EE230-02 RFIC II
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Lecture 13: Oscillators 2

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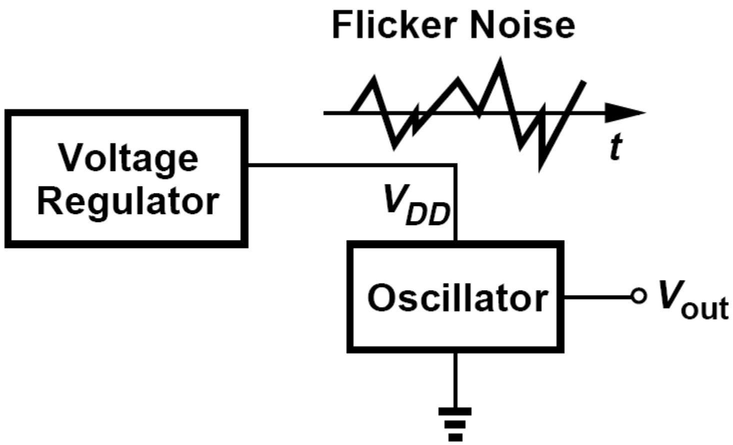
Performance Parameters: Supply Sensitivity & Power Dissipation

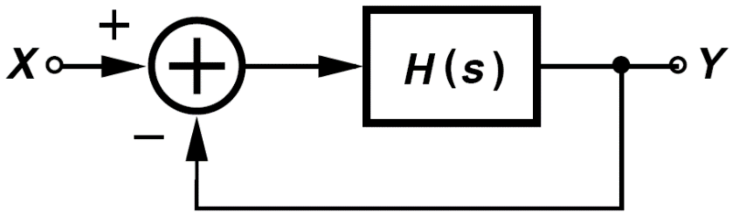
- The frequency of an oscillator may vary with the supply voltage, an undesirable effect because it translates supply noise to frequency (and phase) noise.



- The power drained by the LO and its buffer(s) proves critical in some applications as it trades with the phase noise and tuning range.

Feedback View of Oscillators

- An oscillator may be viewed as a “badly-designed” negative-feedback amplifier—so badly designed that it has a zero or negative phase margin.

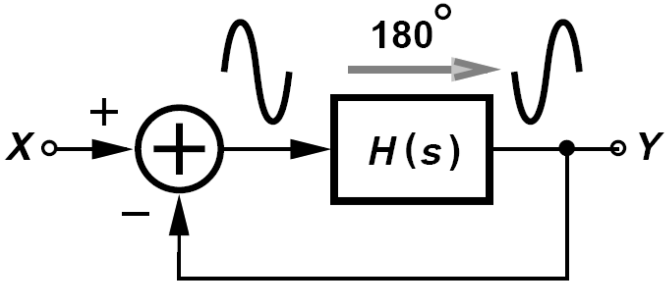


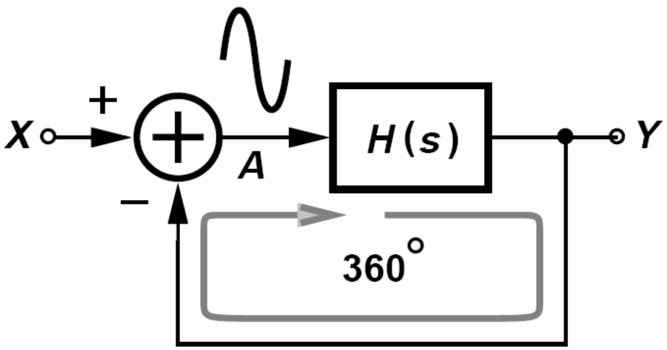
$$\frac{Y}{X}(s) = \frac{H(s)}{1 + H(s)}$$

