

# **EEE-2103: Electronic Devices and Circuits**

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# Difference Amplifiers

Combination of inverting and non-inverting amplifiers.

With  $V_{i2} = 0$ ,  $V_{o1} = -\frac{R_2}{R_1} \times V_{i1}$

With  $V_{i1} = 0$ ,  $V_{o2} = \frac{R_1+R_2}{R_1} \times V_{R4}$

$$V_{R4} = \frac{R_4}{R_3+R_4} \times V_{i2}$$

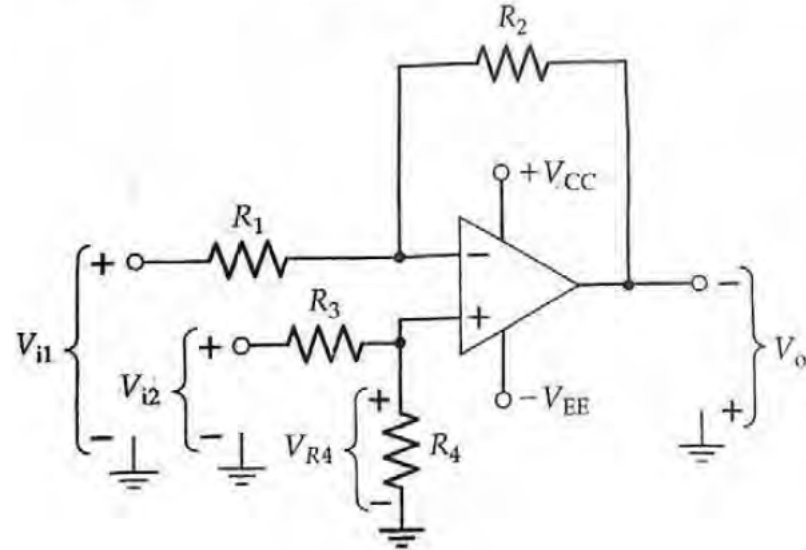
$$V_{o2} = \frac{R_1+R_2}{R_1} \times \frac{R_4}{R_3+R_4} \times V_{i2}$$

With  $R_3 = R_1$  and  $R_4 = R_2$ ,

$$V_{o2} = \frac{R_2}{R_1} \times V_{i2}$$

When both inputs are present,

$$\begin{aligned} V_o &= V_{o2} + V_{o1} \\ &= \frac{R_2}{R_1} \times V_{i2} + \frac{-R_2}{R_1} \times V_{i1} \\ &= \frac{R_2}{R_1} (V_{i2} - V_{i1}) \\ &= V_{i2} - V_{i1} \quad [R_1 = R_2] \end{aligned}$$



# Difference Amplifiers

Input impedance at terminal 1,  $Z_{i1} = R_1$

Input impedance at terminal 2,  $Z_{i1} = R_3 + R_4$

For equal resistances at two input terminals, select

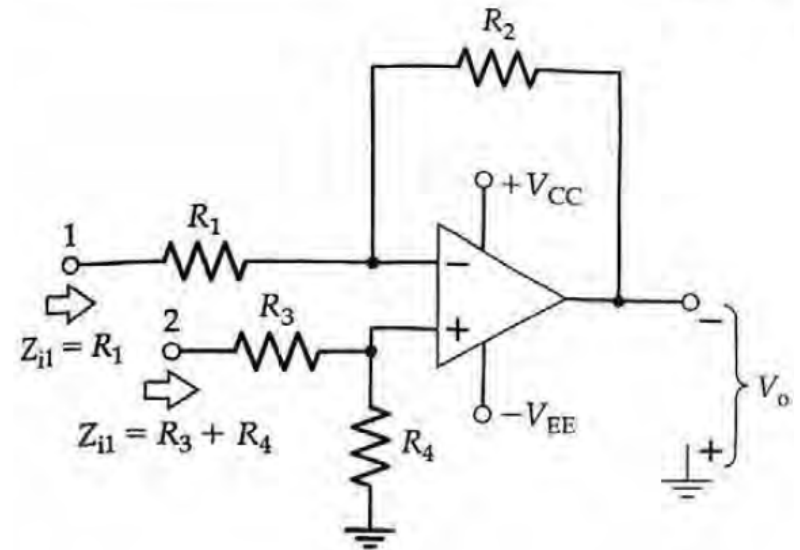
$$R_3 + R_4 = R_1$$

Assuming  $R_3 = R_1$  and  $R_4 = R_2$ ,

$$\frac{R_4}{R_3} = \frac{R_2}{R_1}$$

Select  $R_4 = R_2/A_{CL}$

$$R_3 = R_1/A_{CL}$$



# Difference Amplifiers

## Problem-49:

A difference amplifier is to be designed to amplify the difference between two voltages by a factor of 10. The inputs each approximately equal 1 V. Determine suitable resistor values for a circuit using a 741 op-amp. Assume  $I_{B(max)} = 500 \text{ nA}$ .

