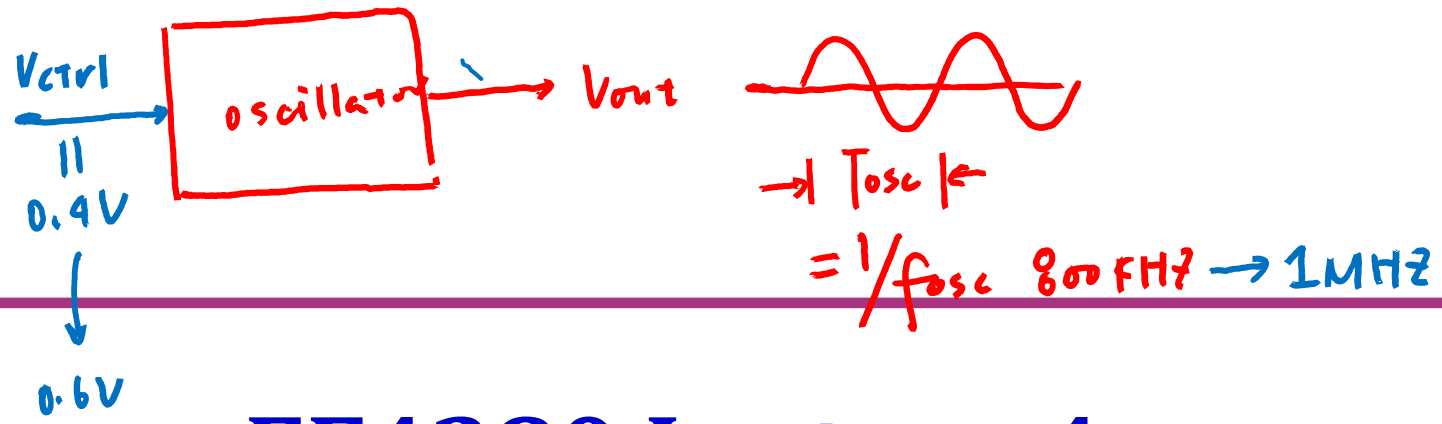
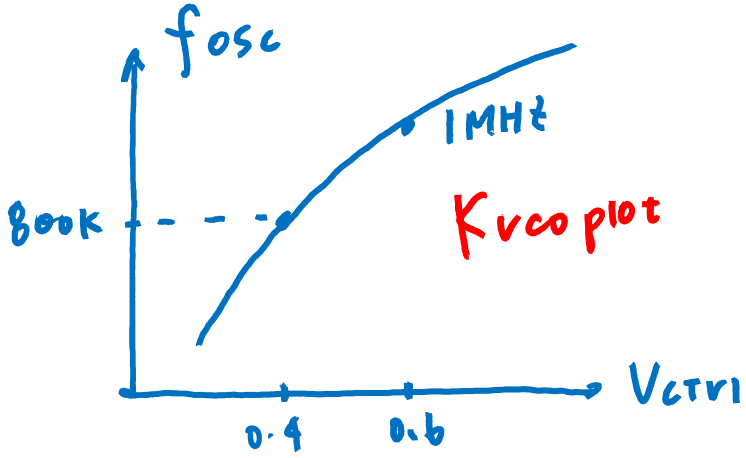


EE4280 Lecture 4:

Voltage-Controlled Oscillator



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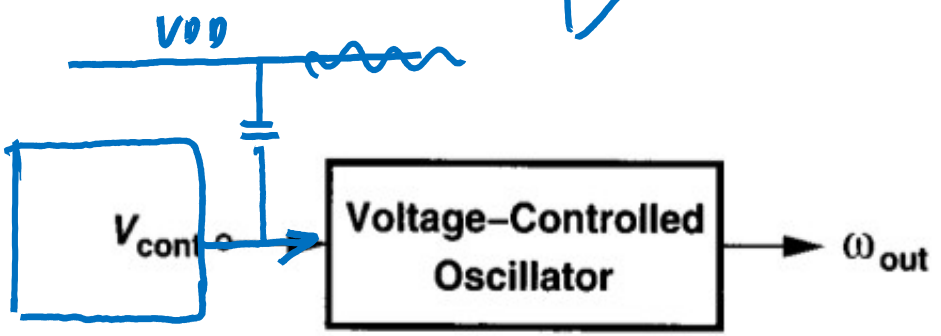
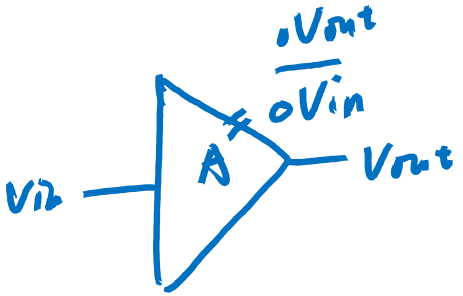
Voltage-Controlled Oscillator

- **To tune the operating frequency**
  - With a control voltage
  - With ideally linear function

