EE4280 Lecture 3: Oscillator

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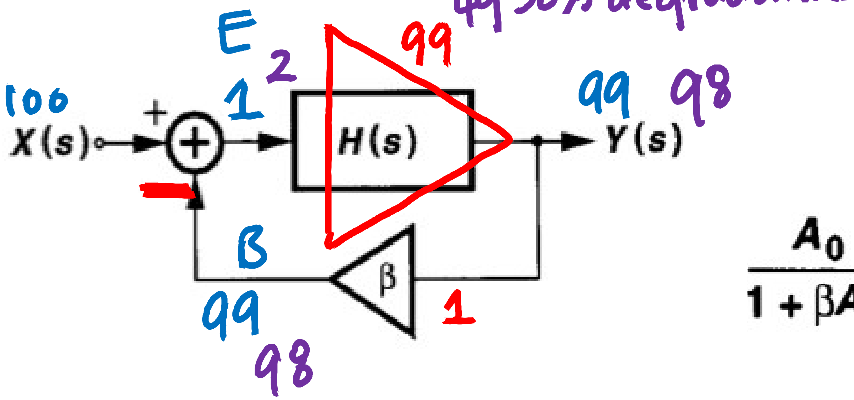
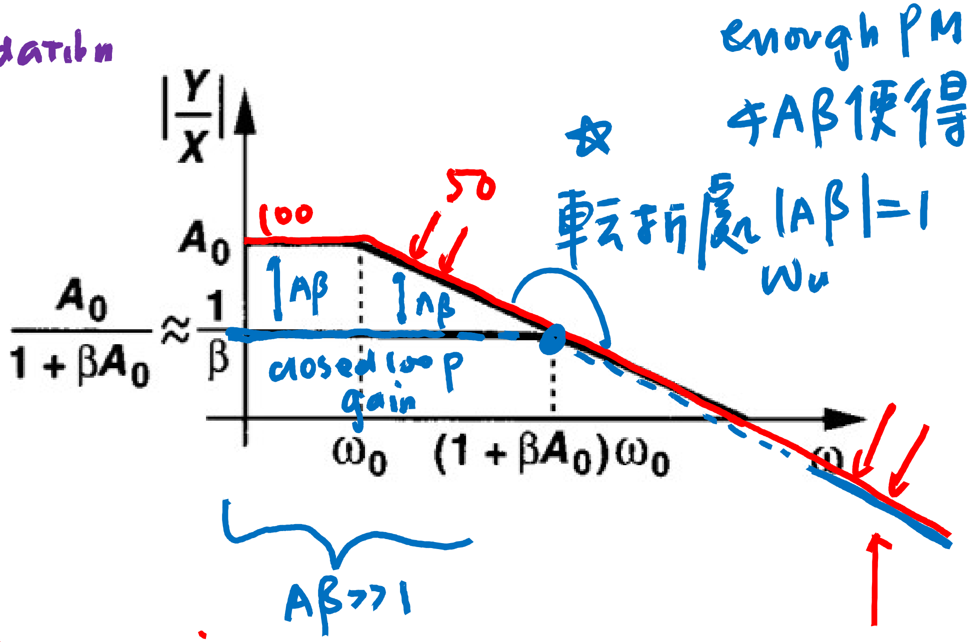
Negative Feedback

