EE4280 Lecture 4:
Voltage-Controlled Oscillator

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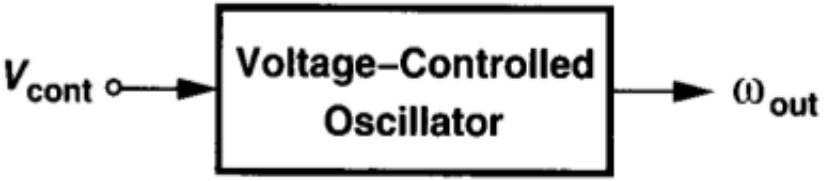
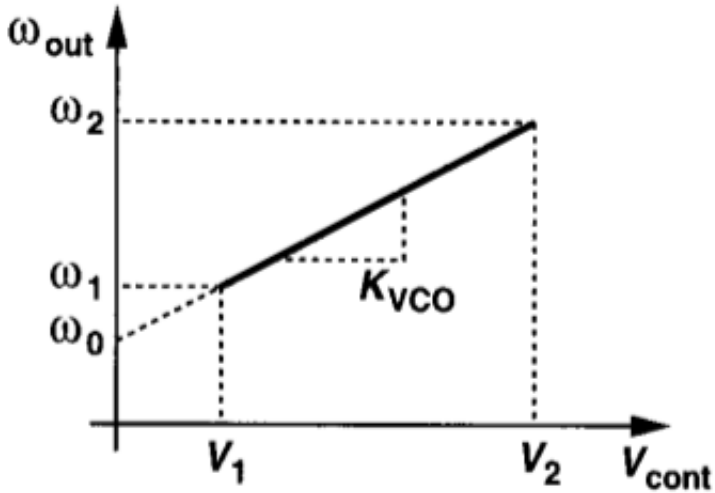
Voltage-Controlled Oscillator

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

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

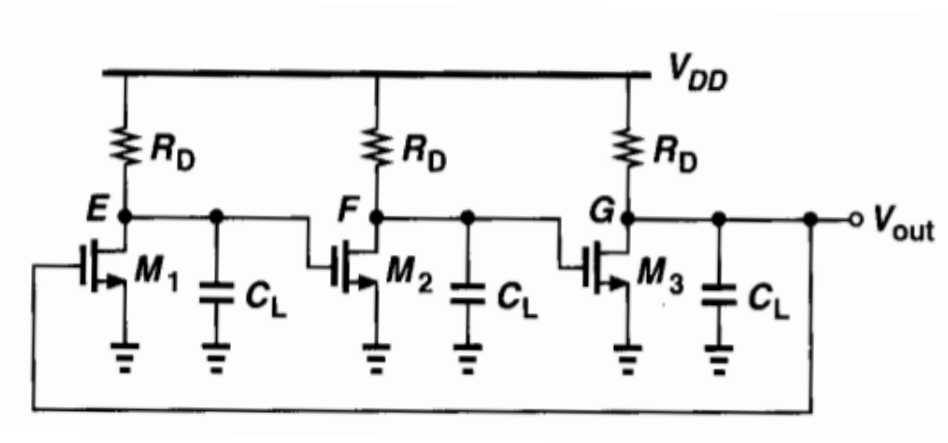
sensitivity, (VCO) gain





  - Center frequency
  - Tuning range
  - Linearity of transfer function
  - Output signal quality
    - Output amplitude
    - Frequency purity
    - Supply and common-mode rejection
  - Power dissipation