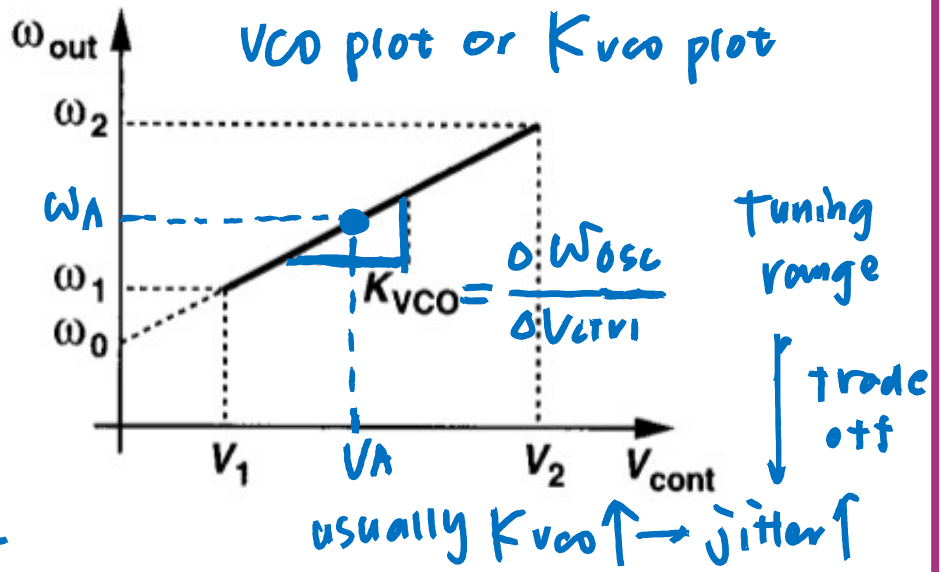
$$\omega_{out} = \omega_0 + K_{VCO} V_{cont}$$

