EE 230
Lecture 17

Nonideal Op Amp Characteristics (wrap up)
Nonlinear Applications

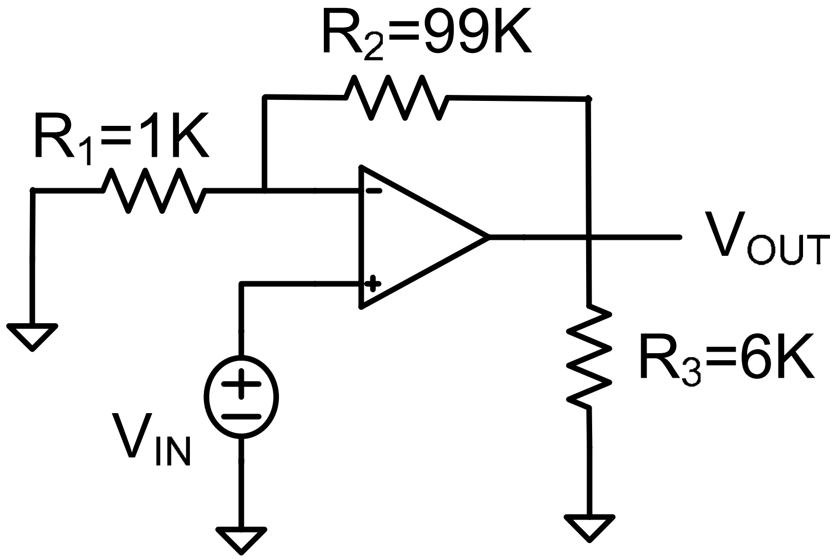
Quiz 12

The operational amplifier is ideal except for a measured offset voltage of 3mV. If V_{IN}=-8mV, determine

a) The desired output

b) The actual output

c) The percent error in the output voltage



And the number is ?

1 3 8

5 4

2 6

9 7

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Quiz 12 Solution:

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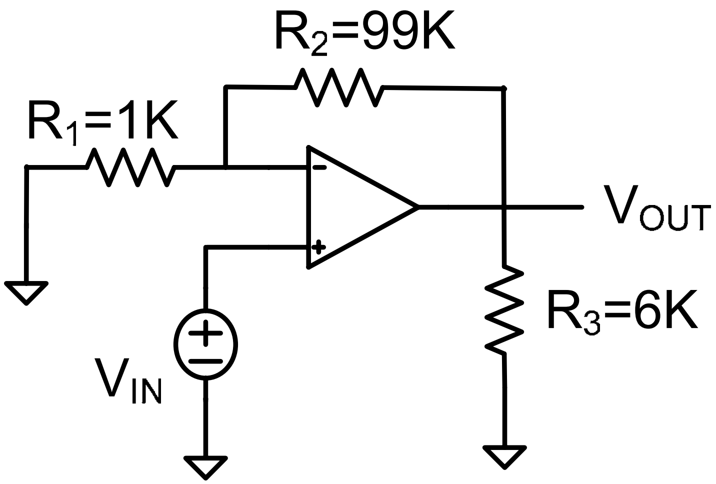

