OSCILLATORS
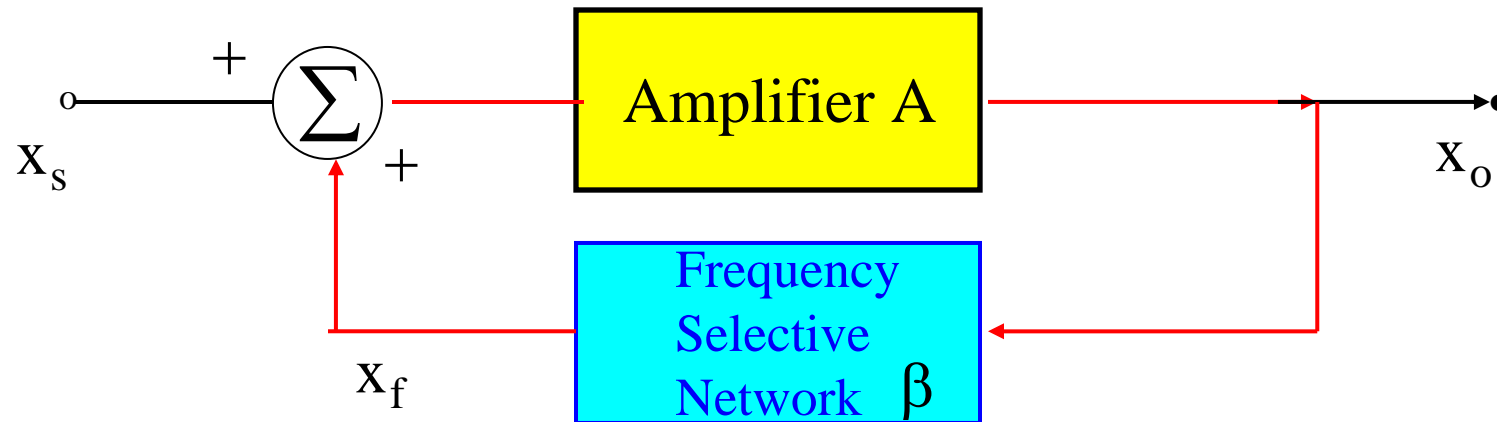
Fundamentals. Linear Aspects: Oscillation conditions.

$$A_f = \frac{x_o}{x_s} = \frac{A}{1-\beta A} = \frac{A(s)}{1-\beta(s)\, A(s)}$$
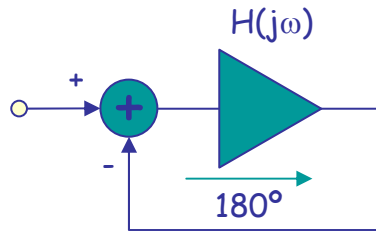
$$D(s) = 1 - \beta(s)\, A(s) = 1 - L(s)$$

$$L(j\omega_o) \triangleq A(j\omega_o)\, \beta(j\omega_o) = 1 \qquad \textbf{Barkhausen Criteria}$$

Note that for the circuit to oscillate at one frequency the oscillation criterion should be satisfied at one frequency only; otherwise the resulting waveform will not be a simple sinusoid.
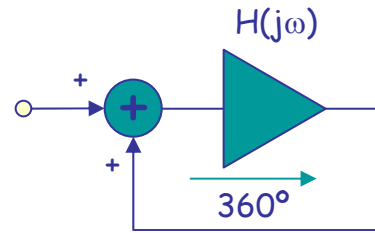
Ring Oscillators

- The main difficulty for using submicron CMOS ring oscillators in wireless communication systems is their relatively poor phase noise response.

- Precaution is required to achieve as low phase noise as possible from CMOS ring oscillators.

  – Dominant noise sources in IC environment are common-mode signals in nature (e.g. power supply noise, substrate-coupled noise).
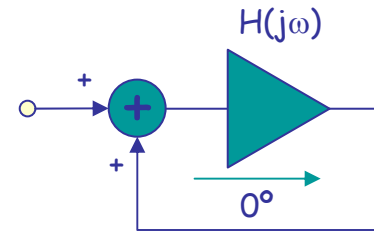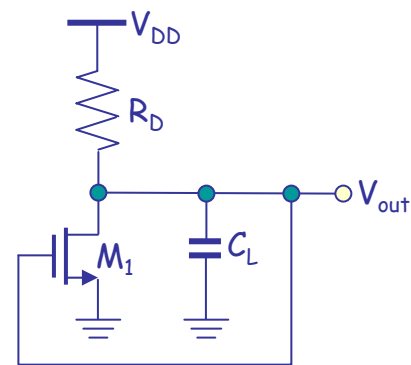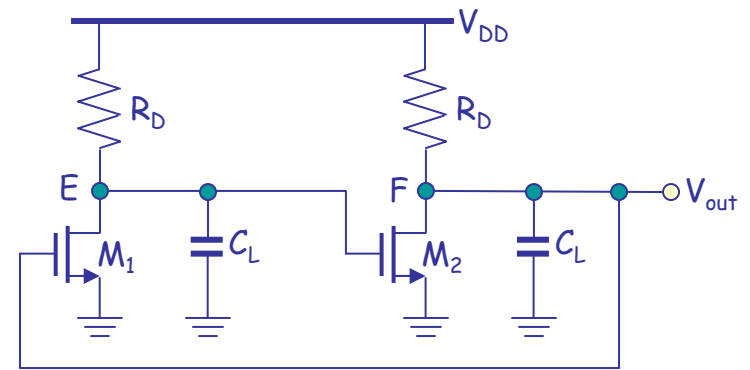
    - Fully differential design is a must!