sensitivity, (VCO) gain

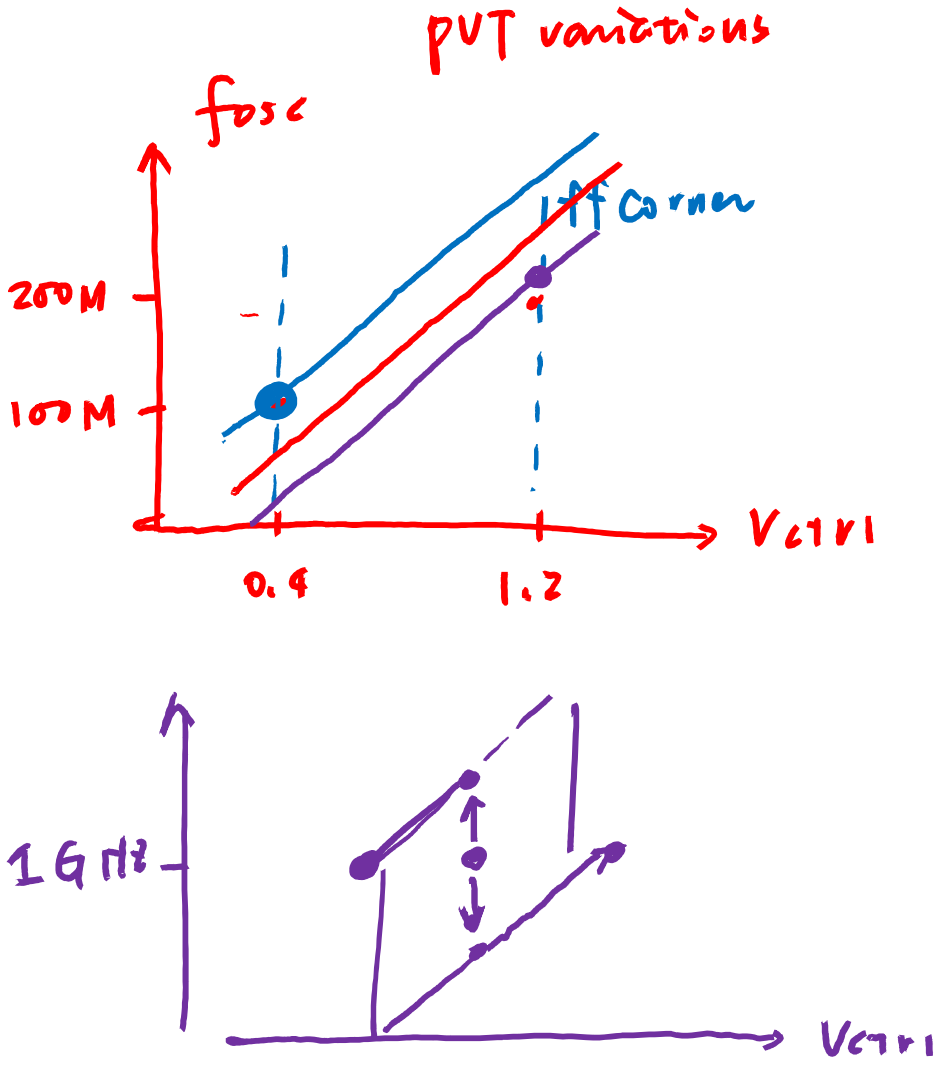




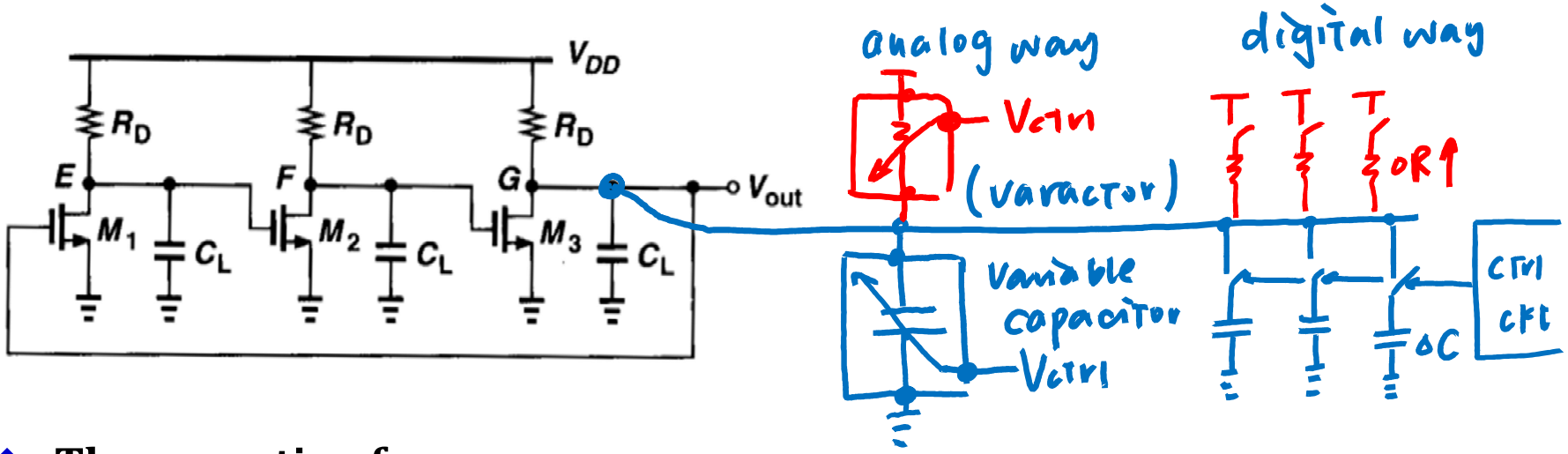
- Center frequency
- Tuning range
- Linearity of transfer function



- Output signal quality
  - Output amplitude
  - Frequency purity
  - Supply and common-mode rejection
- Power dissipation

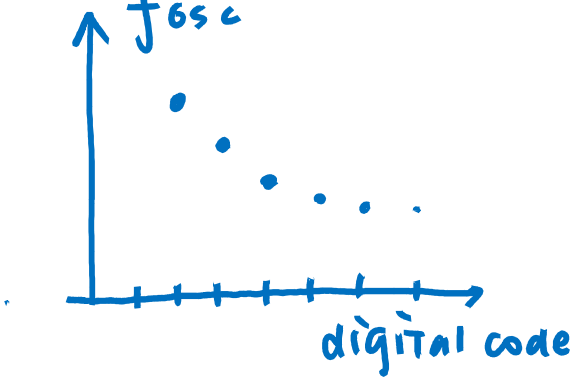

PVT variations
fosc
ff Corner
200M
100M
Vctrl
0.9
1.2
1GHz
Vctrl

Tuning in Ring Oscillators



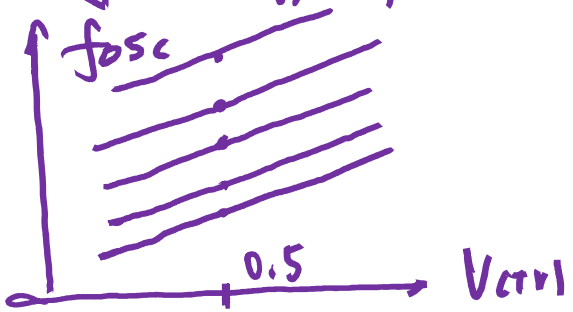
- **The operating frequency**
  - $\sqrt{3}/2\pi RC$ for small-signal operation
  - $1/6T_D$ for large-signal, nonlinear operation