Closed-loop transfer function vs. open-loop transfer function

- Gain desensitization
- Bandwidth extension





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

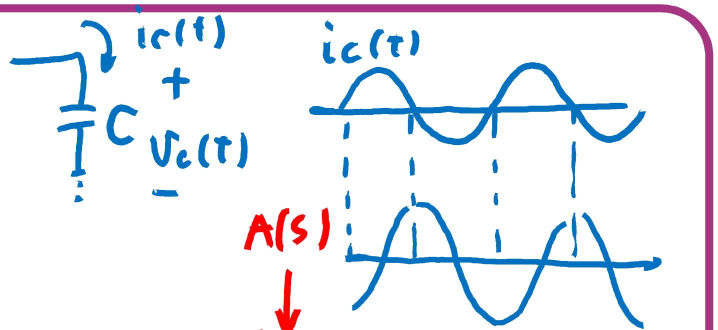
positive gain with subtraction

$$= \frac{\text{open-loop gain}}{1-\text{loop gain}}$$

$$\frac{\beta}{x} = \frac{A\beta}{1+A\beta} \cong 1$$

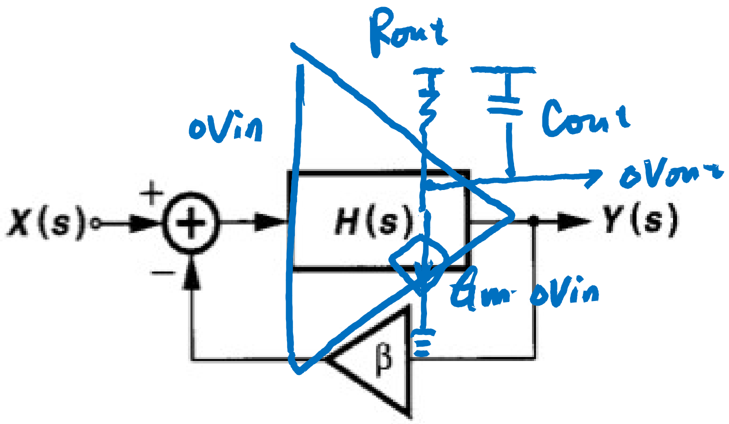