a) The desired output voltage is $V_{OUT}=100V_{IN}$=-800mV

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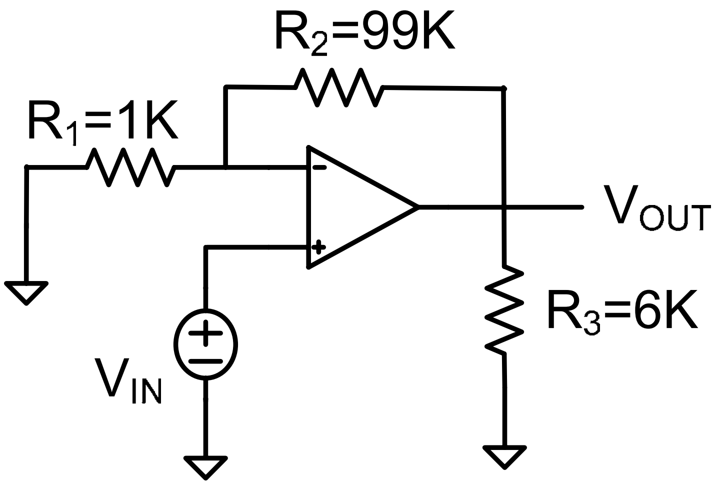
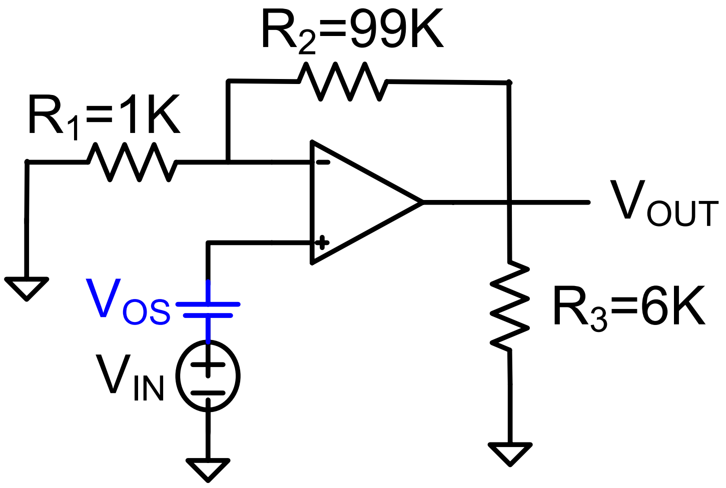


a) The desired output voltage is $V_{OUT}=100V_{IN}$=-800mV

b) By superposition



$$V_{OUT}=V_{IN}\left(1+\frac{R_2}{R_1}\right)+V_{OS}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{OUT}=-8\text{mV}(100)+3\text{mV}(100)=-500\text{mV}$$

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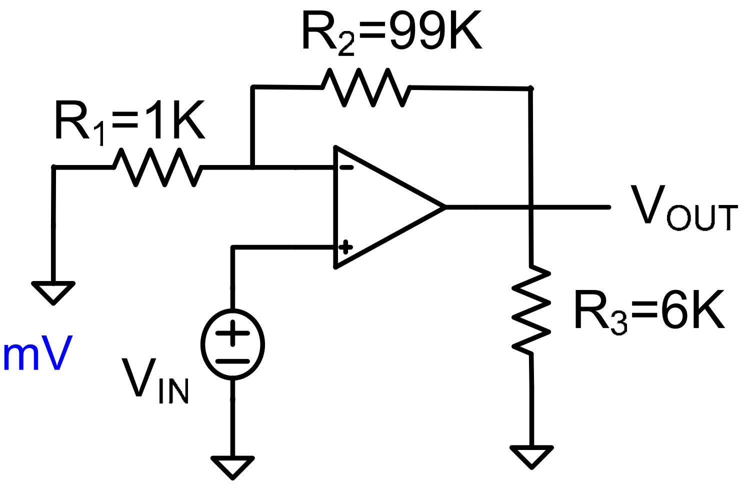


a) The desired output voltage is $V_{OUT}=100V_{IN}=-800mV$

b) By superposition

$$V_{OUT}=V_{IN}\left(1+\frac{R_2}{R_1}\right)+V_{OS}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{OUT}=-8mV(100)+3mV(100)=-500mV$$

c) Percent error

$$error=100\%\left(\frac{-500mV--800mV}{800mV}\right)=37.5\%$$

Review from Last Time:

Nonideal op amp characteristics

- Finite Gain
- Finite BW

〉 GB

- Compensation
- → Output Saturation
- → Slew Rate
- → R_{IN} & R_{OUT}
- → Offset Voltage
- Bias Currents