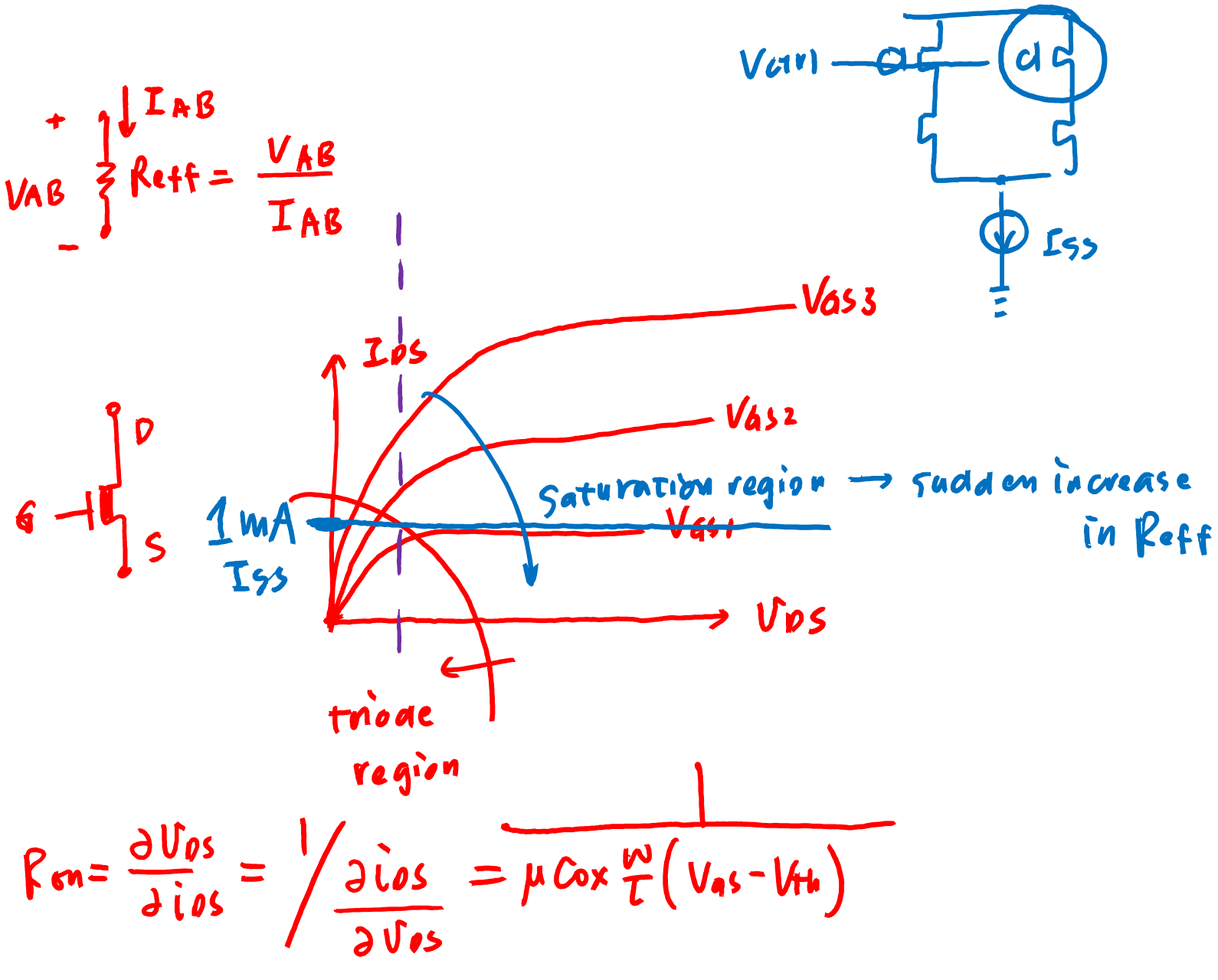
$T \propto R_{eff} \cdot C_{eff}$



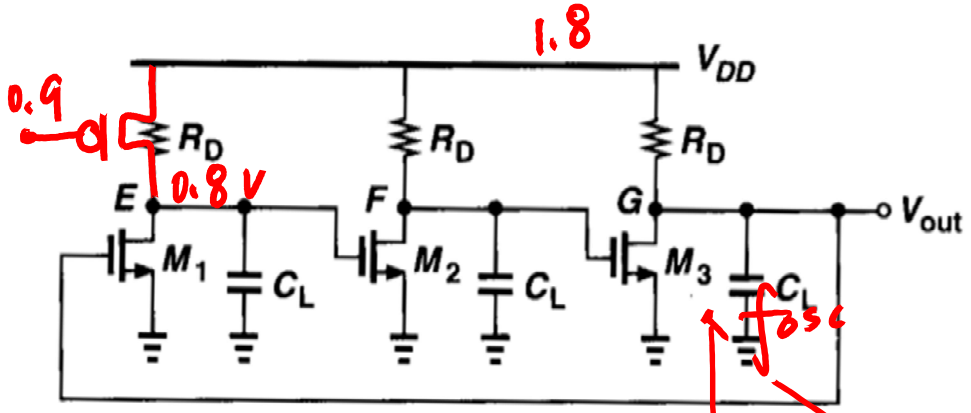
→ **Can be tuned by adjusting the R and C values**