Barkhausen's Criteria

$$|H(s = j\omega_1)| = 1$$

$$\angle H(s = j\omega_1) = 180^\circ$$

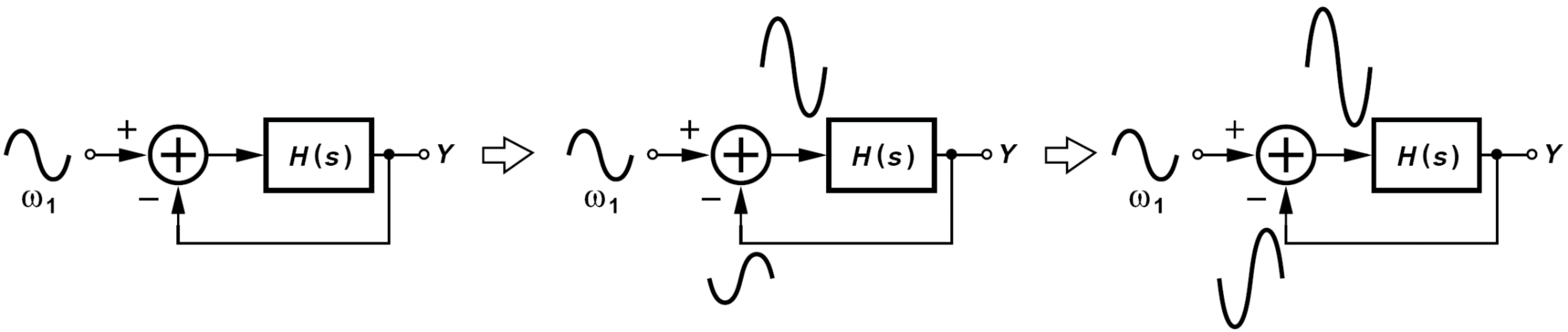




- **For an Oscillation, the signal returning to A must exactly coincide with the signal that started at A.**
- **Requires 180º Phase Shift through H(s).**
- **This additional phase shift of 180º along with the original negative feedback turns into a positive feedback at ω_1, at this frequency.**

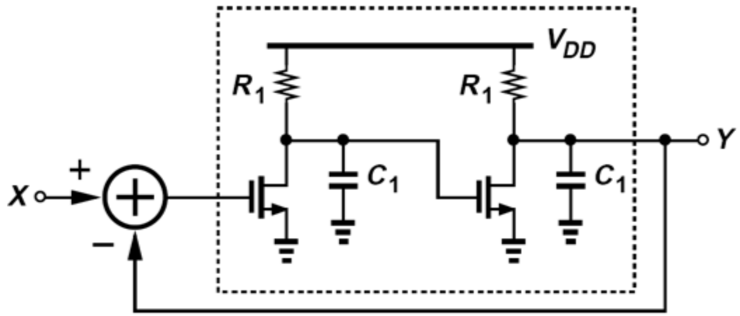
Significance of |H(jw1)| = 1

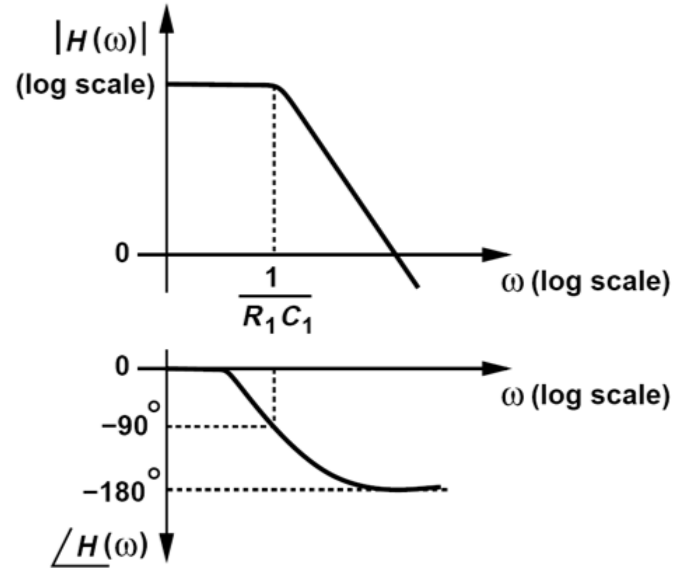
- For a noise component at ω_1 to "build up" as it circulates around the loop with positive feedback, the loop gain must be at least unity.
- We call $|H(j\omega_1)| = 1$ the "startup" condition.



Can a Two-Pole System Oscillate? (I)

Can a two-pole system oscillate?