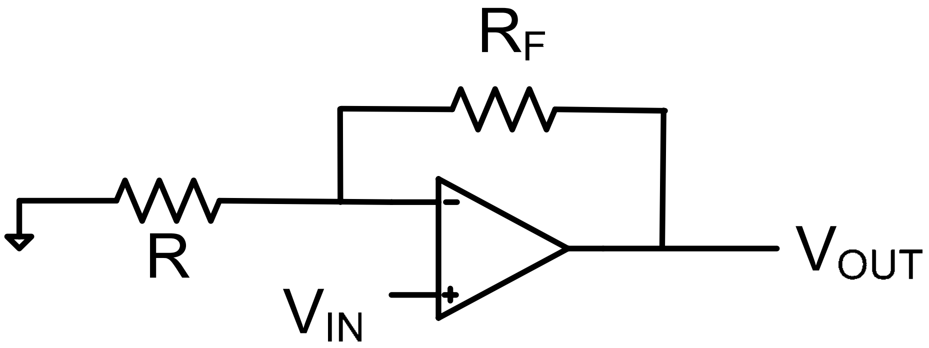
- CMRR
- PSRR
- Offset Current
- Full Power Bandwidth

Review from Last Time:

- Output Saturation
  - Maximum output current and maximum output voltage op amp can provide
  - Changing op amps or adding some sort of “buffer” can be used to mitigate these effects
  - Analysis of effects usually easy to obtain
- Slew Rate
  - Maximum rate of change of the output
  - Positive and Negative Slew Rate Magnitudes usually the same
  - Key spec of op amps – differs from op amp to op amp
  - For sinusoidal output, $\omega V_m < SR$
- R_{IN} and R_{OUT}
  - Thevenin input and ouptut impedances of op amp
  - Varies from op amp to op amp
  - Usually does not cause major problem with feedback
- Offset Voltage
  - Shift in dc transfer characteristics from orgin
  - One of the most problematic op amp nonidealities for many applications
  - Particularly troublesome in applications requiring large dc gains
  - Can often be managed with
    - different op amp
    - offset trimming
    - capacitor coupling

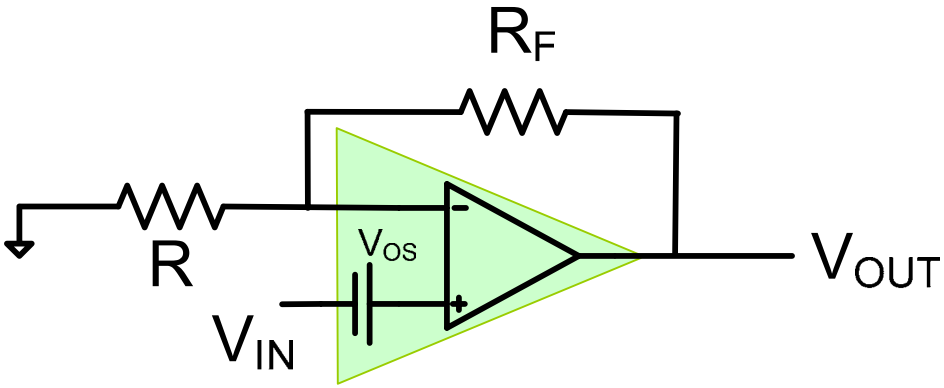
Management of V_{OS} with Capacitor Coupling

Consider a basic noninverting voltage amplifier



$$A_V = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R}$$

If offset voltages are present



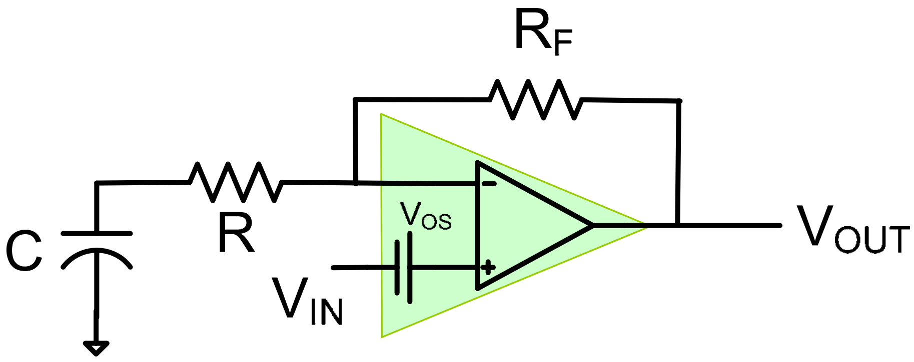
By superposition, it readily follows that

$$V_{OUT} = \left(1 + \frac{R_F}{R}\right) V_{IN} + \left(1 + \frac{R_F}{R}\right) V_{OS}$$

