Analog Systems and Applications (32221403)

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Unit 5:

Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

Feedback

A sampling network samples the output voltage or current and this signal is applied to the input through a feedback two port network.(Signal source can be a voltage source V_s or a current source I_s)

- For voltage feedback, the feedback element (resistor) will be in parallel with the output.
- For current feedback the element will be in series.
- If the feedback signal is proportional to voltage, it is Voltage Feedback.
- If the feedback signal is proportional to current, it is Current Feedback.
- Conditions to be satisfied.
- Input signal is transmitted to the output through amplifier A and not through feedback network β.

- The feedback signal is transmitted to the input through feedback network and not through amplifier.
- The reverse transmission factor β is independent of R_s and R_L.

There are two types of feedback:

- Positive Feedback
- Negative Feedback (degenerative feedback)

Advantages of Negative Feedback

- Input impedance can be increased.
- Output impedance can be decreased.
- Bandwidth is increased.
- Linearity of operation is improved.
- Distortion is reduced.
- Noise reduces.

Effect of negative feedback on gain factor.

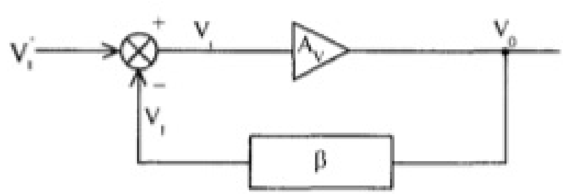

Figure 1: schematic for -Ve feedback.

Without negative feedback in the Fig.1

$$A_v = \frac{V_0}{V_1} \tag{1}$$

by including negative feedback,

$$A_v' = V_o/V_1' \tag{2}$$

since

$$V_1' = V_1 - \beta V_0 \tag{3}$$

$$V_0 = A_v(V_1 - \beta V_0) \tag{4}$$

$$V_0 = A_v(V_1 - \beta V_0) \tag{5}$$

$$V_0 = A_v.V_1 - A_v.\beta V_0 \tag{6}$$

$$V_0(1 + \beta A_v) = A_v V_1 \tag{7}$$

$$A_{vf} = \frac{V_0}{V_1} = \frac{A_v}{1 + \beta A_v} \tag{8}$$

Here A_{vf} is voltage gain with negative feedback.

Reduction in Gain

For positive feedback,

$$A_v' = \frac{A_v}{1 - \beta A_v} \tag{9}$$

A_v = voltage gain without feedback. β is negative for negative feedback.

$$A_v' = \frac{A_v}{1 - (-\beta.A_v)} \tag{10}$$

As can be seen the denominator is greater than 1. $A_v{}'$ is less than the A_v. there is reduce in gain with negative feedback.

Reduction of noise

Let N be noise constant without feedback and N_F with feedback. $N_F$is fed to the input and its value is βN_F It is amplified to -βAN_F. So,

$$N_F = N - \beta A N_F \tag{11}$$

$$N_F = \frac{N}{1 + \beta A} \tag{12}$$

Here can be concluded that N_F is less than N, which implies tha noise is reduced with negative feedback.

- Now we will obtain expressions for gain & impedance for the noninverting and inverting amplifier with feedback.
- when input signal is connected to the inverting (-) terminal of amplifier, it is inverting amplifier and when input signal is connected to the noninverting terminal (+) then it is noninverting amplifier.

Noninverting amplifier

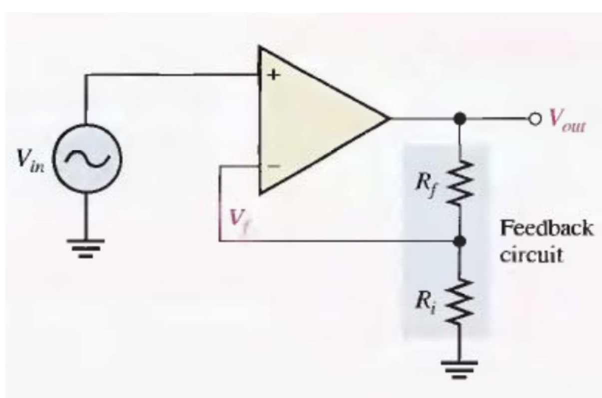

Figure 2: Schematic for noninverting amplifier with negative feedback

Op-amp is connected in a closed loop as noninverting amplifier with controlled voltage gain. Here input signal is connected to the noninverting input. Output is connected to the inverting terminal through feedback circuit. Feedback voltage (V_f) is ($\frac{R_i}{R_i+R_f}V_{out}$). Output voltage is $A_{openloop}(V_{in}-V_f)$

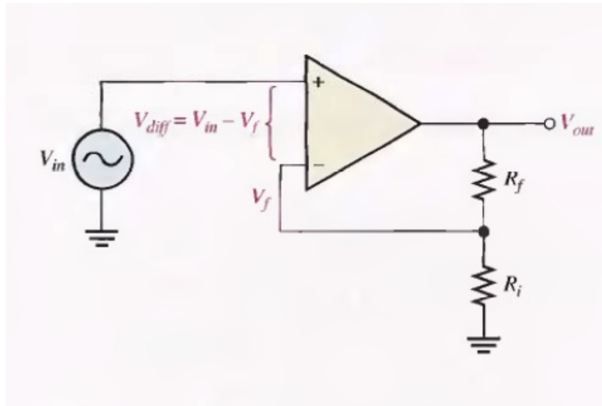

Figure 3: With differential input

Attenuation (B)=$\frac{R_i}{R_i+R_f}$. by putting BV_{out} for V_f in V_{out} equation.