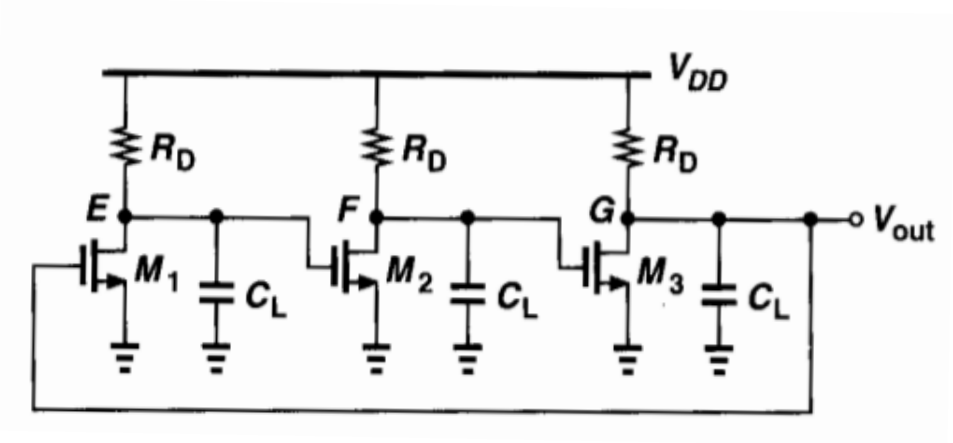
Tuning in Ring Oscillators

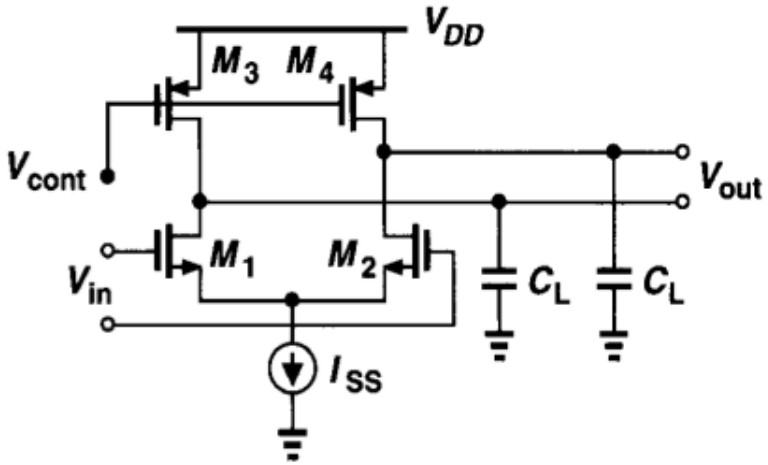


- **The operating frequency**
  - $\sqrt{3}/2\pi RC$ for small-signal operation
  - $1/6T_D$ for large-signal, nonlinear operation

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

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**

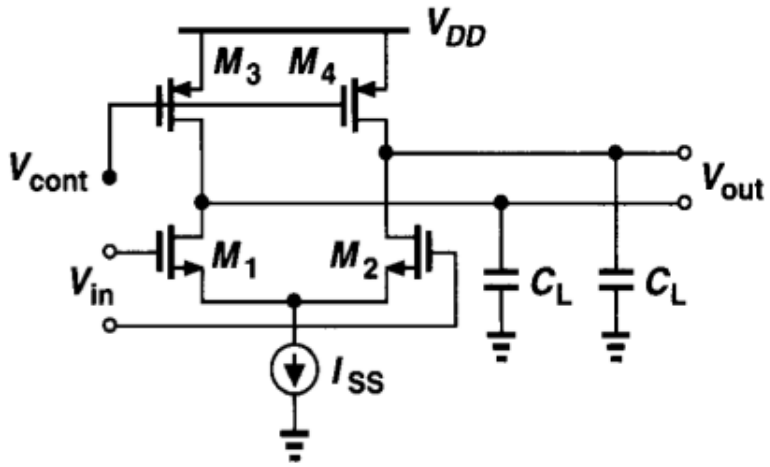
- Resistive load implemented with PMOS operating in triode region

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

Resistive Load with PMOS in Triode Region

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

→ Differential swing of



→ Adjust tail current along with operating frequency

Adjust Tail Current with Operating Frequency (I)

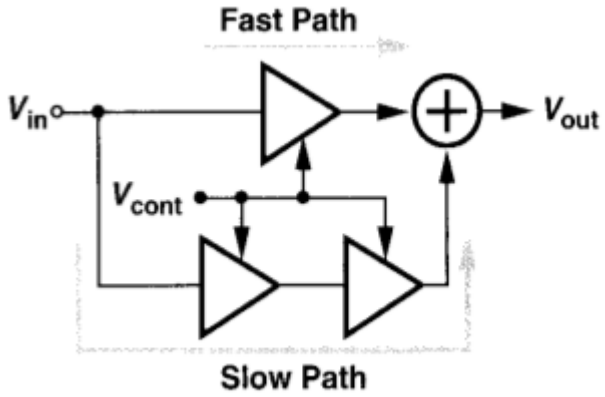
- **To maintain constant oscillation swing**
  - Method #1

Adjust Tail Current with Operating Frequency (II)