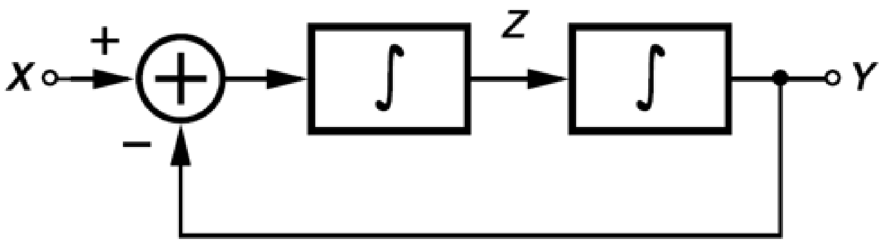


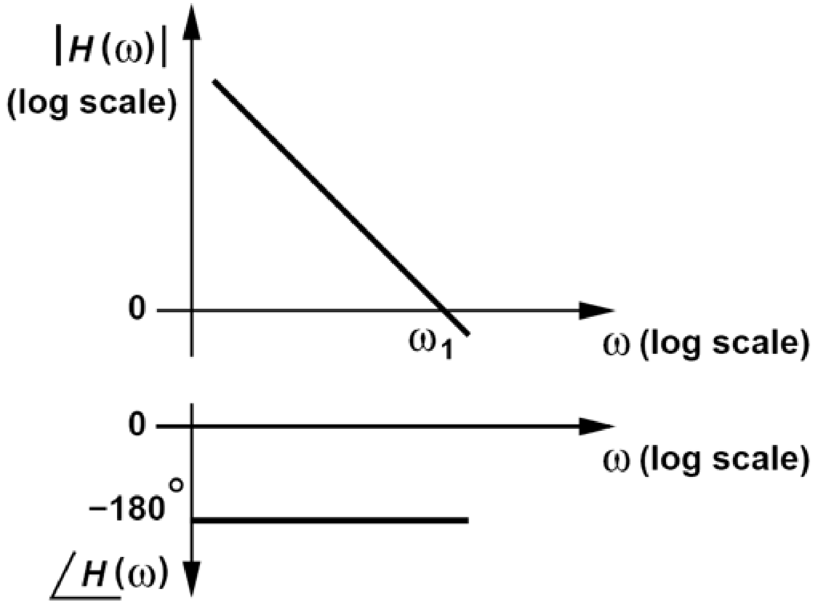
- Two coincident real poles at $\omega_p = (R_1C_1)^{-1}$.
- Cannot satisfy both of Barkhausen's criteria because the phase shift associated with each stage reaches 90^o only at $\omega = \infty$, but $|H(\infty)| = 0$.
- Bode plots $|H|$ and $\angle H$ reveal no frequency at which both conditions are met.
- Thus, the circuit cannot oscillate.

Can a Two-Pole System Oscillate? (Ⅱ)

Can a two-pole system oscillate?

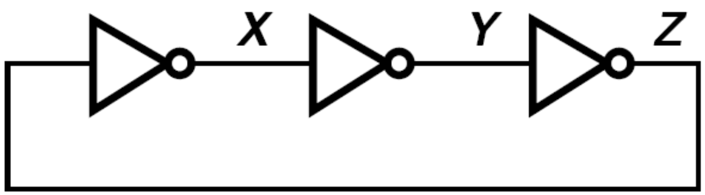
- But, what if both poles are located at the origin?
- Realized as two ideal integrators in a loop, such a circuit does oscillate because each integrator contributes a phase shift of -90º at any nonzero frequency.

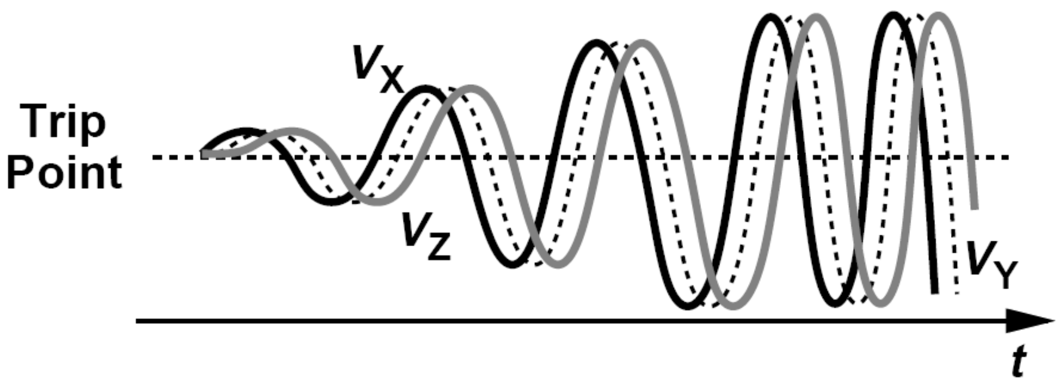




Ring Oscillator

- Other oscillators oscillate at a frequency at which the loop gain is higher than unity, thereby experiencing an exponential growth in their output amplitude.
- The growth eventually stops due to the saturating behavior of the amplifier(s) in the loop.





