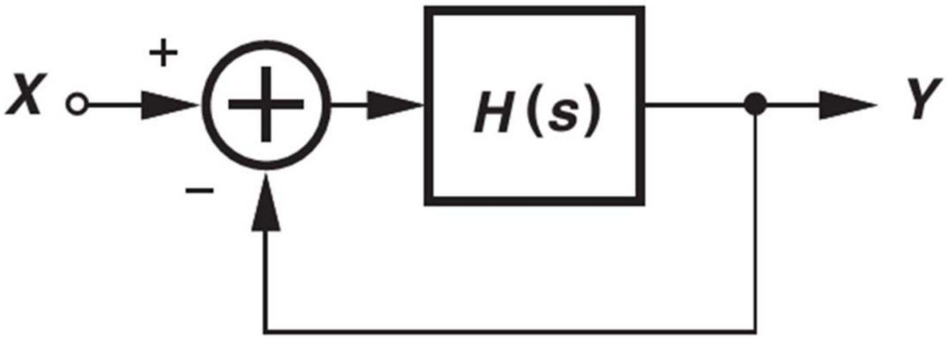
High-Speed Serial Interface Circuits and Systems

Lect. 2 – Ring Oscillators

Oscillator: A device undergoing periodic changes in certain physical quantities

Our interests: MOS circuits that oscillate

Consider a negative feedback system



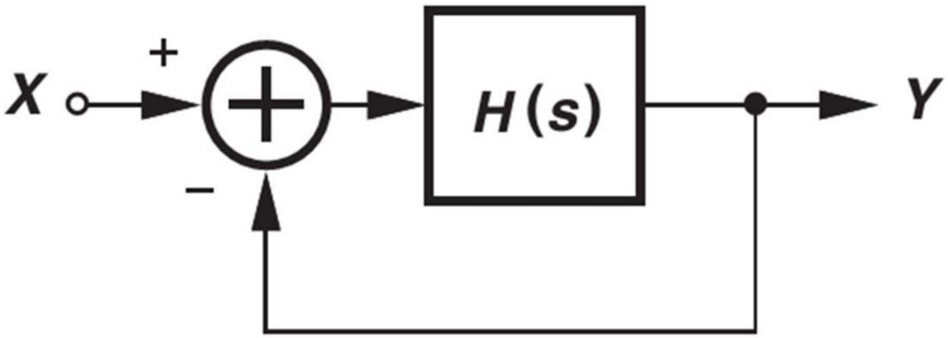
$$\frac{Y}{X}(s)=\frac{H(s)}{1+H(s)}$$

What happens when $H(j\omega) = -1$?

➔ Unstable

➔ Output without input?

➔ Oscillation at ω



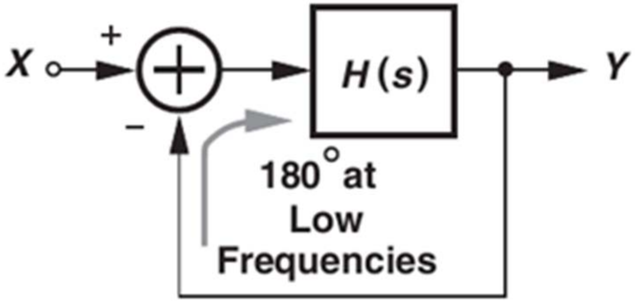
$$\frac{Y}{X}(s) = \frac{H(s)}{1 + H(s)}$$

Barkhausen oscillation condition: $|H(j\omega)| = 1$ and $\angle H(j\omega) = 180^{\circ}$

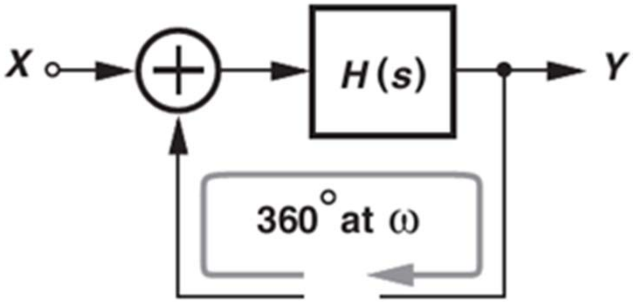
Heinrich Barkhausen (1881-1956)