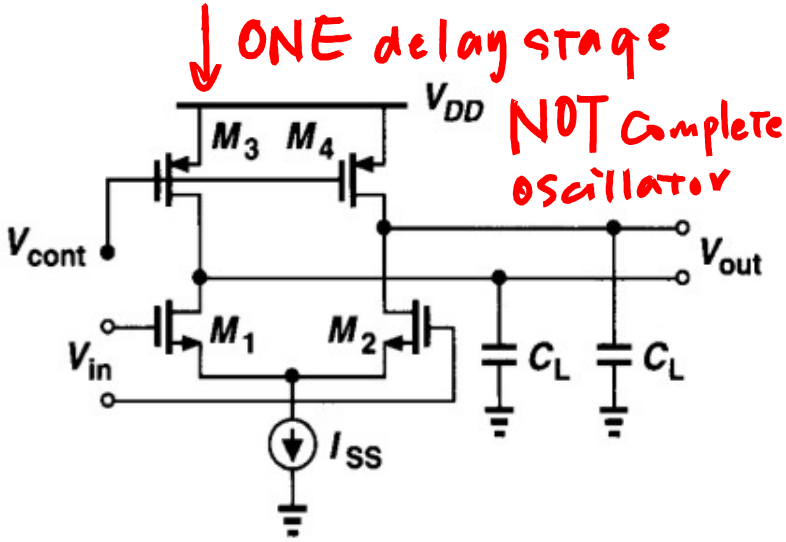
combining analog/digital method

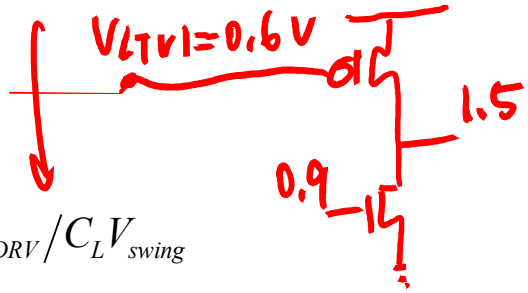



+
VAB
-
IAB
Reff = VAB / IAB
Vctrl
Iss
Vgs3
Vgs2
Vgs1
IDS
VDS
D
G
S
1 mA
Iss
Saturation region → sudden increase in Reff
triode region
Ron = ∂VDS/∂iDS = 1 / (∂iDS/∂VDS) = μCox (W/L)(Vgs - Vth)

Tuning in Ring Oscillators







- **Operating frequency**
  - $\sqrt{3}/2\pi RC$ for small-signal operation
  - $1/6T_D$ for large-signal, nonlinear operation $\propto I_{DRV}/C_L V_{swing}$

→ **Can be tuned by adjusting the R and C values**

- Resistive load implemented with PMOS operating in triode region

$$R_{on3,4} = 1\Big/\mu_p C_{ox}\left(\frac{W}{L}\right)_{3,4}\left(V_{DD} - V_{cont} - |V_{THP}|\right)$$

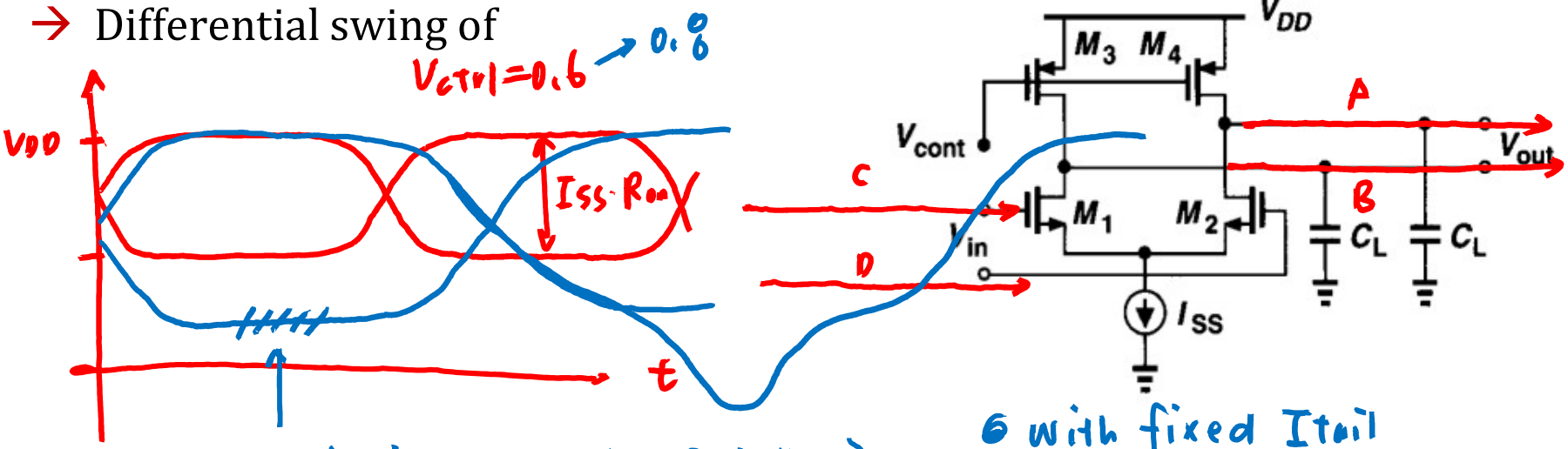
① wider PMOS
② Vctrl ↓

$T_{osc} \propto RC$ freq $\propto \frac{1}{R} \propto \left(\frac{W}{L}\right)(V_{DD} - V_{ctrl} - |V_{thp}|)$