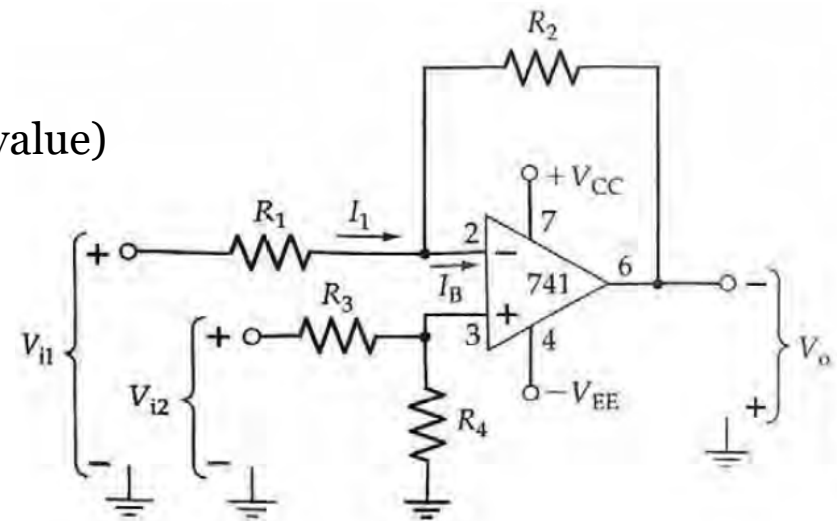
Select,  $I_1 \approx 100I_{B(max)} = 100 \times (500 \times 10^{-9}) = 50 \text{ } \mu\text{A}$

$R_1 = V_{i1}/I_1 = 1/(50 \times 10^{-6}) = 20 \text{ k}\Omega$  (use 18 k $\Omega$  standard value)

$R_2 = A_{CL}R_1 = 10 \times 18 \times 10^3 = 180 \text{ k}\Omega$

$R_4 = R_1 = 18 \text{ k}\Omega$

$R_3 = R_1/A_{CL} = (18 \times 10^3)/10 = 1.8 \text{ k}\Omega$



# **Nyquist Criterion**

Negative feedback occurs only for some mid-frequency range.

Amplifier gain and phase shift changes with frequency →  
some of feedback signal will add to input signal.  
amplifier breaks into oscillations due to positive feedback.  
circuit is no longer useful as amplifier.

Circuit be stable at frequencies in range of interest.

Nyquist plot →  
complex plane.  
combines two Bode plots on single plot →  
1) gain versus frequency  
2) phase shift versus frequency.  
quickly show whether amplifier is stable for all frequencies.  
how stable amplifier is relative to gain or phase-shift criteria.

# Nyquist Criterion

Complex plane →

points = gain ( $\beta A$ ) at phase-shift angles.  
+ve real axis = reference ( $0^\circ$ ).

