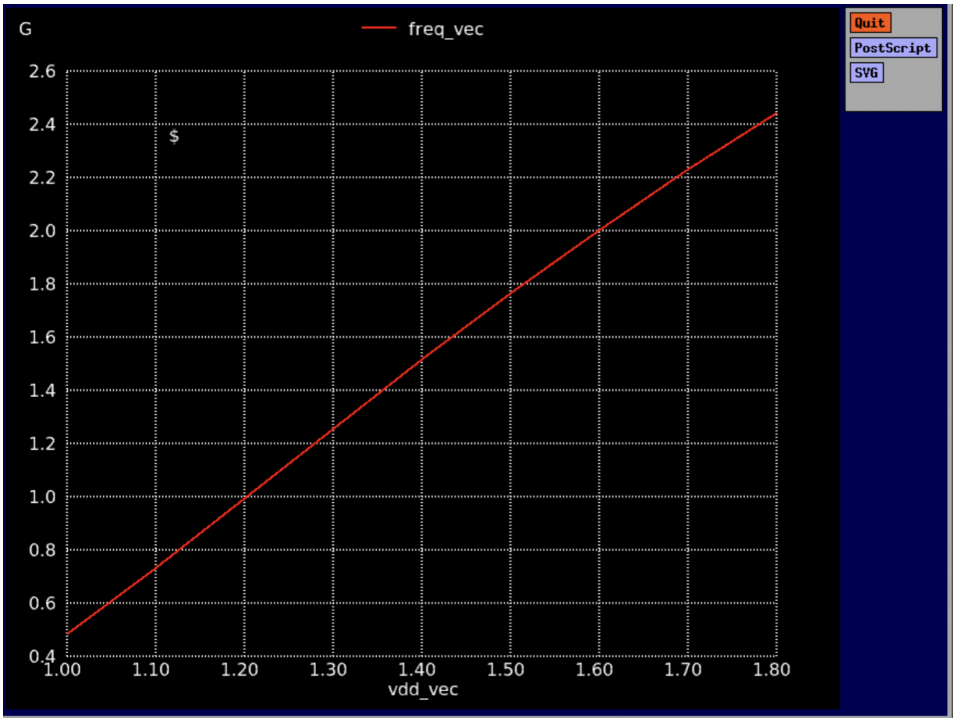
```
sim
 .param width_p = 0.84
 .param VDDval = 1.8
 .ic V(Vout) = 0
 .control
 let index = 0
 let N = 9
 let freq_vec = vector(N)
 let vdd_vec = vector(N)

 let timeperiod_vec = vector(N)
 while index < N
   let vdd = 1.0 + (index * 0.1)
   let vdd_vec[index] = vdd
   let vby2 = vdd/2
   alterparam VDDval = $&vdd
   reset
   tran 1p 10n
   meas tran t trig V(Vout) val = vby2 rise = 3 targ V(Vout) val = vby2 rise = 4
   let freq = 1/t
   let timeperiod_vec[index] = $&t
   let freq_vec[index] = $&freq
   let index = index + 1
   echo Frequency: $&freq Hz
 end
 print vdd_vec freq_vec
 plot freq_vec vs vdd_vec
 plot timeperiod_vec vs vdd_vec
 .endc
```

# Measurements:




**Time period vs $V_{DD}$**



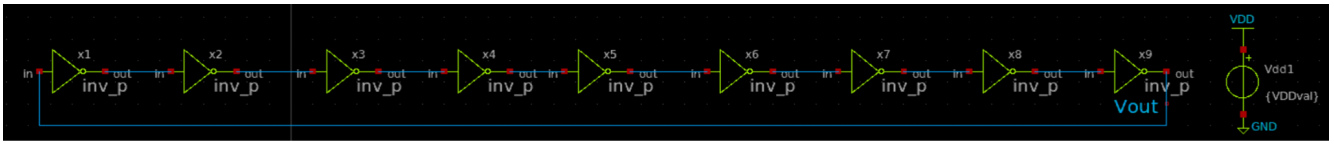

**Frequency vs $V_{DD}$**

| Index | vdd_vec | freq_vec |
|---|---|---|
| 0 | 1.000000e+00 | 4.842260e+08 |
| 1 | 1.100000e+00 | 7.338170e+08 |
| 2 | 1.200000e+00 | 9.955860e+08 |
| 3 | 1.300000e+00 | 1.258760e+09 |
| 4 | 1.400000e+00 | 1.517090e+09 |
| 5 | 1.500000e+00 | 1.766770e+09 |
| 6 | 1.600000e+00 | 2.005390e+09 |
| 7 | 1.700000e+00 | 2.231490e+09 |
| 8 | 1.800000e+00 | 2.444320e+09 |

**Data Points**

1(c) Repeat the experiment (b) with nine inverter stages.