German
physicist / electrical engineer

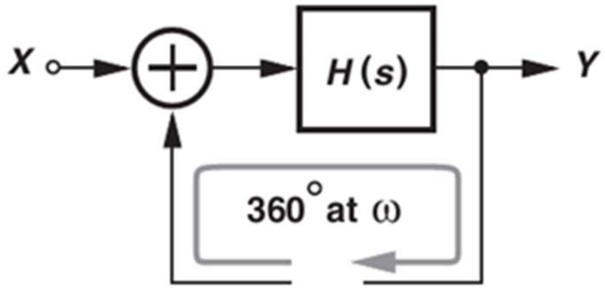
Invented first vacuum tube
electronic oscillator in 1920



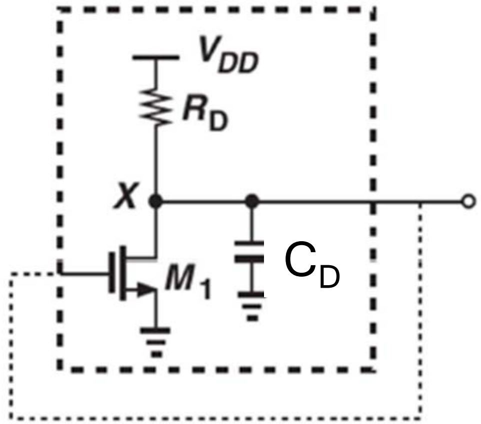
Barkhausen oscillation criterion:
$|H(j\omega)| = 1$ and $\angle H(j\omega) = 180^\circ$



➔ in phase and same magnitude after one round trip

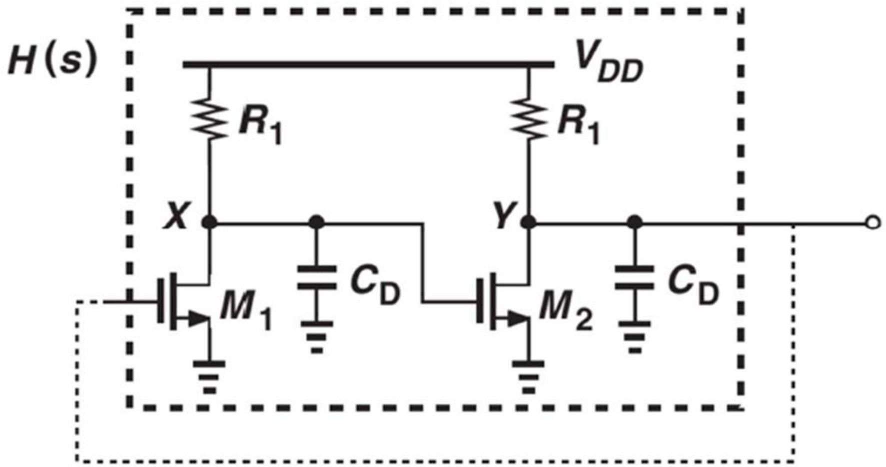


Oscillation:
in phase and same magnitude after one round trip

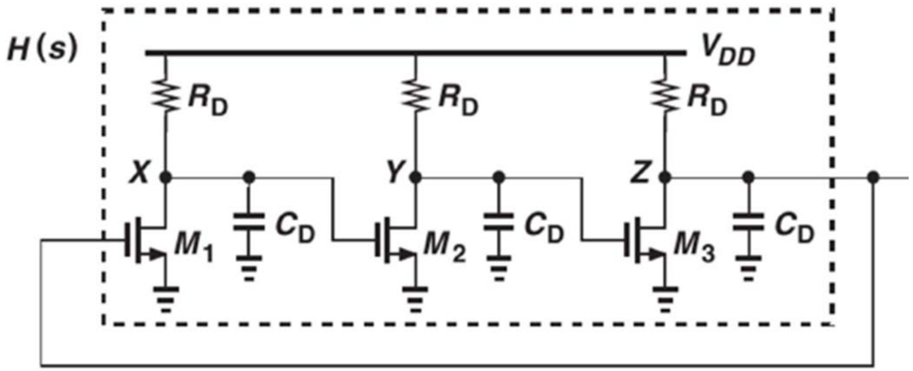


C_D represents all capacitive elements

Oscillation?