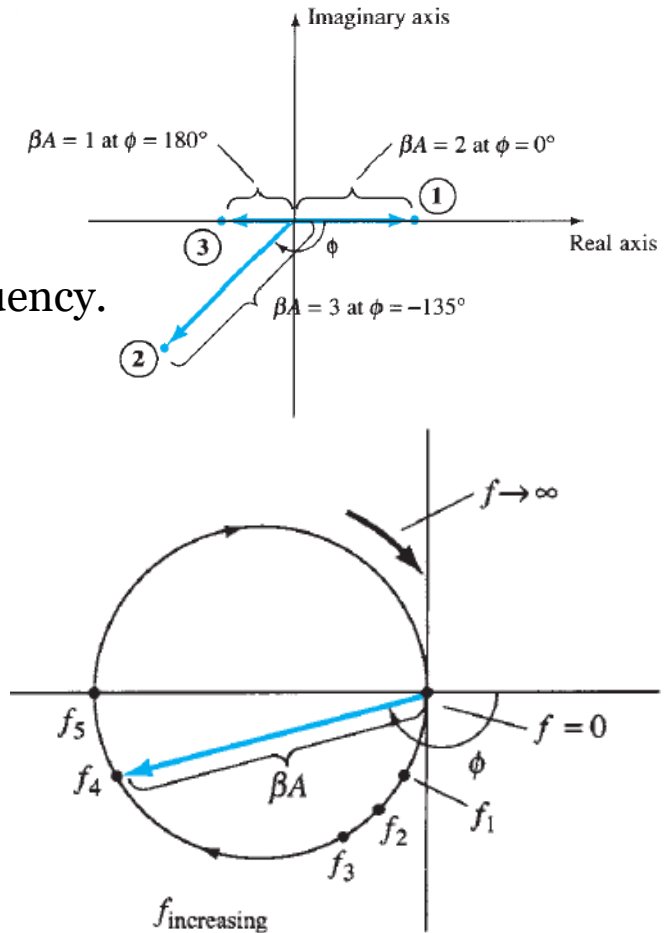
Nyquist plot →

points for amplifier circuit are plotted at increasing frequency.  
origin → gain = 0, frequency = 0  
increasing frequency →

points  $f_1, f_2, f_3, f_4$  and  $f_5$   
phase shift increases,  
magnitude of gain ( $\beta A$ ) increases.

At frequency  $f_4$  →

$\beta A$  = vector length from origin to point  $f_4$   
phase shift = angle  $\Phi$ .



# Nyquist Criterion

Nyquist criterion for stability →  
 amplifier is unstable if Nyquist curve encloses  $-1$  point.  
 stable otherwise.

## Gain and Phase Margins:

feedback amplifier is stable → phase angle =  $180^\circ$   
 loop gain ( $\beta A$ ) < unity (0 dB).

Gain margin (GM) →

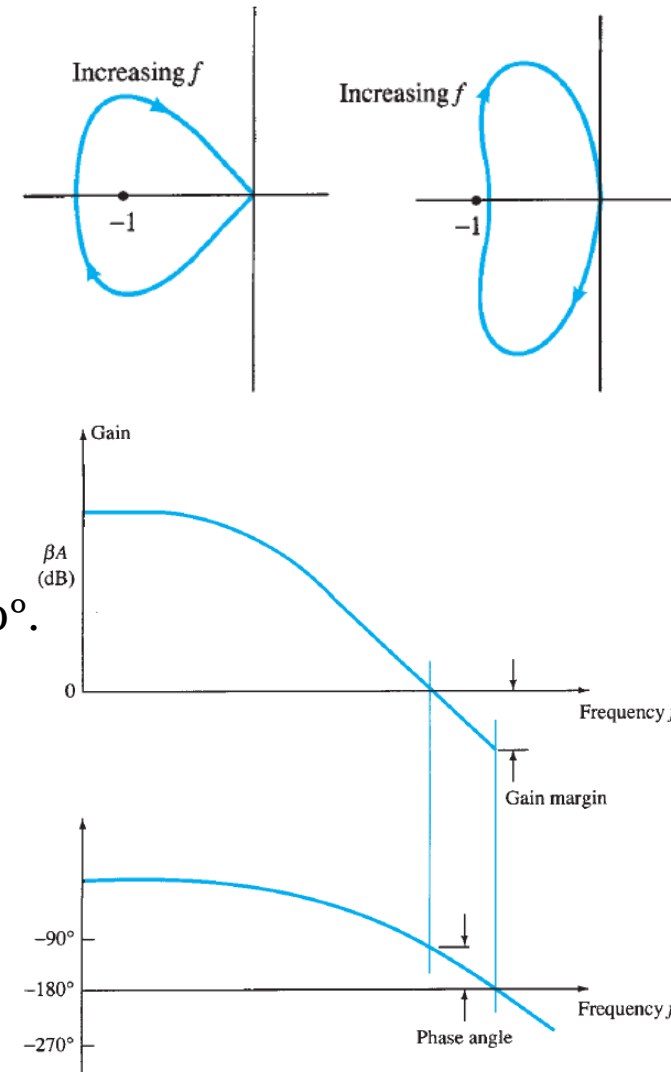
-ve of  $|\beta A|$  in dB at frequency at which phase angle is  $180^\circ$ .

$|\beta A| = 1 \rightarrow 0$  dB: border of stability.

-ve dB: stable.

Phase margin (PM) →

$180^\circ - |\Phi|$  at which  $|\beta A|$  is unity (0 dB).



# Oscillator Operation

Feedback circuit used as oscillator →

Barkhausen criterion for oscillation →

- 1)  $|\beta A| \geq 1$ , and
- 2) Feedback signal feeding back at input must be phase-shifted by  $360^\circ = 0^\circ$ .  
condition for self-sustained oscillation.

Feedback circuit acts as oscillator input signal →

feedback eqn.  $A_f = A/(1 + \beta A)$ .

$\beta A = -1 \rightarrow A_f = \infty$ .

infinitesimal signal (noise voltage)  
can provide measurable  $V_{out}$ .