If the desired voltage gain is large, the effects of V_{OS} are a major problem

Management of V_{OS} with Capacitor Coupling

Consider a noninverting voltage amplifier requirement and assume V_{IN} is a time-varying (sinusoidal) signal



The capacitor C blocks dc current In R

The overall amplifier becomes a first-order high-pass amplifier

By superpositon, the transfer function from V_{IN} to V_{OUT} equals that of V_{OS} to V_{OUT}

$$T(s)=\frac{V_{OUT}}{V_{IN}}=1+\frac{R_F}{R+\frac{1}{sC}}$$

$$T(s)=\frac{1+sC(R+R_F)}{1+sRC} \Rightarrow T(s)=A_0\frac{\frac{s}{z}+1}{\frac{s}{p}+1}$$

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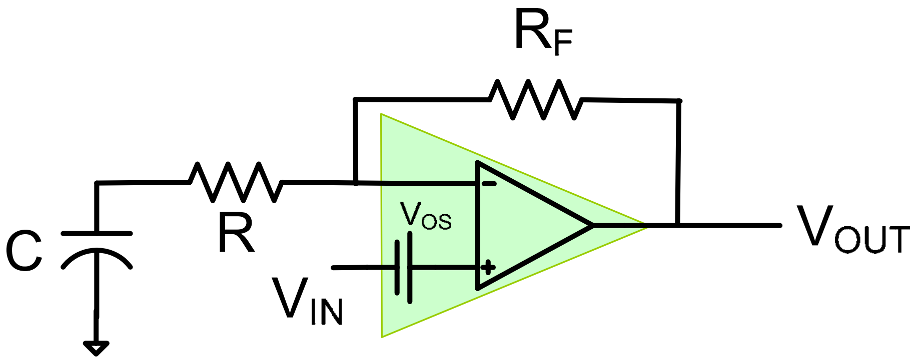