$$\frac{Y}{X} \cong H(s)$$

Stability in Negative Feedback

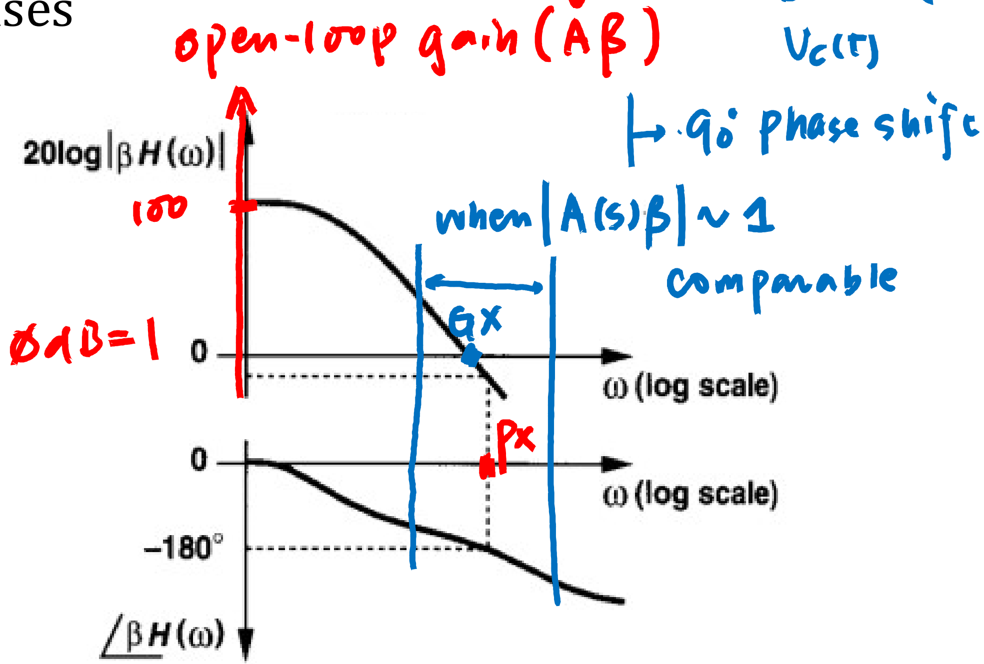


As the operating frequency increases

- The open-loop gain decreases
- The open-loop phase shift increases

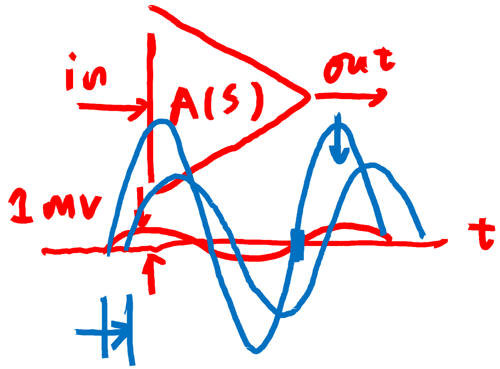


$$\frac{Y}{X}(s) = \frac{H(s)}{1 + \beta H(s)}$$



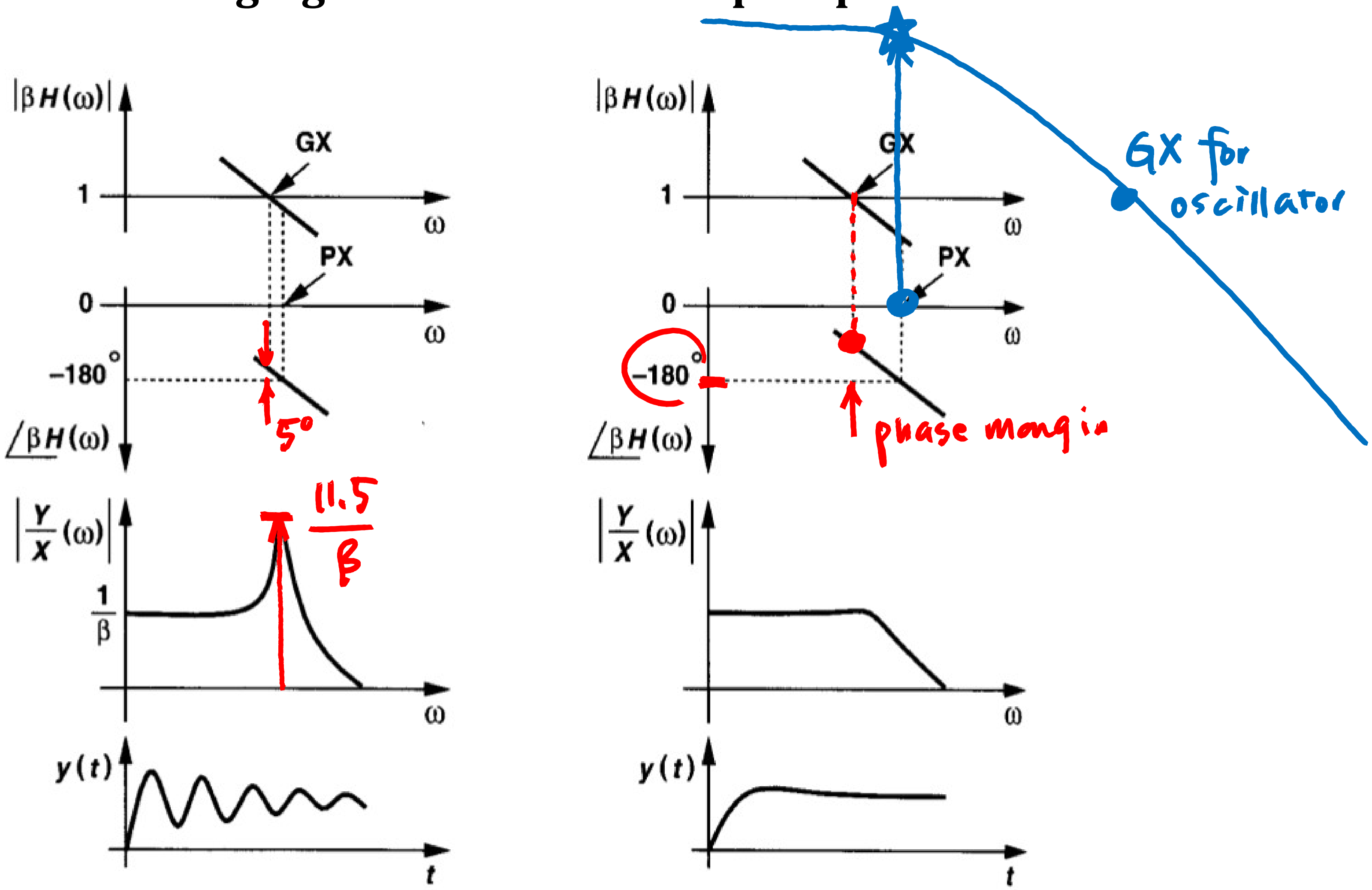
In fact, we care about the frequencies at which