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

Delay Adjustment through Interpolation

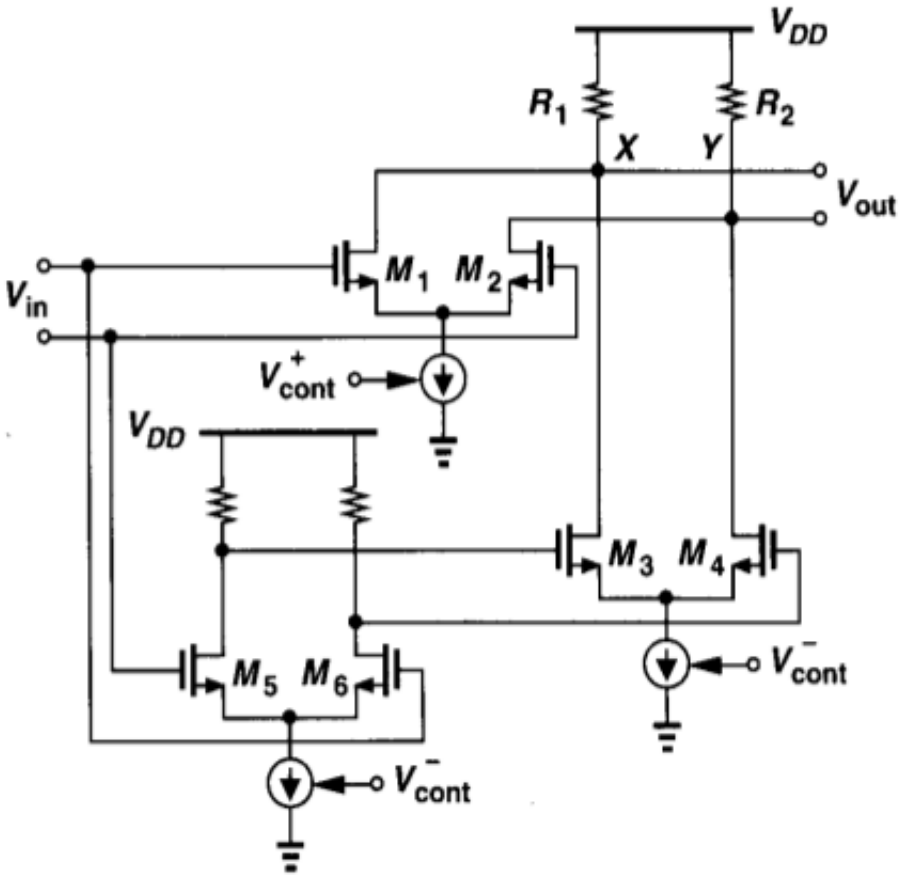
- **V_{cont} changes weighting of two paths with different delays**

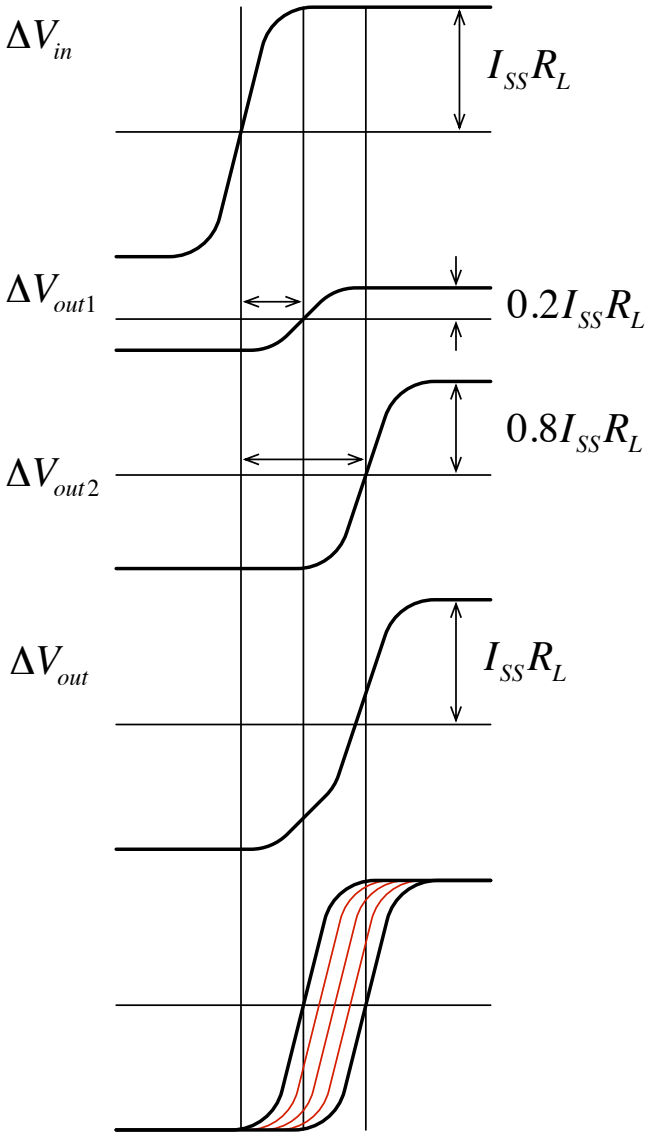


- Two paths with different delays
  - Multiple stages or different RC time constant
- Addition of two signals
  - In voltage or current domain
- To change weighting of two