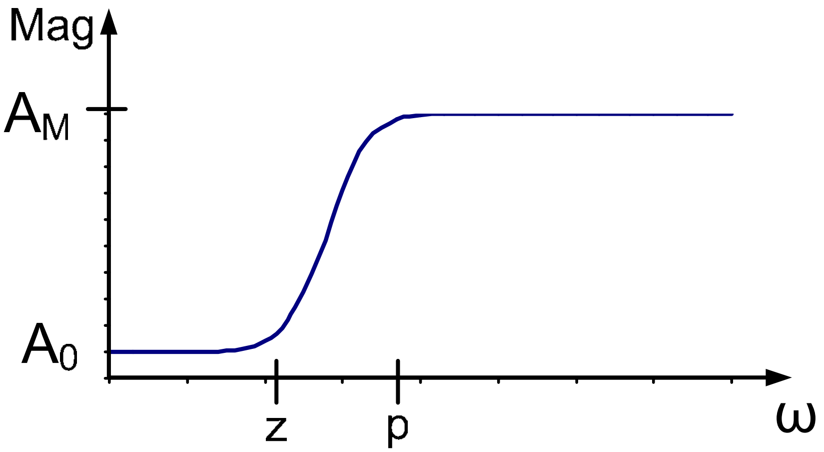

$$T(s)=\frac{1+sC(R+R_F)}{1+sRC}$$

$$T(s)=A_0\frac{\frac{s}{z}+1}{\frac{s}{p}+1}$$

$$p=\frac{1}{RC} \qquad z=\frac{1}{(R+R_F)C}$$

$$A_0=1 \qquad A_M=1+\frac{R_F}{R}$$

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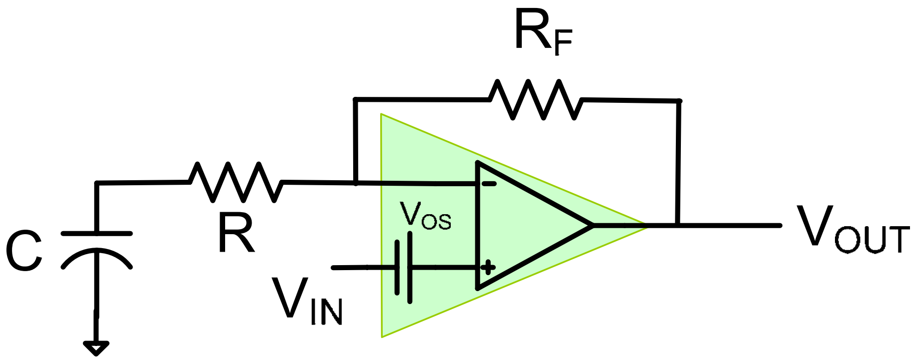

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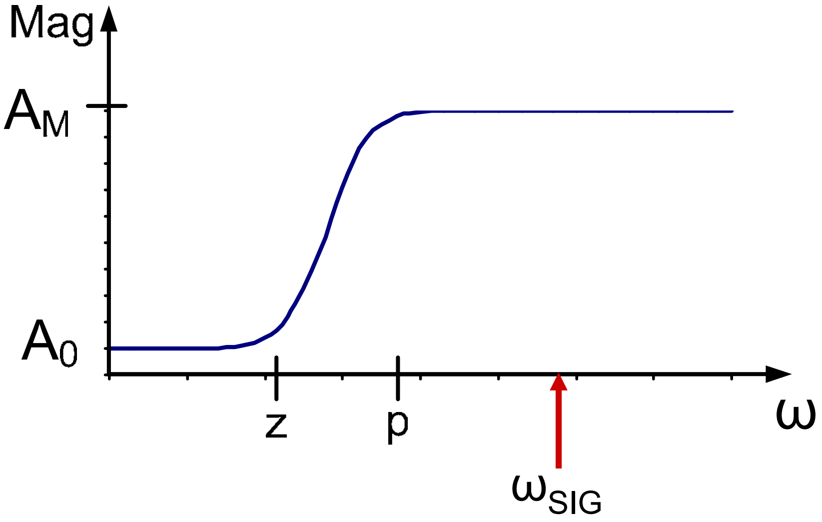
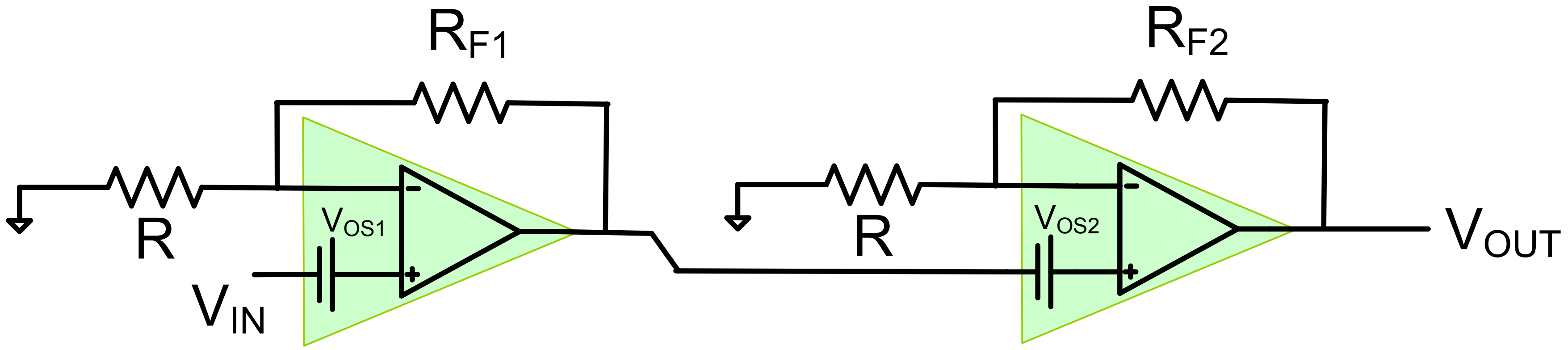