Courtesy of Fikret Dulger

Ring Oscillators

H(jω)

+ − 180°

(a)

H(jω)

+ + 360°

(b)

H(jω)

+ + 0°

(c)

Various views of oscillatory feedback system.

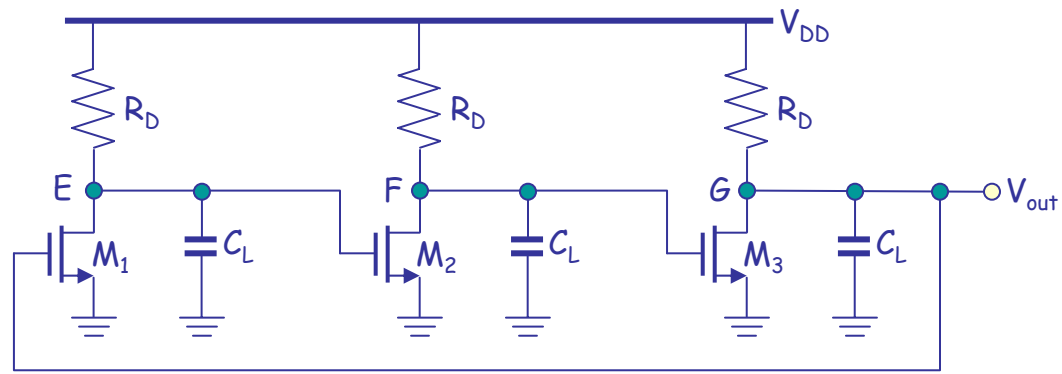V_{DD}

R_D

V_{out}

M_1 C_L

One-pole feedback

V_{DD}

R_D R_D

E   F V_{out}

M_1 C_L M_2 C_L

Two-pole feedback system

V_{DD}

R_D R_D

E   F   Ideal −1 V_{out}

M_1 C_L M_2 C_L
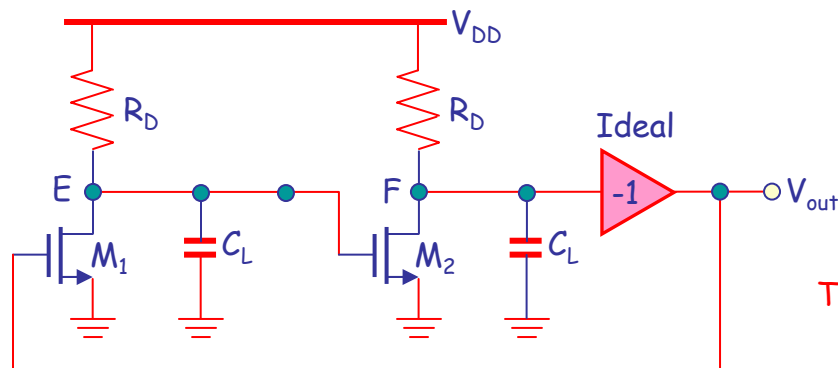
Two-pole feedback system plus an inverter

Three-stage ring oscillator

$$H(s) = -\frac{A_0^3}{\left(1 + \dfrac{s}{\omega_0}\right)^3}$$
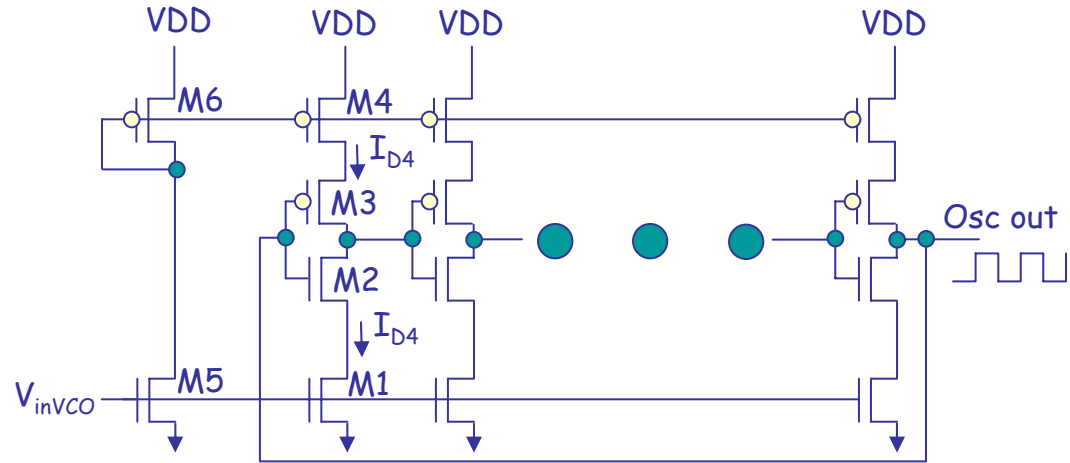
$$\omega_{osc} = \sqrt{3}\,\omega_0$$