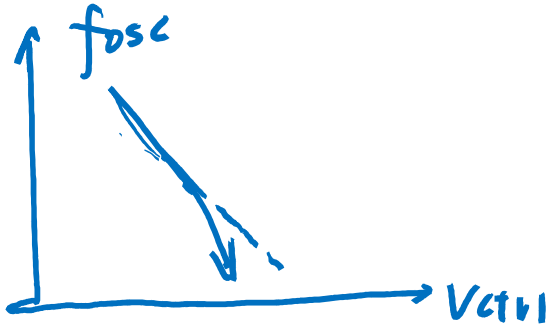
Resistive Load with PMOS in Triode Region

- **Oscillation amplitude varies with operating frequency**
  - Assume large swing with complete switching

→ Differential swing of



PMOS is likely to enter saturation

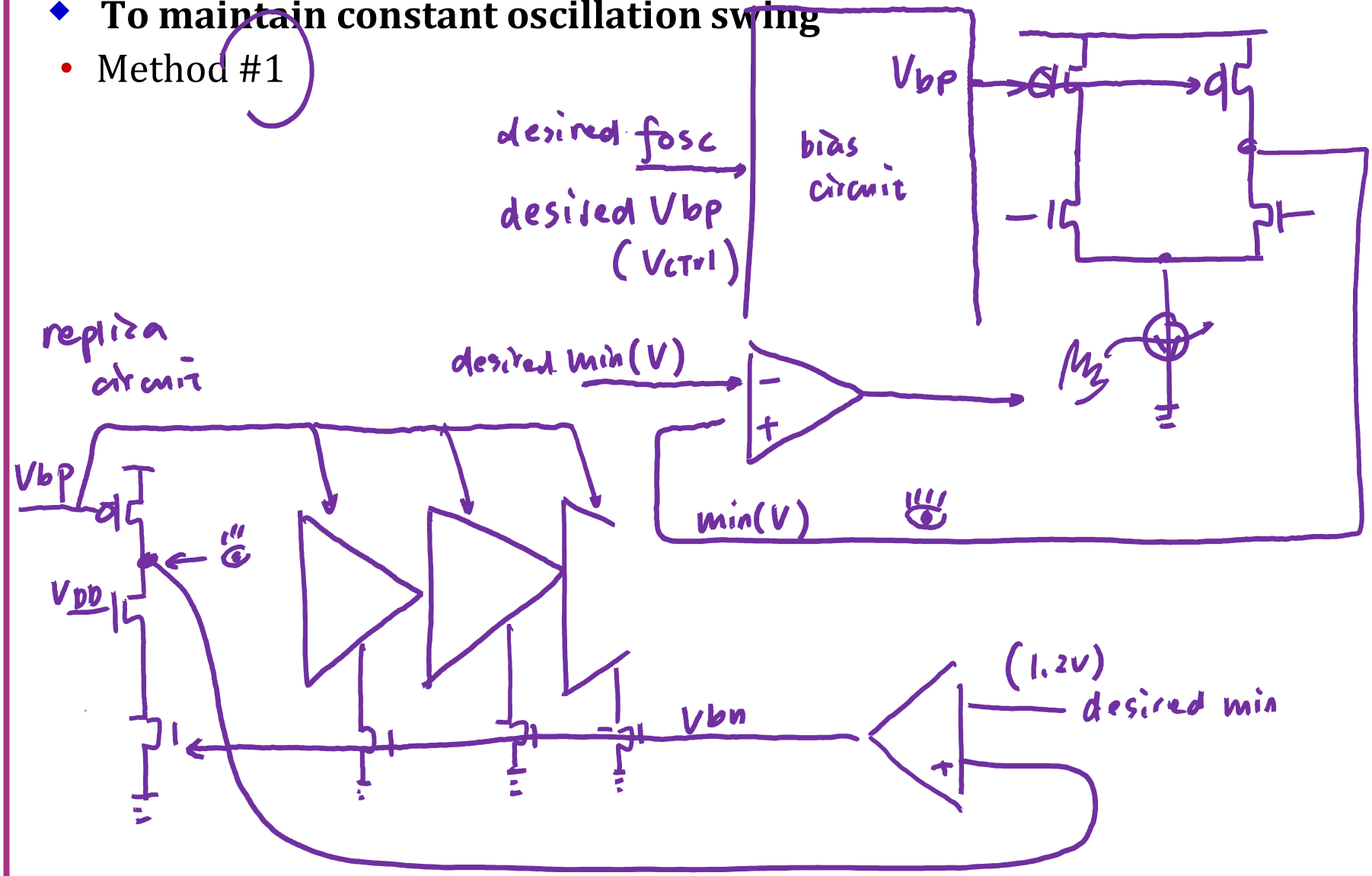


- with fixed Itail
- as V_{ctrl} ↑, R_{on} ↑, fosc ↓
  V_{swing} ↑, min(V) ↓
  → driving PMOS into Sat.
  → small change in Reff
  → Kvco plot not well controlled
  → stability issue in PLL