Must pick C so that $\omega_{SIG} >> p$

$$C >> \frac{1}{R\omega_{SIG}}$$

Management of V_{OS} with Capacitor Coupling

Consider Cascaded Amplifier

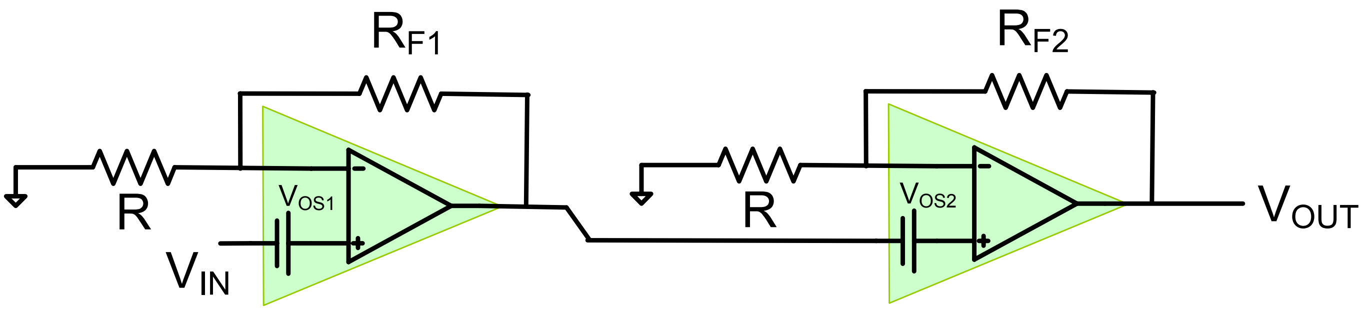


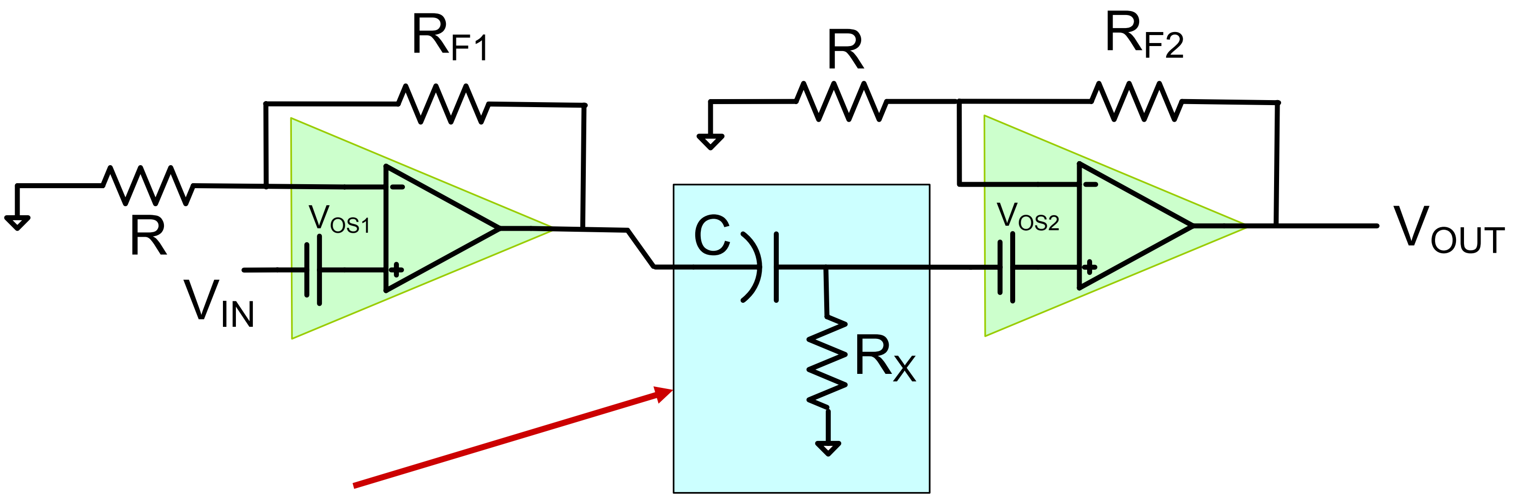
$$V_{OUT} \overset{R_{F1}=R_{F2}}{=} \left(1+\frac{R_{F1}}{R}\right)^2 V_{IN} + \left(1+\frac{R_{F1}}{R}\right)^2 V_{OS1} + \left(1+\frac{R_{F1}}{R}\right) V_{OS2}$$