A Possible Implementation of Interpolation

- Summation in current domain
- Weighting adjusted through tail current



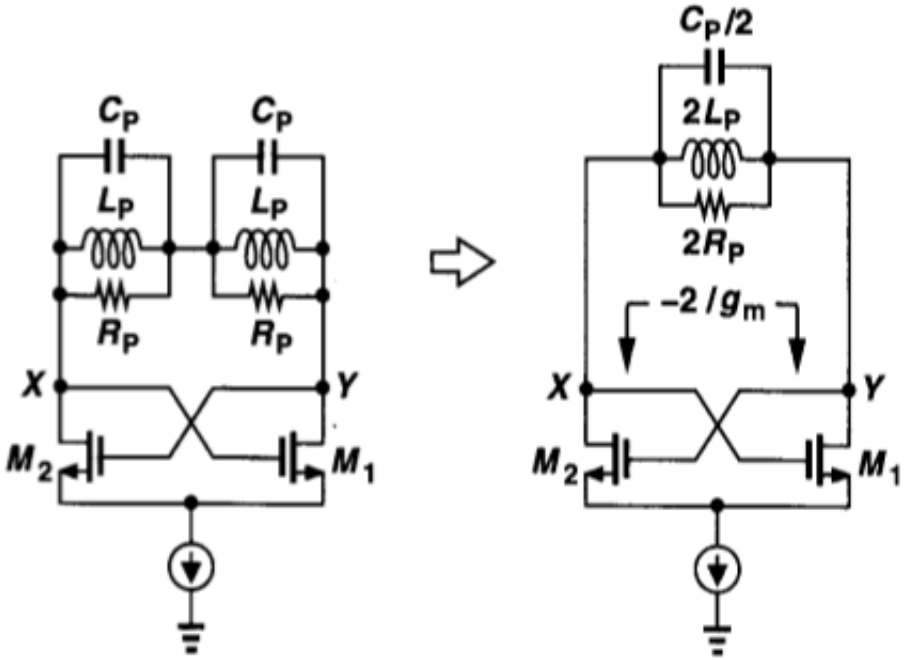


Tail Current Adjustment with Constant Swing

- **Folded structure to save voltage headroom**

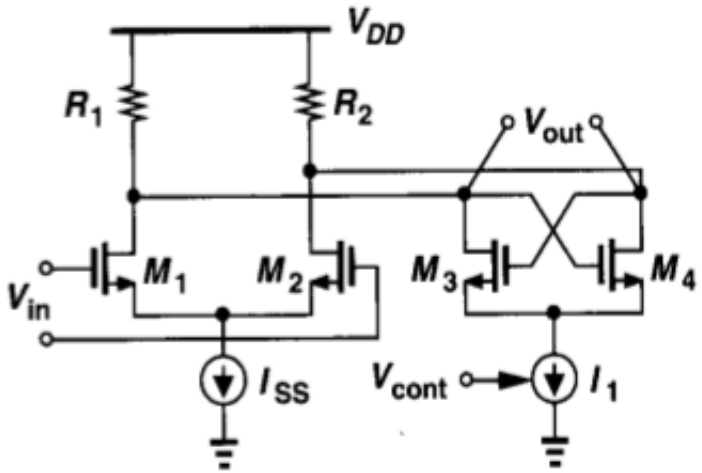
Negative Resistance from Positive Feedback

- **Cross-coupled transistor pair exhibits a negative resistance**
  - Single-ended (half-circuit) of
  - Differential resistance of



Delay Variation by Positive Feedback (I)

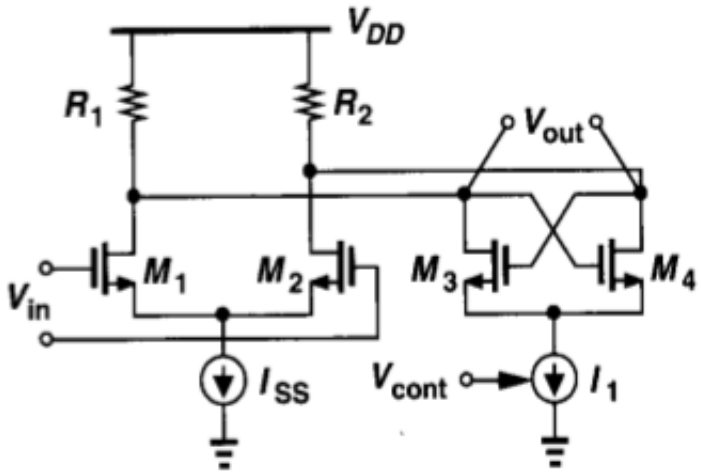
- A negative resistance $-R_N$ in parallel with the load R_P



- As V_{cont} increases ➔ positive feedback

Delay Variation by Positive Feedback (II)

- To maintain a constant swing across the tuning range



- To avoid turning off M_1 and M_2
- Trade-off between voltage headroom and linear range and K_{VCO}