EEE-2103: Electronic Devices and Circuits

Dept. of Computer Science and Engineering
University of Dhaka

Prof. Sazzad M.S. Imran, PhD
Dept. of Electrical and Electronic Engineering
sazzadmsi.webnode.com

Difference Amplifiers

Combination of inverting and non-inverting amplifiers.

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

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

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

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

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

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

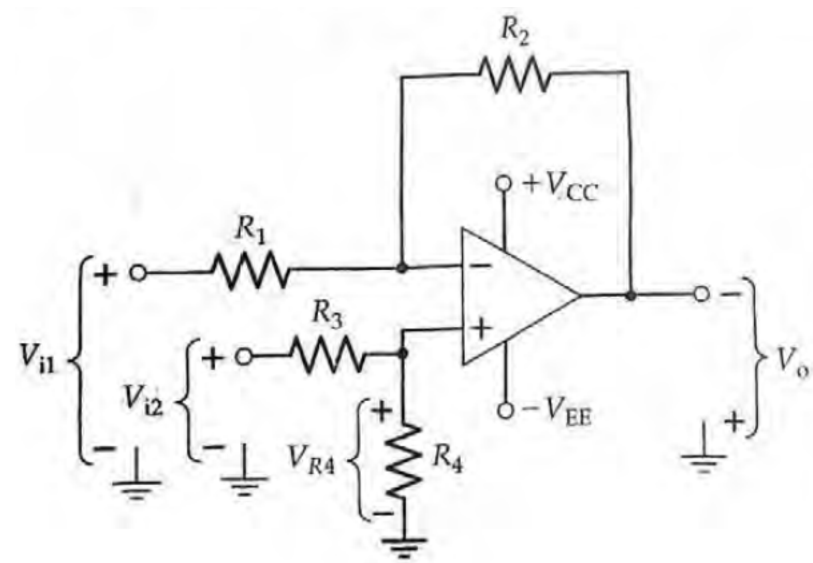
When both inputs are present,

$$V_o = V_{o2} + V_{o1}$$

$$= \frac{R_2}{R_1} \times V_{i2} + \frac{-R_2}{R_1} \times V_{i1}$$

$$= \frac{R_2}{R_1}(V_{i2} - V_{i1})$$

$$= V_{i2} - V_{i1} \qquad [R_1 = R_2]$$



Difference Amplifiers

Input impedance at terminal 1, $Z_{i1} = R_1$
Input impedance at terminal 2, $Z_{i1} = R_3 + R_4$

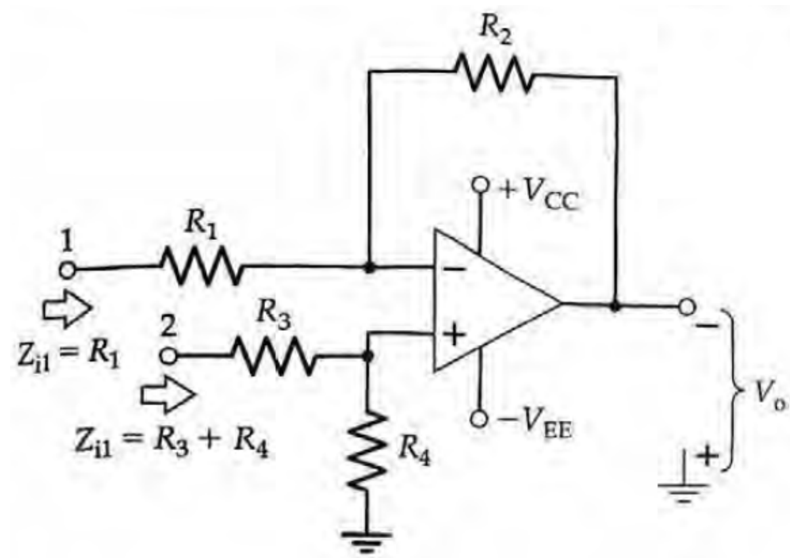
For equal resistances at two input terminals, select

$$R_3 + R_4 = R_1$$

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 nA.