$$\tan^{-1}\frac{\omega_{osc}}{\omega_o} = 60°$$

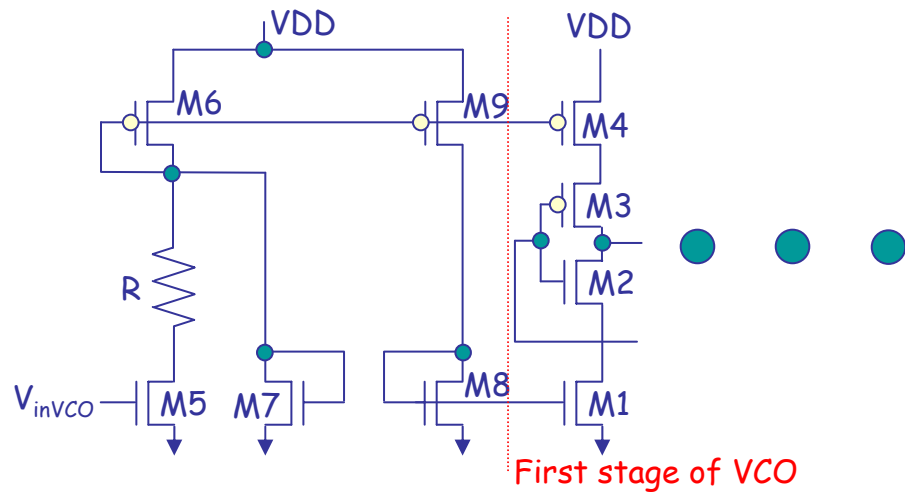$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{\dfrac{-A_0^3}{(1 + s/\omega_0)^3}}{1 + \dfrac{A_0^3}{(1 + s/\omega_0)^3}} = \frac{-A_0^3}{(1 + s/\omega_0)^3 + A_0^3}$$

$$\frac{A_0^3}{\left[\sqrt{1 + \left(\dfrac{\omega_{osc}}{\omega_0}\right)^2}\,\right]^3} = 1$$
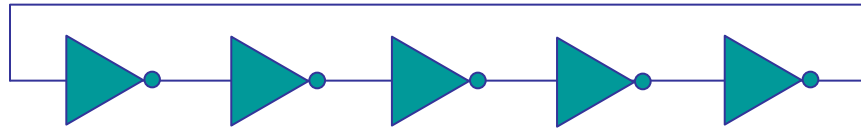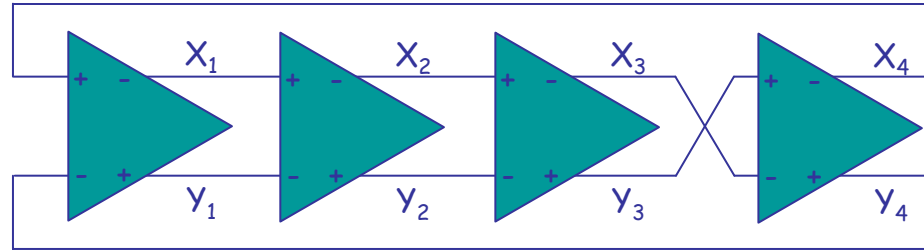
$$A_0 = 2$$

Single –ended Inverters
(delay elements)

Current – starved VCO.