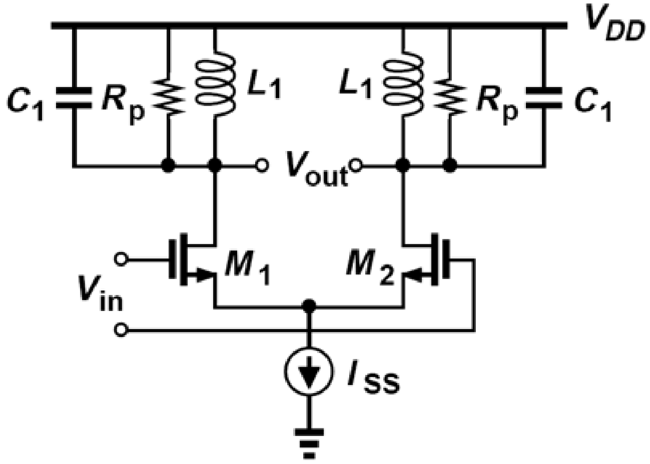
- Each stage operates as an amplifier, leading to an oscillation frequency at which each inverter contributes a frequency-dependent phase shift of 60° .

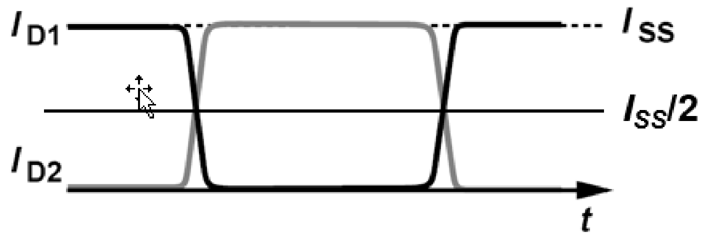
Example of Voltage Swings (I)

The inductively-loaded differential pair driven by a large input sinusoid at

$$\omega_0 = 1/\sqrt{L_1 C_1}$$

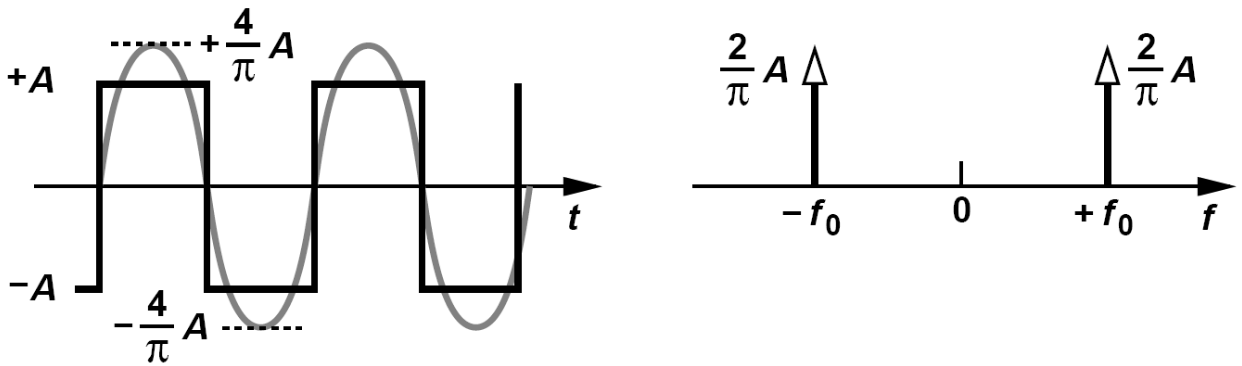
Plot the output current waveforms and determine the output Current swing.





- **With large swings, M_1 and M_2 experience complete switching injecting nearly square current waveforms into the tanks.**
- **The first harmonic of the current is multiplied by R_p**
- **Higher harmonics are attenuated by the tank selectivity.**

Example of Voltage Swings (Ⅱ)