# Schematic:

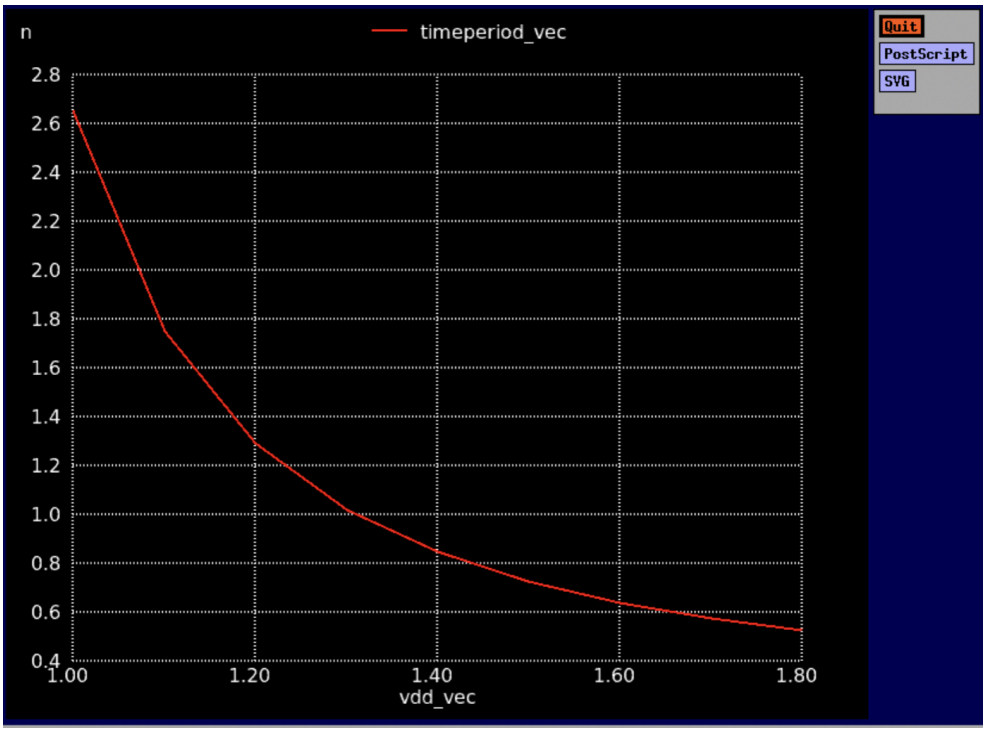



# Code:

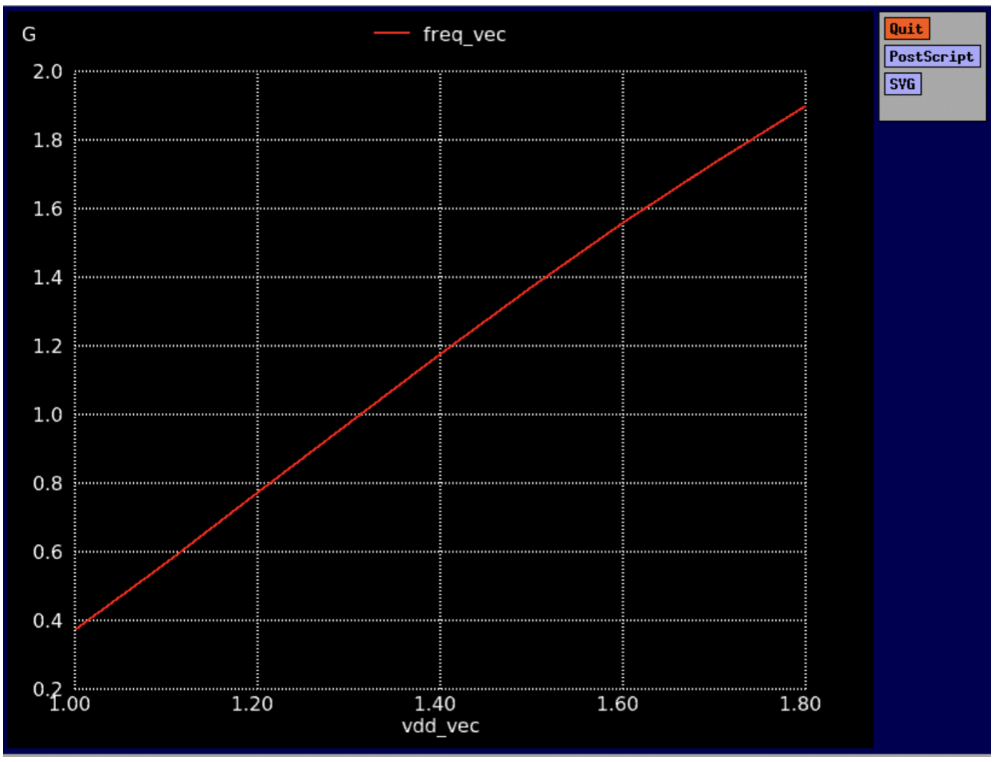
Same as 1(b)

```
sim
  .param width_p = 0.84
  .param VDDval = 1.8
  .ic V(Vout) = 0
  .control
  let index = 0
  let N = 9
  let freq_vec = vector(N)
  let vdd_vec = vector(N)
  let timeperiod_vec = vector(N)
  while index < N
    let vdd = 1.0 + (index * 0.1)
    let vdd_vec[index] = vdd
    let vby2 = vdd/2
    alterparam VDDval = $&vdd
    reset
    tran 1p 10n
    meas tran t trig V(Vout) val = vby2 rise = 3 targ V(Vout) val = vby2 rise = 4
    let freq = 1/t
    let timeperiod_vec[index] = $&t
    let vdd_vec[index] = $&vdd
    let freq_vec[index] = $&freq
    let index = index + 1
    echo Frequency: $&freq Hz
  end
  print vdd_vec freq_vec
  plot freq_vec vs vdd_vec
  plot timeperiod_vec vs vdd_vec
  .endc
```

# Measurements:




**Time period vs $V_{DD}$**




**Frequency vs $V_{DD}$**

| Index | vdd_vec | freq_vec |
|---|---|---|
| 0 | 1.000000e+00 | 3.766180e+08 |
| 1 | 1.100000e+00 | 5.707420e+08 |
| 2 | 1.200000e+00 | 7.743350e+08 |
| 3 | 1.300000e+00 | 9.790170e+08 |
| 4 | 1.400000e+00 | 1.179930e+09 |
| 5 | 1.500000e+00 | 1.374110e+09 |
| 6 | 1.600000e+00 | 1.559690e+09 |
| 7 | 1.700000e+00 | 1.735530e+09 |
| 8 | 1.800000e+00 | 1.901010e+09 |

**Data Points**