- The open-loop gain drops to 0 dB
- The open-loop phase delay is 180°

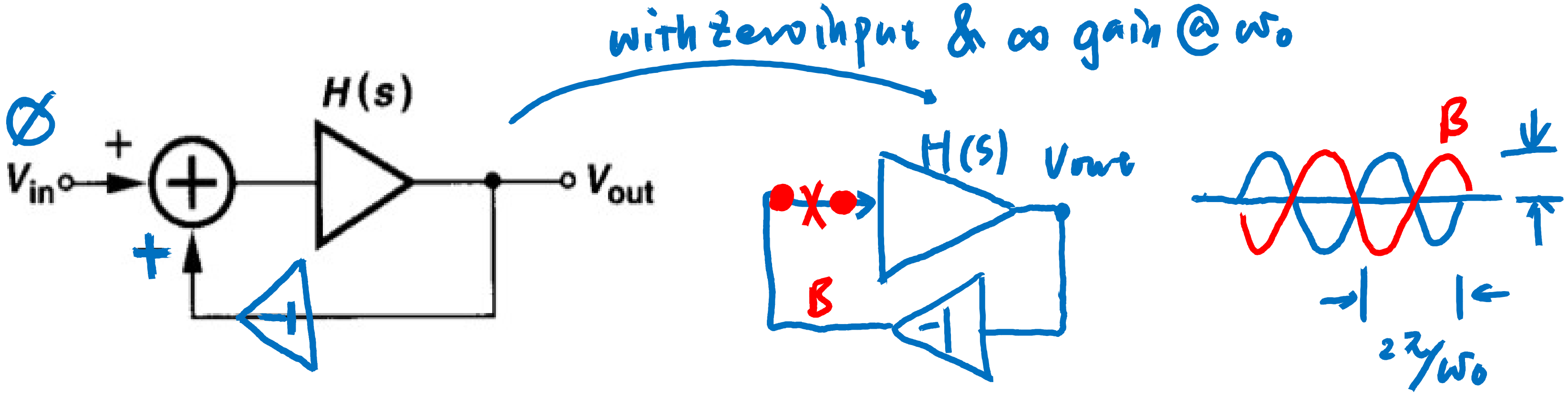


Gain Margin and Phase Margin

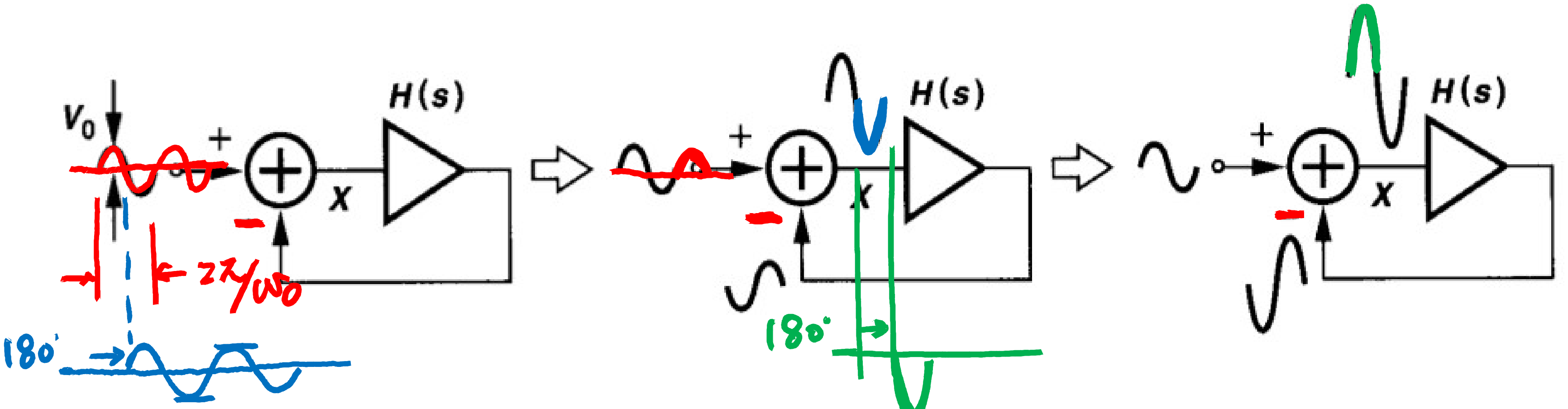
- **Insufficient phase margin results in peaking in closed-loop transfer function and ringing in time-domain step response**