Oscillation?



$$H(j\omega) = -\left(\frac{g_m R_D}{1 + j\omega R_D C_D}\right)^3$$

Ring oscillator

$$\angle\left(\frac{g_m R_D}{1 + j\omega R_D C_D}\right)^3 = -\pi$$

$$-3\tan^{-1}(\omega R_D C_D) = -\pi$$

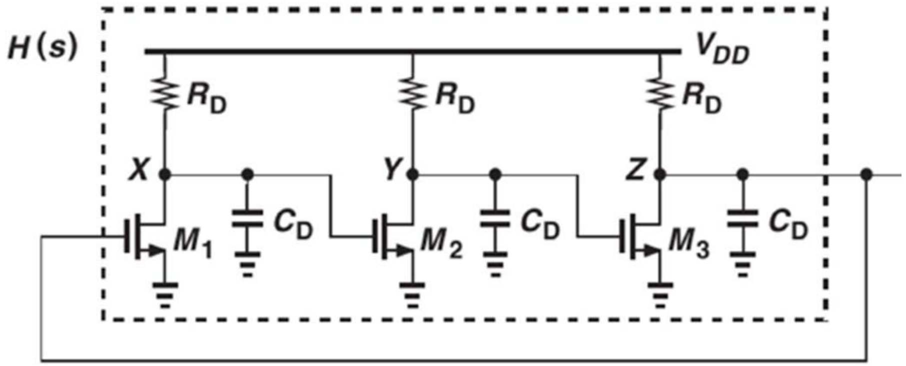
$$\omega R_D C_D = \tan\left(\frac{\pi}{3}\right) = \sqrt{3}$$

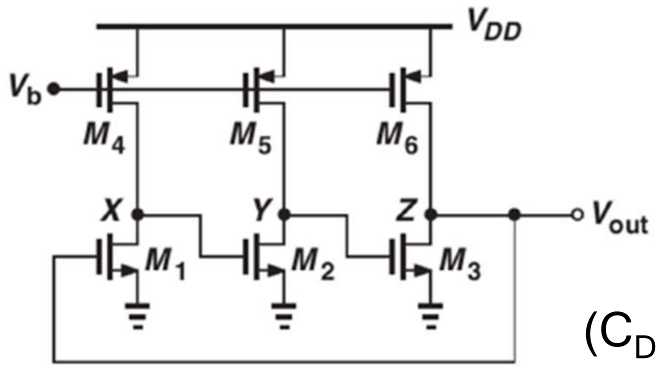
$$\therefore \omega = \frac{\sqrt{3}}{R_D C_D}$$

$$\left|H(j\omega)\right|^3 = 1$$

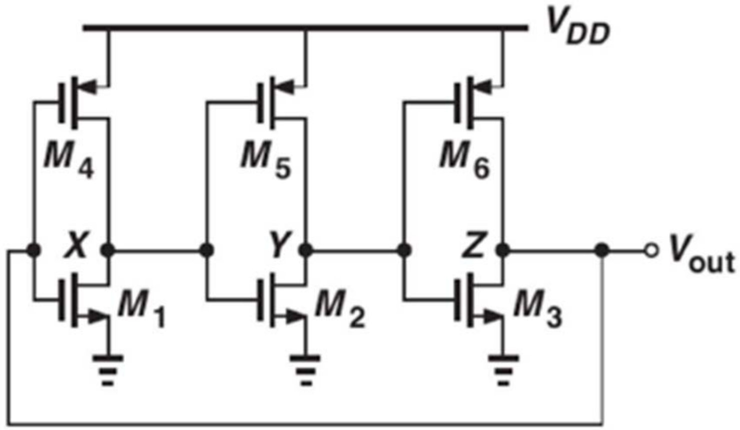
$$\left|H(j\omega)\right|^2 = \frac{(g_m R_D)^2}{1 + (\omega R_D C_D)^2} = \frac{(g_m R_D)^2}{1 + 3} = 1$$

$$\therefore g_m R_D = 2$$





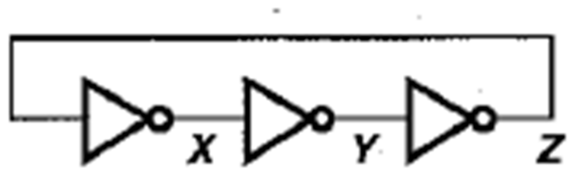
(C_D not shown)