→ Adjust tail current along with operating frequency

Adjust Tail Current with Operating Frequency (I)

- **To maintain constant oscillation swing**
  - Method #1

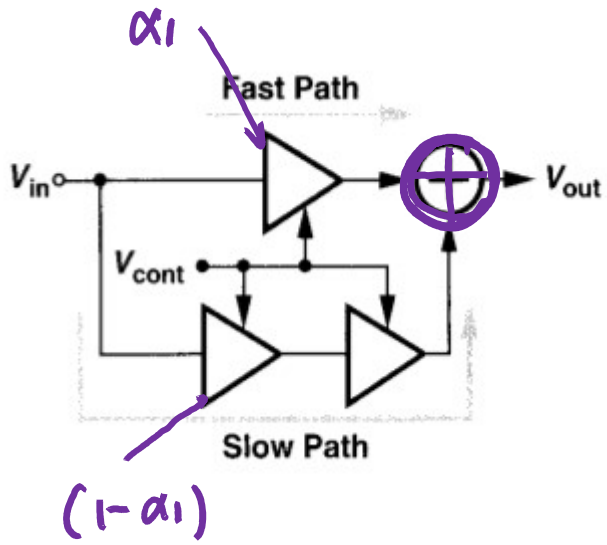


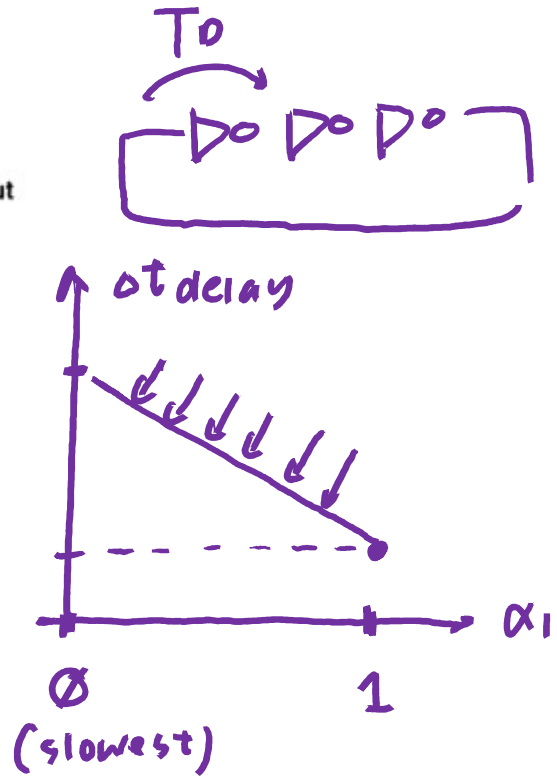
Adjust Tail Current with Operating Frequency (II)