First stage of VCO

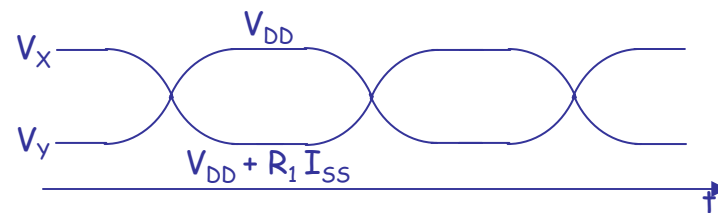Modifications to the current-starved VCO to set minimum and maximum frequencies.
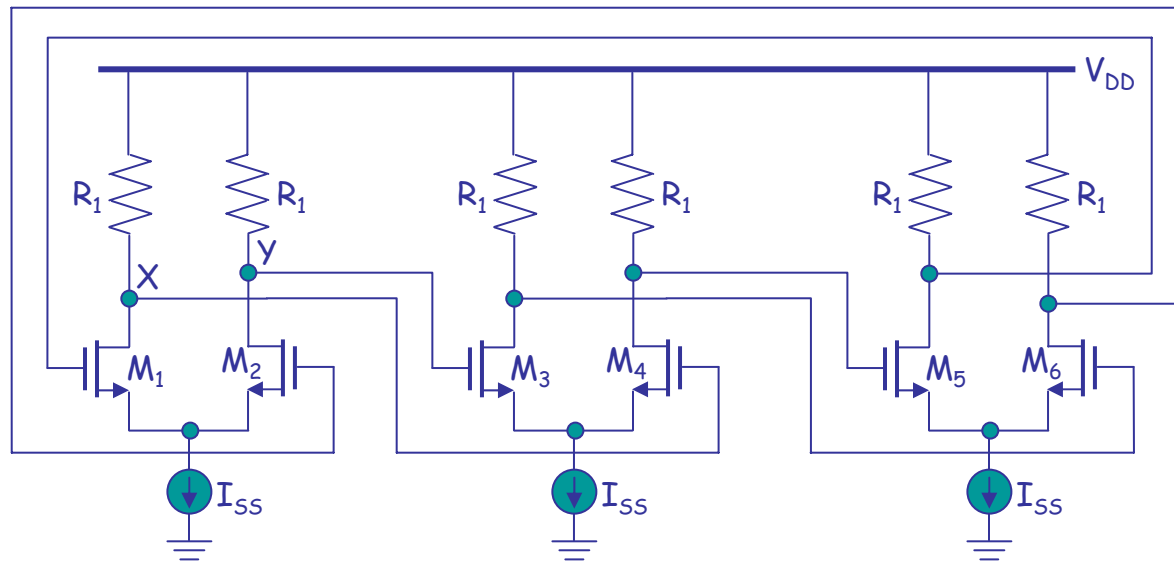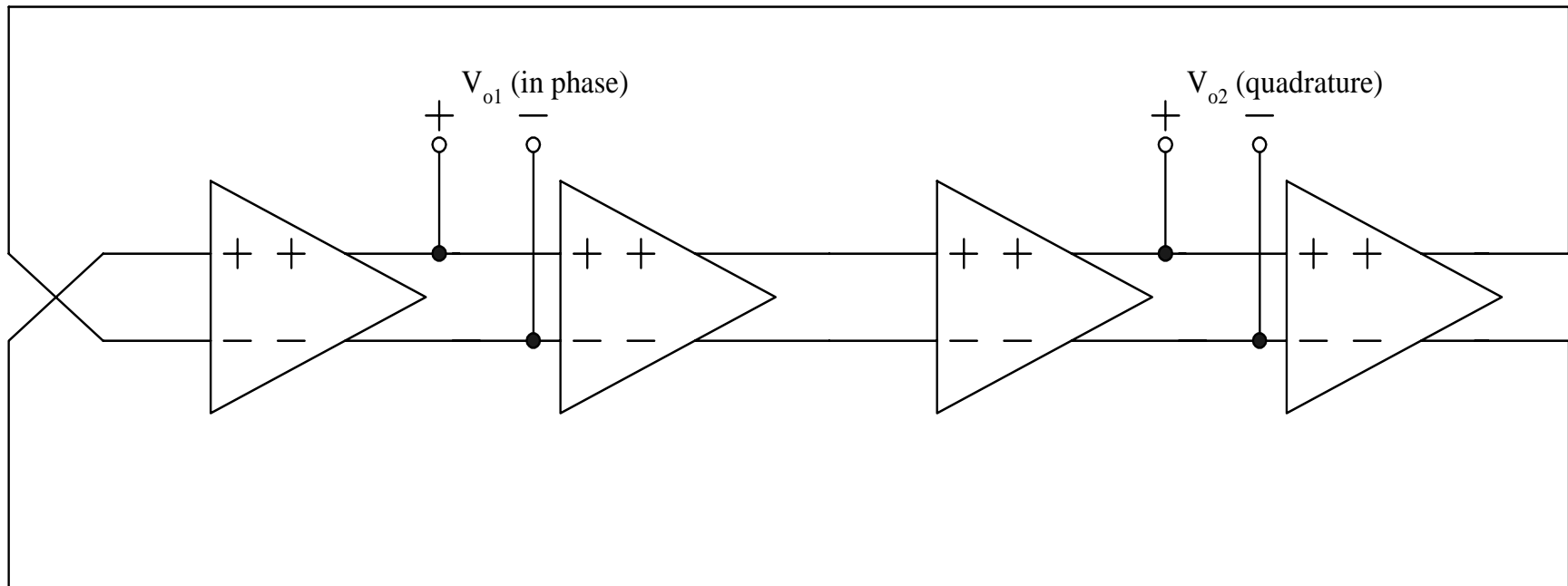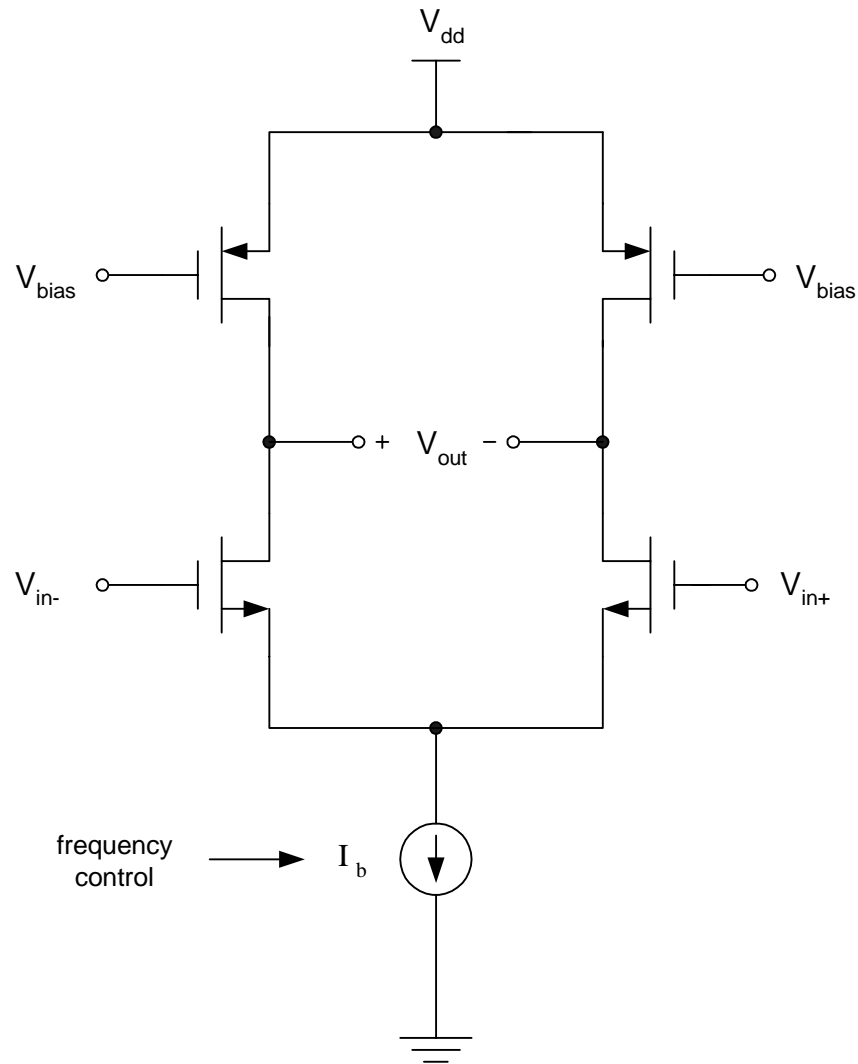
(a)