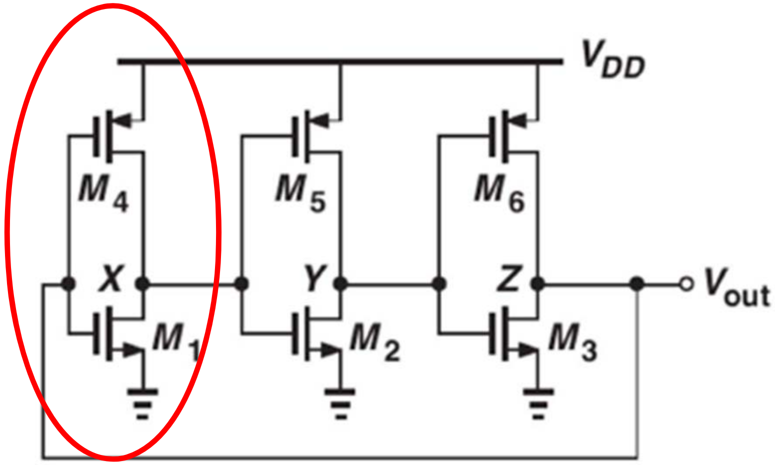
➔ CMOS inverter

Gain for each stage

$$A_v = \left(g_{m1} + g_{m2}\right)\left(r_{0n} \parallel r_{0p}\right)$$

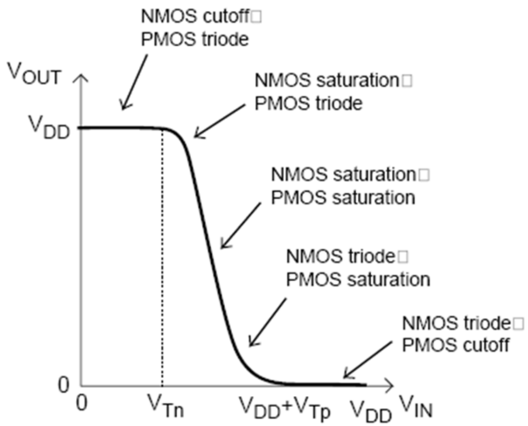


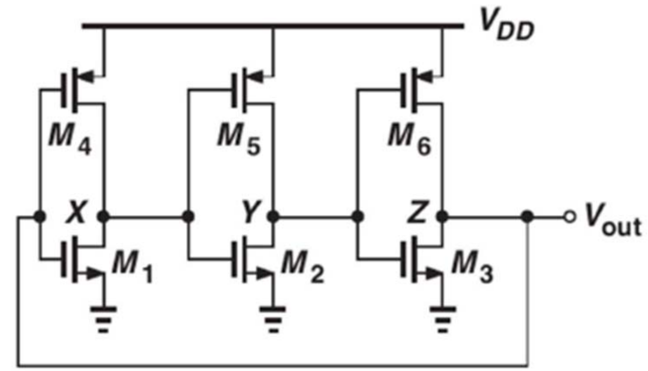
Without any input, what initiates oscillation?

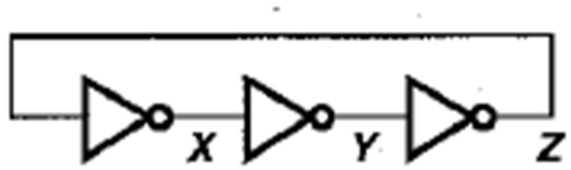


How large is the oscillation?

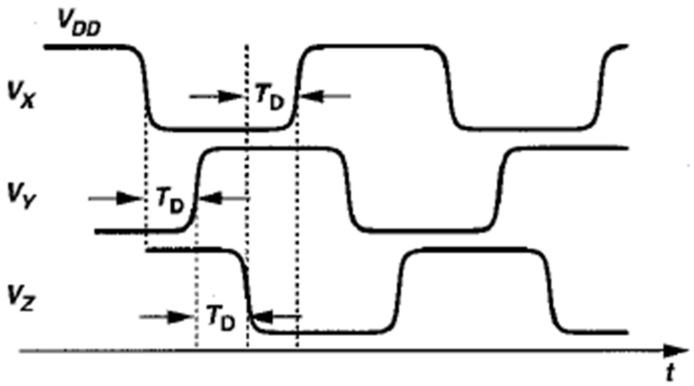
➔ Large signal analysis







Oscillation frequency with large-signal analysis?