- **To maintain constant oscillation swing**
  - Method #2

Delay Adjustment through Interpolation - based Method

- V_{cont} changes weighting of two paths with different delays

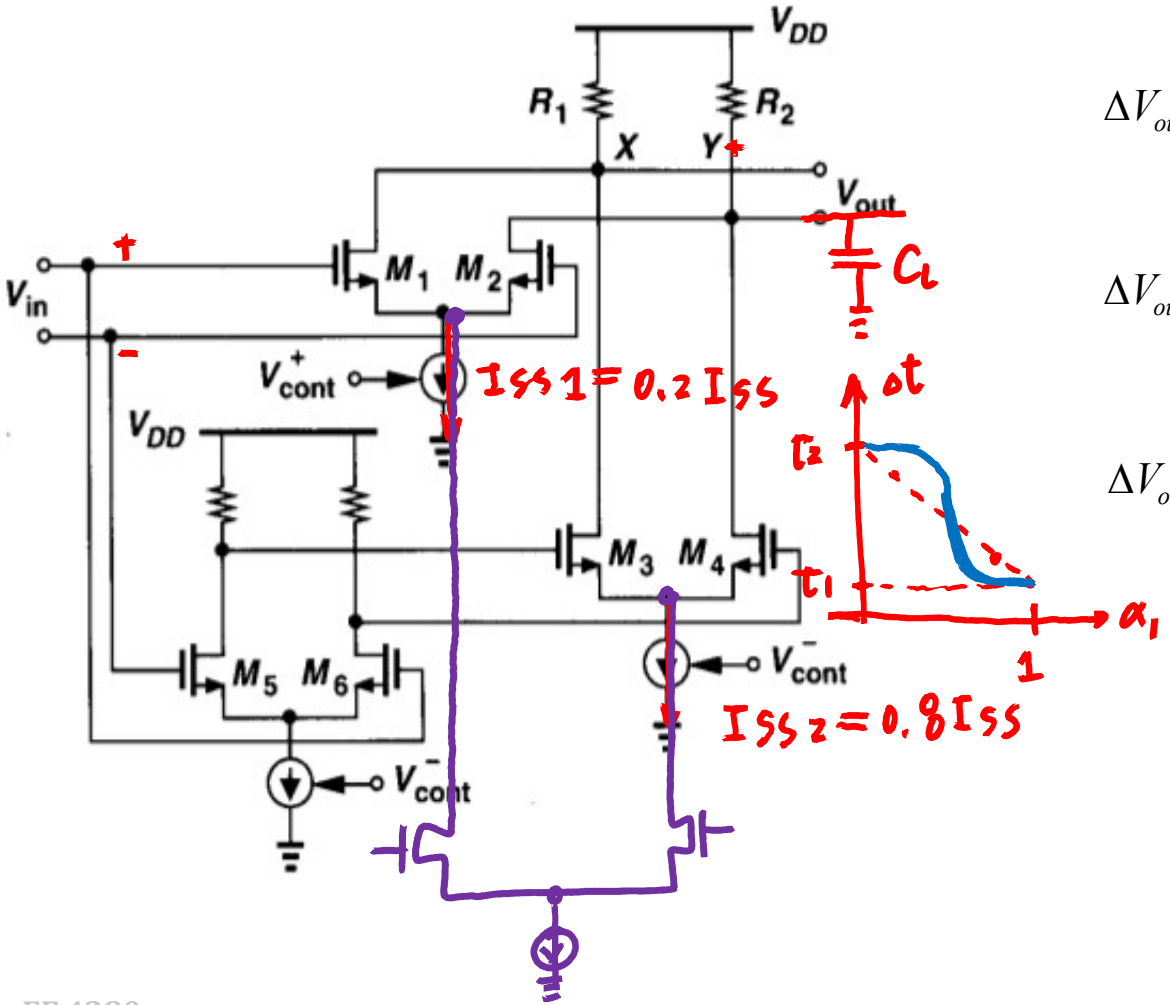


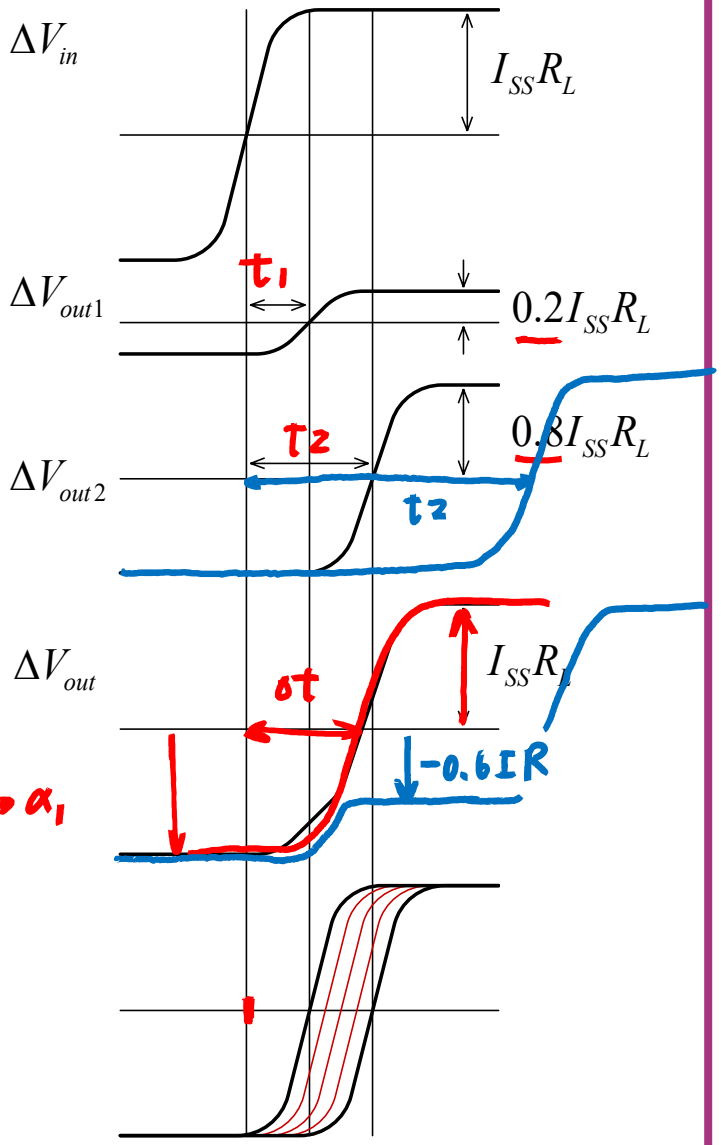


- Two paths with different delays
  - Multiple stages or different RC time constant
- Addition of two signals
  - In voltage or current domain
- To change weighting of two

A Possible Implementation of Interpolation

- Summation in current domain
- Weighting adjusted through tail current





Tail Current Adjustment with Constant Swing

- **Folded structure to save voltage headroom**