Offset voltage affects modestly worse than that for the single-stage amplifier

Management of V_{OS} with Capacitor Coupling

Consider Cascaded Amplifier with V_{IN} sinusoidal





First-Order Highpass
Filter Blocks V_{OS1}

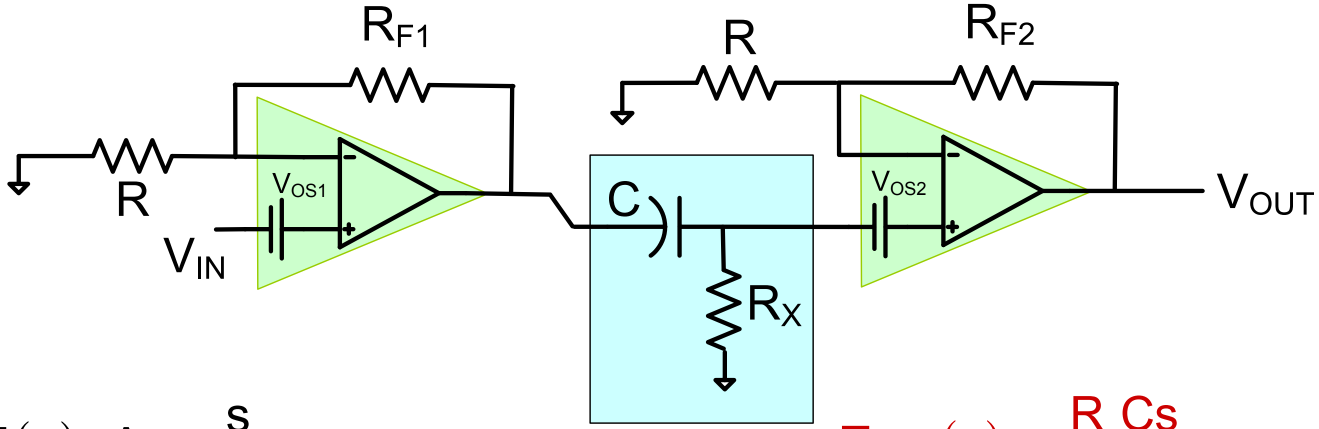
$$T_{FILTER}(s)=\frac{R_xCs}{1+R_xCs}$$

Pole at –p where

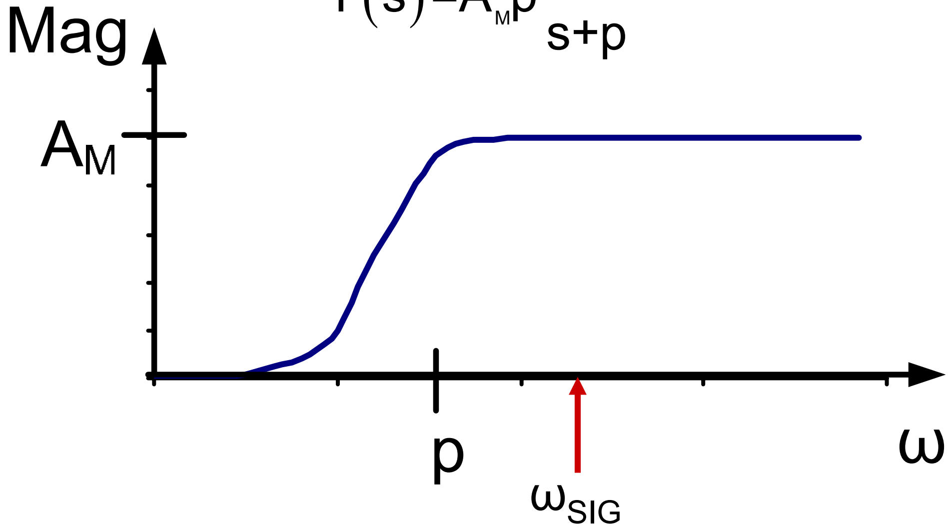
$$p=\frac{1}{R_xC}$$

Management of V_{OS} with Capacitor Coupling

Consider Cascaded Amplifier with V_{IN} sinusoidal



$$T(s)=A_M p\frac{s}{s+p}$$



$$T_{FILTER}(s)=\frac{R_x Cs}{1+R_x Cs}$$

$$p=\frac{1}{R_x C}$$

Must pick C, R_X so that $\omega_{SIG} >> p$

$$C\,R_x >> \frac{1}{\omega_{SIG}}$$

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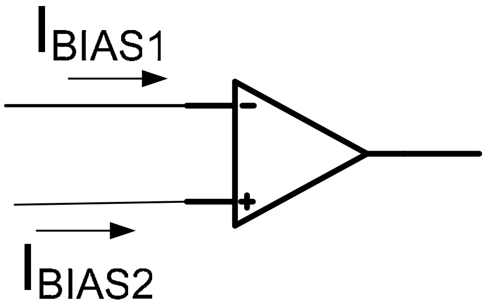
Bias and Offset Currents



I_{BIAS} is small for bipolar input op amps, extremely small for FET input op amps

Can be neglected in most designs regardless of whether FET or Bipolar input