(b)

(a) Five-stage single-ended ring oscillator, (b) four-stage differential ring oscillator
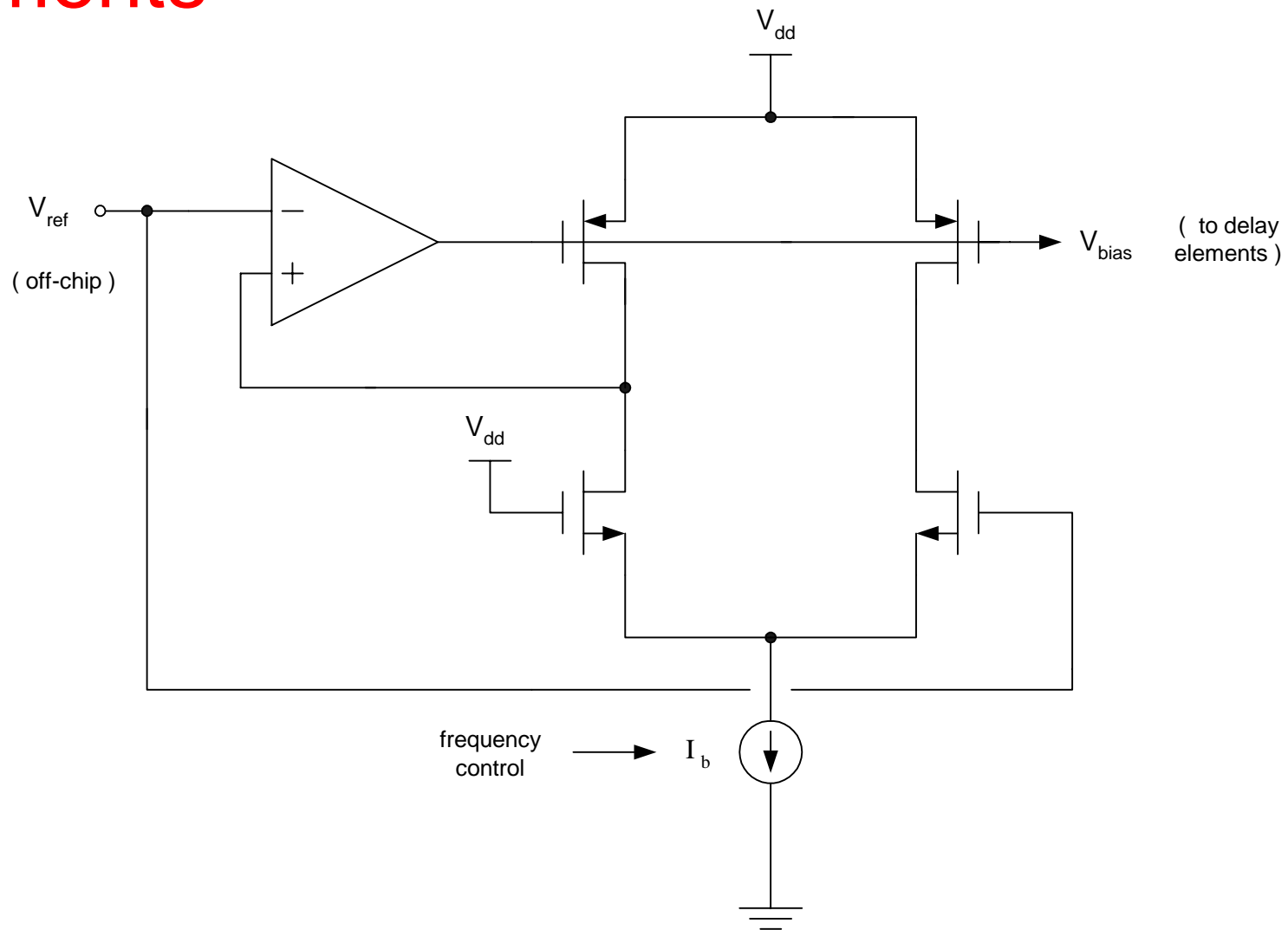
Fully-Differential Ring Oscillator