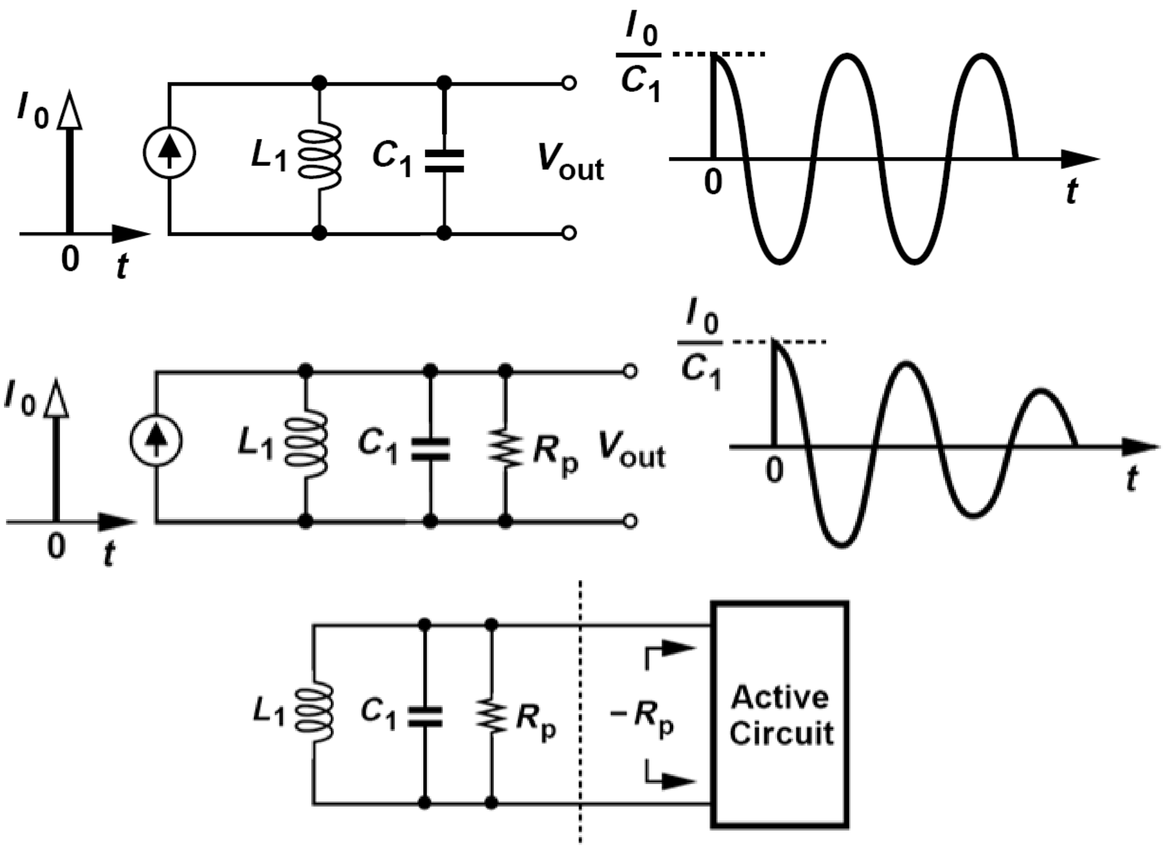


- **Fourier expansion of a square wave of peak amplitude A (with 50% duty cycle) that the first harmonic exhibits a peak amplitude of (4/*π*)*A* (slightly greater than A).**
- **The peak single-ended output swing therefore yields a peak differential output swing of**

$$\boxed{V_{out} = \frac{4}{\pi} I_{SS} R_p}$$

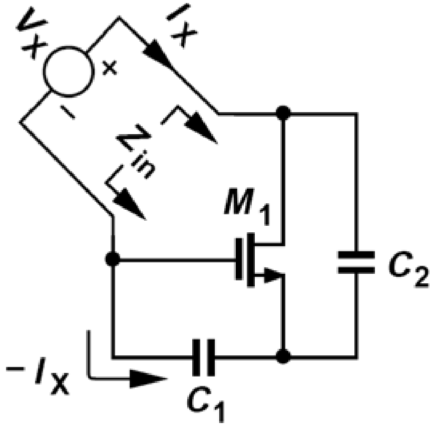
One-Port View of Oscillators

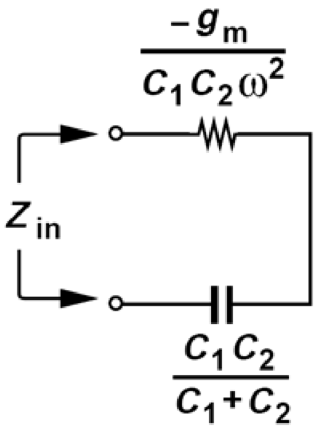
- Oscillators as two one-port components, namely, **a lossy resonator and an active circuit** that cancels the loss.



- Active circuit replenishes the energy lost in each period to sustain oscillation

How Can a Circuit Present a Negative Input Resistance?





$$-\frac{I_X}{C_1 s} + V_X = \left(I_X + I_X\frac{g_m}{C_1 s}\right)\frac{1}{C_2 s}$$

$$\frac{V_X}{I_X}(s) = \frac{1}{C_1 s} + \frac{1}{C_2 s} + \frac{g_m}{C_1 C_2 s^2}$$

$$\frac{V_X}{I_X}(j\omega) = \frac{1}{jC_1\omega} + \frac{1}{jC_2\omega} - \frac{g_m}{C_1 C_2 \omega^2}$$

- **The negative resistance varies with frequency.**