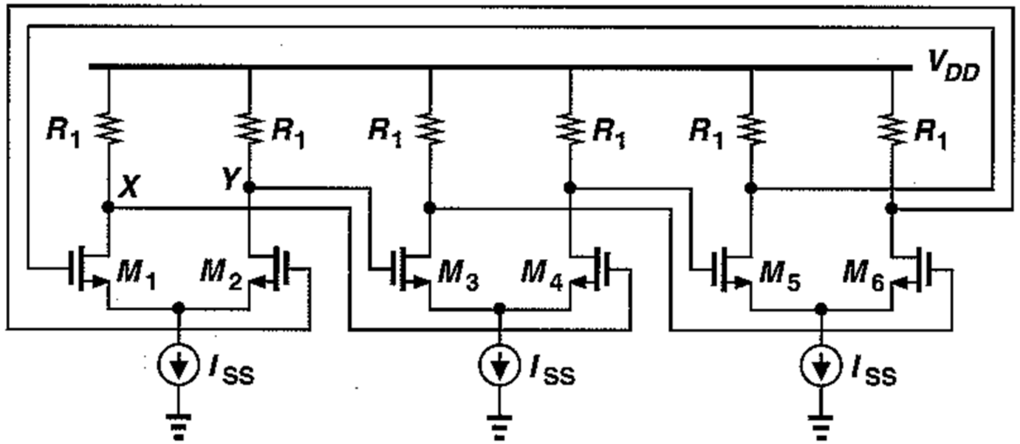


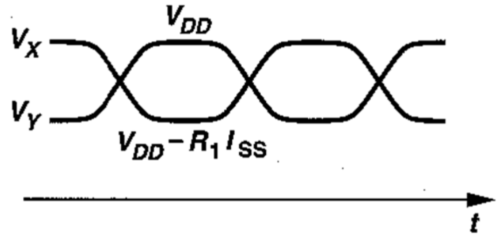
T_D: Time delay between input and output:

$$f_{osc} = 1 / (2 \times N \times T_D)$$

Requirement for N ?

Differential amplifier for ring oscillator

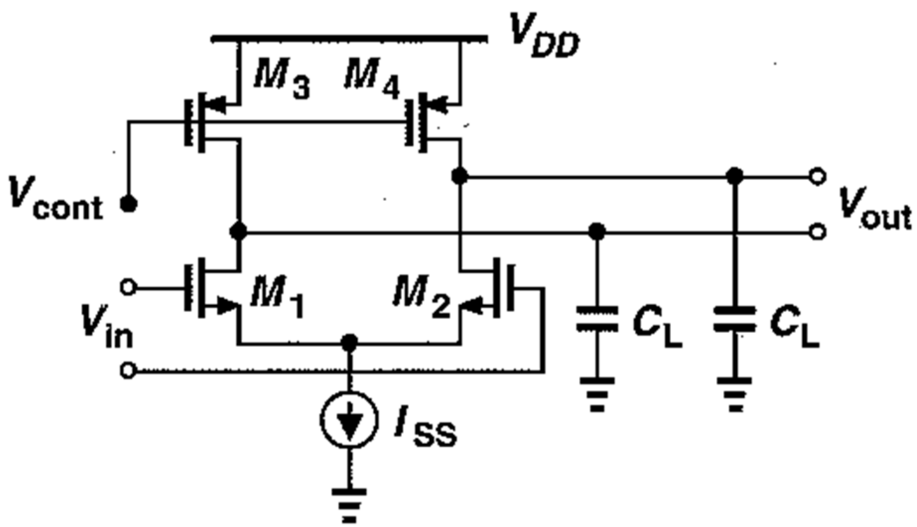




Can be faster than CMOS inverter chain but consumes more power

Even-number stage possible

How can we control oscillation frequency with voltages?
(Voltage-Controlled Oscillator: VCO)



➔ Design Exercise