One potential delay element

# Replica Biasing needed for the Delay Elements

Frequency Control

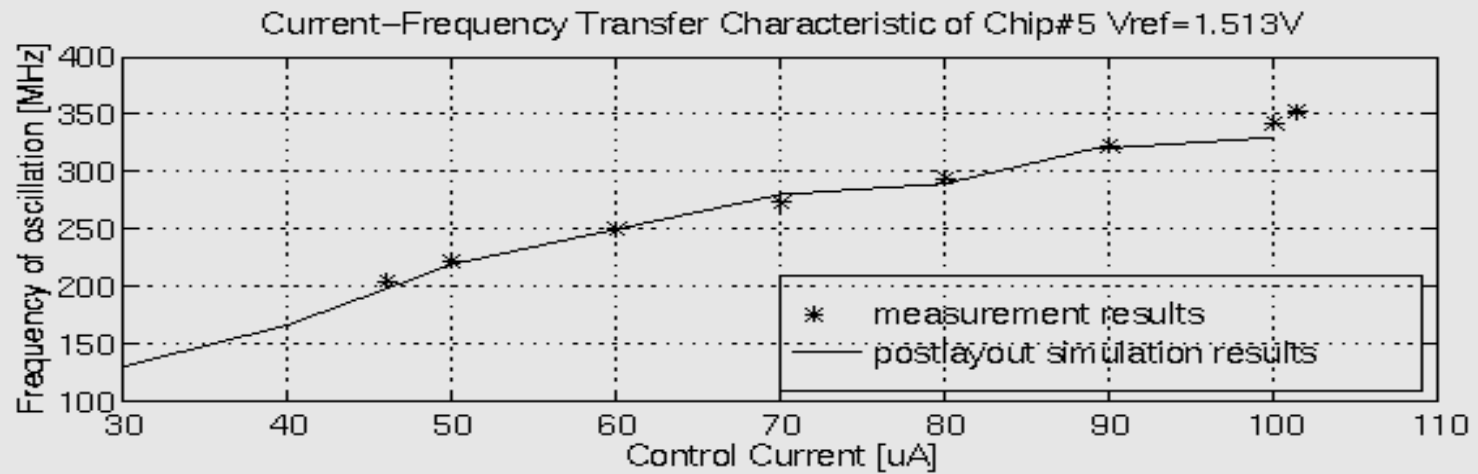- Frequency of oscillation, (f_{osc}), is controlled through the bias current of a delay element (I_b).

- Maximum peak-to-peak voltage, (V_{pp}), is controlled through the replica biasing.