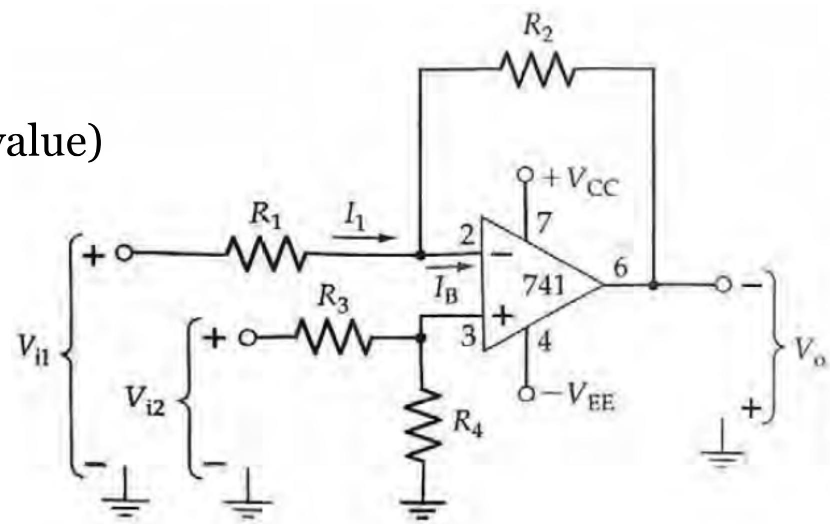
Select, $I_1 \approx 100 I_{B(max)} = 100\times(500\times10^{-9}) = 50\ \mu A$

$R_1 = V_{i1}/I_1 = 1/(50\times10^{-6}) = 20\ k\Omega$ (use 18 kΩ standard value)

$R_2 = A_{CL}R_1 = 10\times18\times10^3 = 180\ k\Omega$

$R_4 = R_1 = 18\ k\Omega$

$R_3 = R_1/A_{CL} = (18\times10^3)/10 = 1.8\ k\Omega$



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.

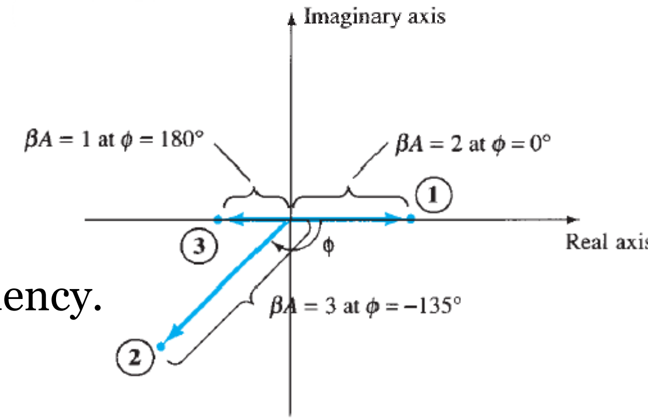
how stable amplifier is relative to gain or phase-shift criteria.

Nyquist Criterion

Complex plane →

points = gain (βA) at phase-shift angles.

+ve real axis = reference (0°).



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

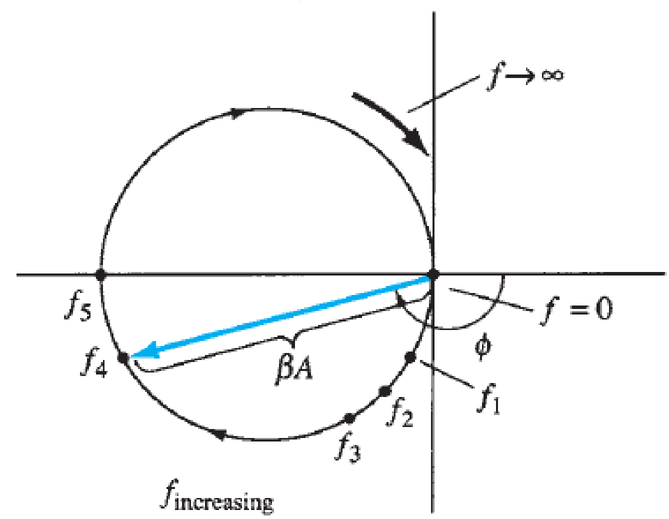
phase shift increases,

magnitude of gain (βA) increases.

At frequency f_4 →

βA = vector length from origin to point f_4

phase shift = angle Φ.