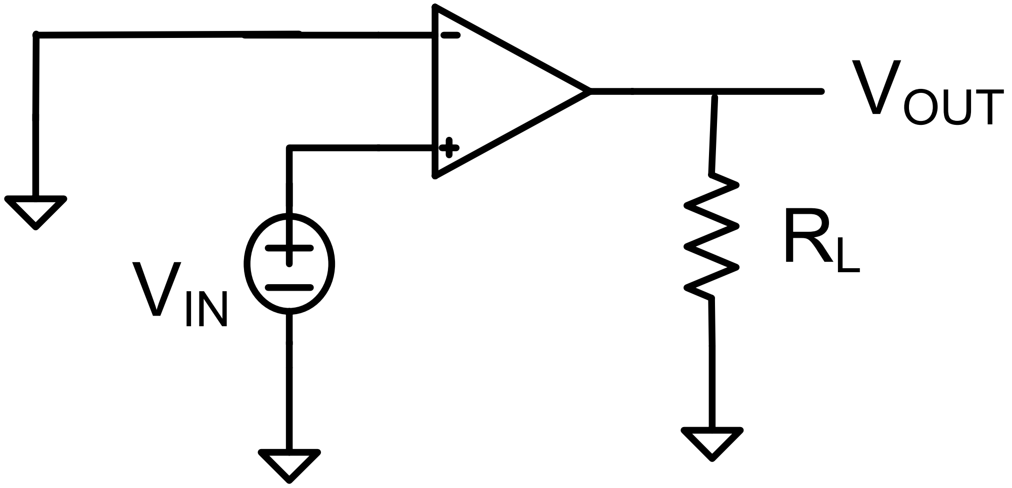
Typical question on many interviews

$$I_{OFSET} = I_{BIAS1} - I_{BIAS2}$$

I_{OFFSET} is a random variable with zero mean for most designs

I_{BIAS} around 50 nA for 741, I_{OFFSET} around 3nA for 741

Op Amp Is Almost Never Used as an Open Loop High Gain Amplifier !!



But what will happen if an engineer attempts to use this circuit as an amplifier?

To address this problem, must investigate the concept of nonlinear circuits

Nonlinear Applications

- Circuits in which one or more devices do not operate linearly
- In general, superposition can not be used to analyze circuit
- Many very useful applications of nonlinear circuits
  - Will first consider applications where op amp operates nonlinearly
  - Will then consider other nonlinear devices

Will first discuss the concepts of nonlinear circuits and nonlinear circuit analysis techniques