- Total output capacitance of a delay element, (C_{out}), directly affects the frequency of oscillation.
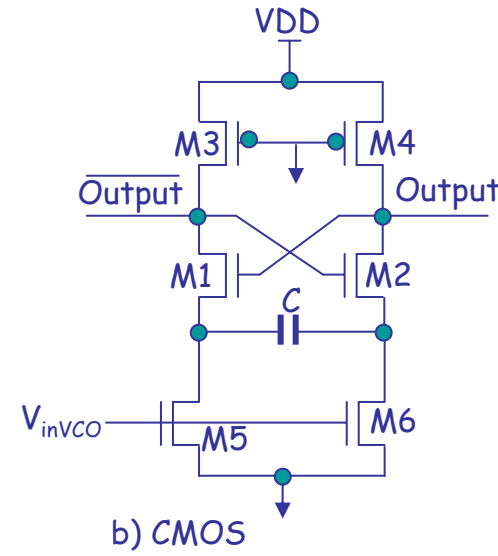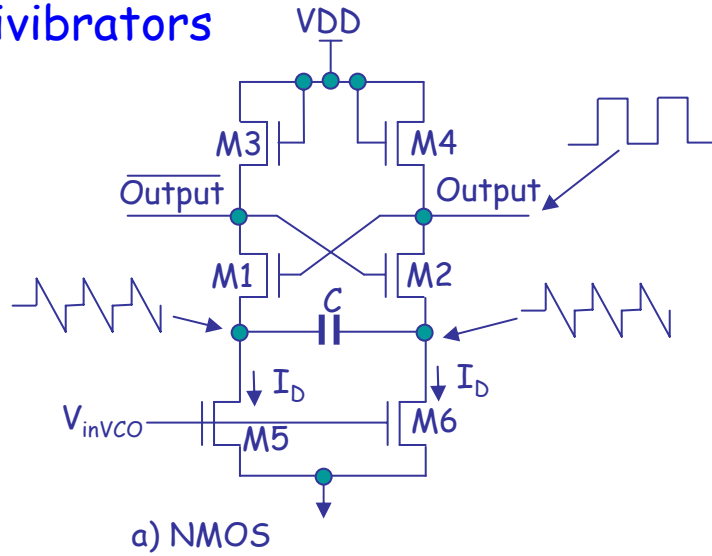
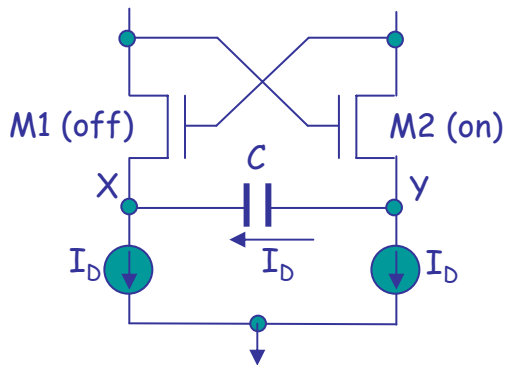$$f_{osc} \approx \frac{I_b}{V_{pp} \cdot C_{out}}$$
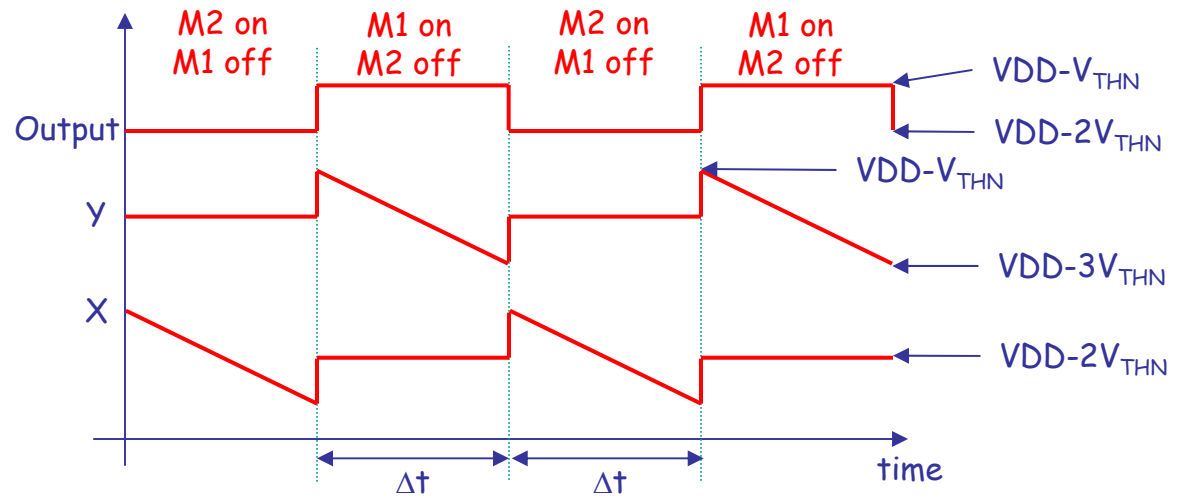
Chip Photomicrograph
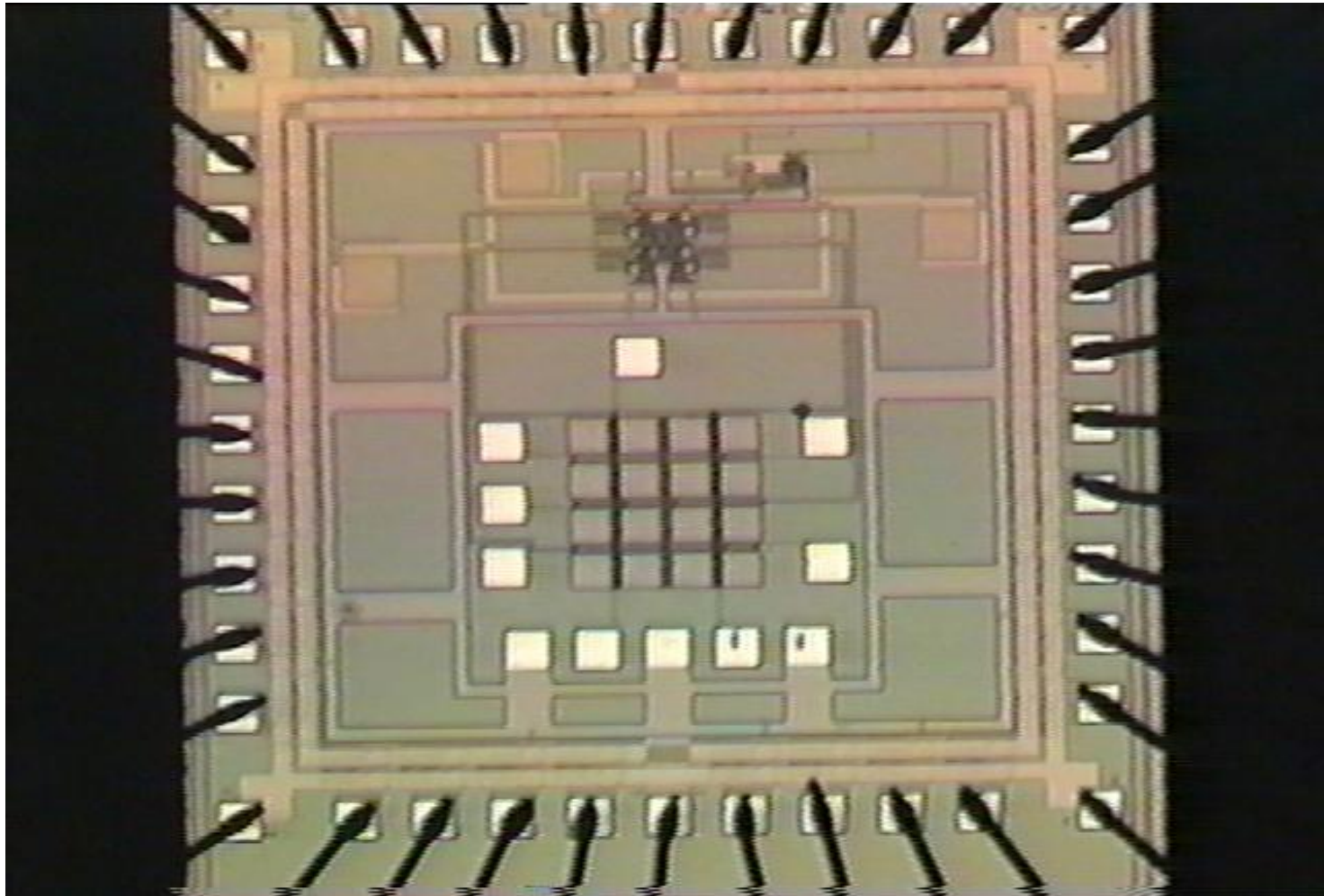
Test Results