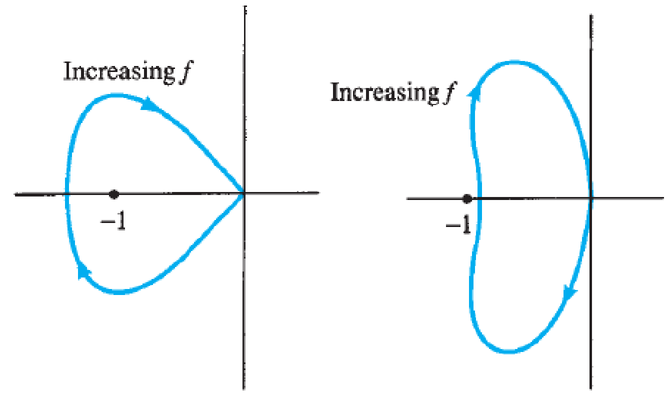


Nyquist Criterion

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°

loop gain (βA) < unity (0 dB).

Gain margin (GM) →

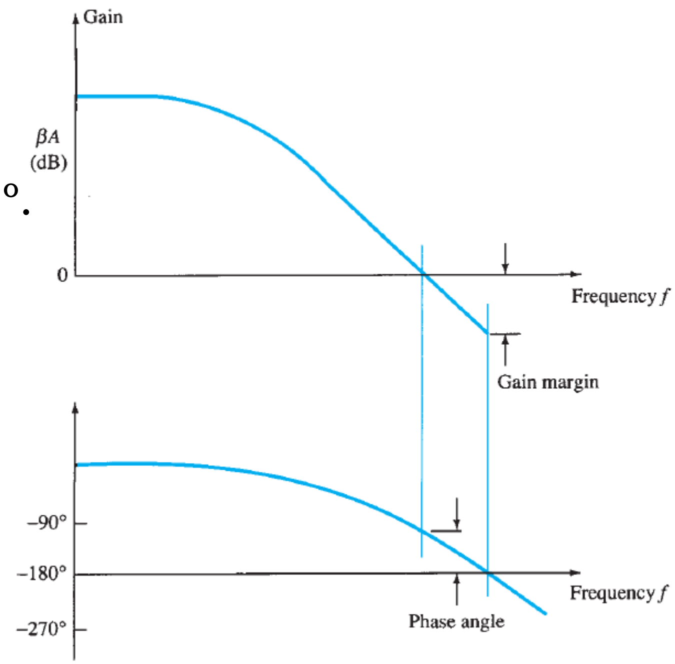
-ve of $|\beta A|$ in dB at frequency at which phase angle is 180°.

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

-ve dB: stable.

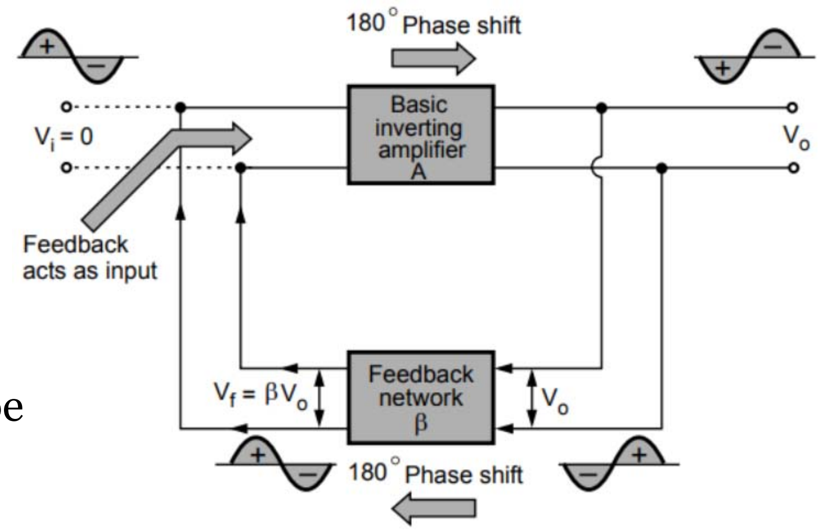
Phase margin (PM) →

180° – $|\Phi|$ 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 $360^o = 0^o$.
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}.