What happens with zero phase margin?



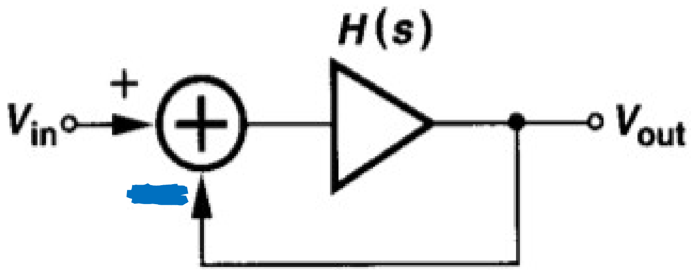
- **In other words, if when** $s = j\omega_0$, $H(j\omega_0) = -1$



- The closed-loop gain approaches infinity at ω_0
- The circuit generates an output signal without input – autonomous

Oscillator – Barkhausen Criteria

- **For an open-loop transfer function that satisfies two conditions:**



$|H(j\omega_0)| \geq 1$ gain requirement (3, 4, 10)

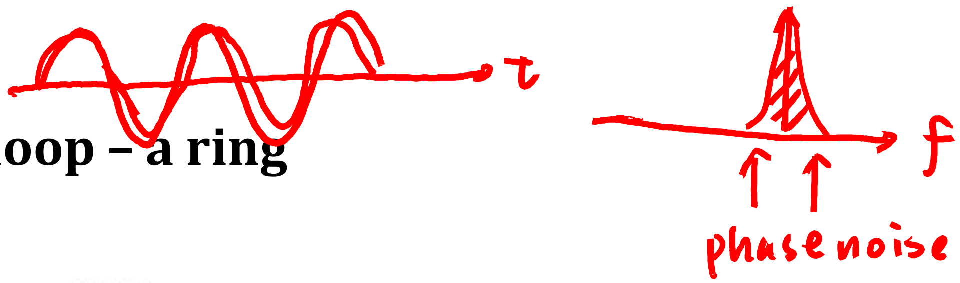
$\angle H(j\omega_0) = 180°$ phase requirement

→ loop becomes positive feedback

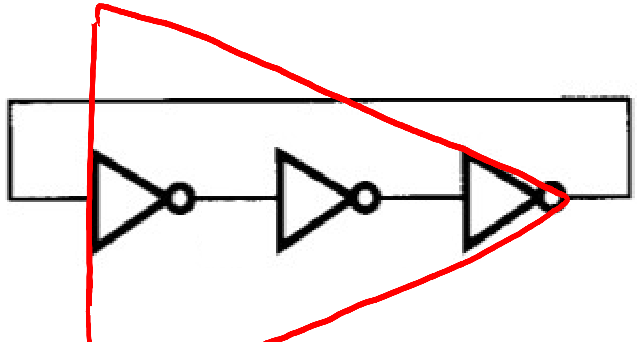
- **The circuit may oscillate at ω_0**
  - These conditions are necessary but not sufficient
  - In order to ensure oscillation in the presence of PVT variations, we typically choose the loop gain to be at least twice or three times the required value

  - Negative feedback at low frequency to build "stable" DC bias point
  - Total phase shift of 360° at ω_0 → positive feedback at ω_0
    → additional *frequency-dependent* phase delay that is 180° at ω_0

Ring Oscillator (I)



- A number of gain stages in a loop – a ring



- Starting from a single-stage of common-source amplifier