Coupled Multivibrators

a) NMOS
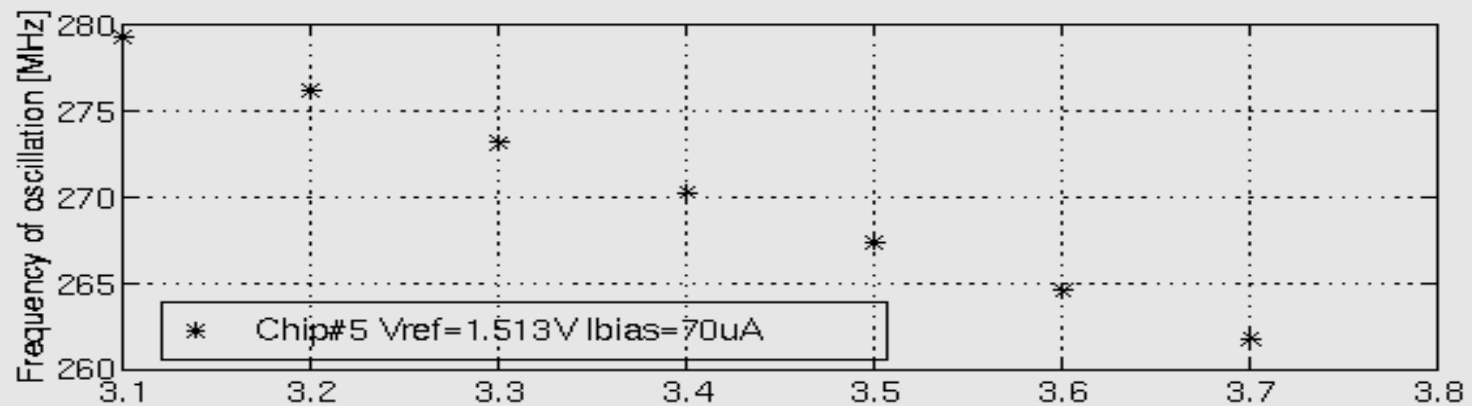
b) CMOS

Source coupled voltage-controlled oscillators (also known as source coupled multivibrators).

Simplified schematic of source coupled oscillator, M1 is on and M2 is off.

Voltage waveforms for the NMOS source coupled VCO.