$$V_{out} = A_{ol}(V_{in} - BV_{out}) \tag{13}$$

$$V_{out} = A_{ol}V_{in} - A_{ol}BV_{out} \tag{14}$$

$$V_{out} + A_{ol}BV_{out} = A_{ol}V_{in} \tag{15}$$

$$V_{out}(1 + A_{ol}B) = A_{ol}V_{in} \tag{16}$$

Overall voltage gain is $V_{out}/V_{in} = A_{ol}/(1+A_{ol}B)$. $A_{ol}B$ is geater than 1.

$$\frac{V_{out}}{V_{in}} = \frac{A_{ol}}{A_{ol}B} = 1/B \tag{17}$$

Closed loop gain is

$$A_{cl(NI)} = \frac{V_{out}}{V_{in}} = \frac{1}{B} = \frac{R_i + R_f}{R_i} \tag{18}$$

So, $A_{cl(NI)} = 1+\frac{R_f}{R_i}$

Voltage follower

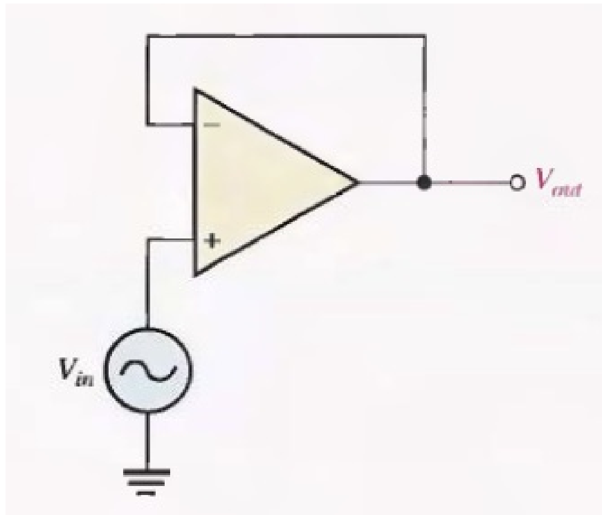

Figure 4: Voltage follower OP-AMP

It is aspecial case where all output voltage is feedback to input. it has high iput impedance and low output impedance.

$$A_{cl(VF)} = 1 \tag{19}$$

Inverting amplifier

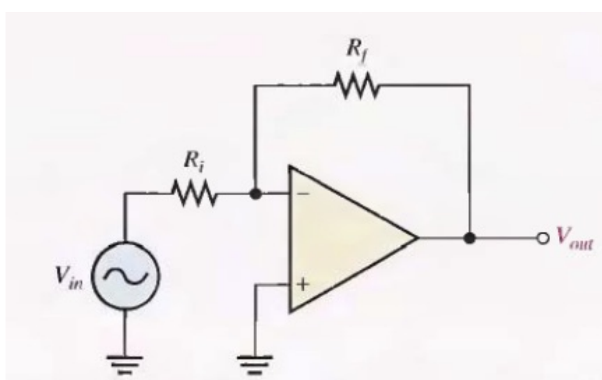

Figure 5: Schematic for inverting amplifier with negative feedback

$$I_{in} = I_f \tag{20}$$

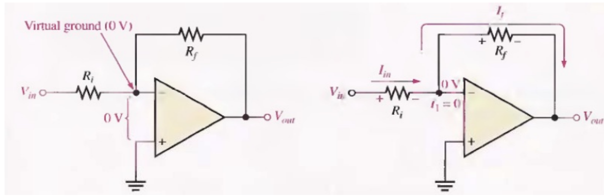

Figure 6: Virtual ground case and closed loop voltage gain for inverting amplifier.

Since there is no current at the inverting input and $I_{in} = V_{in}/R_i$. Voltage across R_f is $-V_{out}$. $I_f = \frac{-V_{out}}{R_f}$, since $I_f = I_{in}$,

$$\frac{-V_{out}}{R_f} = \frac{V_{in}}{R_i} \tag{21}$$

$$A_{cl(I)} = -\frac{R_f}{R_i} \tag{22}$$

The closed loop gain is independent of the op-amp's internal open- loop gain. negative feedback stabilizes the voltage gain.

Impedances of a noninverting amplifier

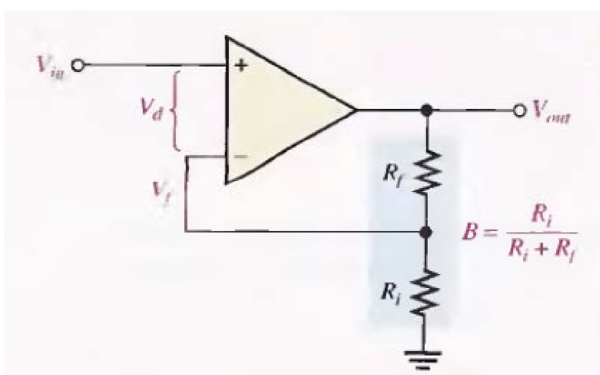

Figure 7: Input impedance schematics

Input Impedance

From Fig.7,

$$V_{in} = V_d + V_f = V_d + BV_{out} \tag{23}$$

Since V_{out} + $A_{ol}V_d$,

$$V_{in} = V_d + A_{ol}BV_d = (1 + A_{ol}B)V_d \tag{24}$$

substituting V_d equal $I_{in}Z_{in}$

$$V_{in} = (1 + A_{ol}B)I_{in}Z_{in} \tag{25}$$

Z_{in} is the open loop input impedance of op-amp without feedback.

$$\frac{V_{in}}{I_{in}} = (1 + A_{ol}B)Z_{in} \tag{26}$$

$$Z_{in(NI)} = V_{in}/I_{in} = (1 + A_{ol}B)Z_{in} \tag{27}$$

The above expression shows that input impedance of the noninverting amplifier with negative feedback is much greater than the input impedance of op-amp (without feedback).

Output Impedance

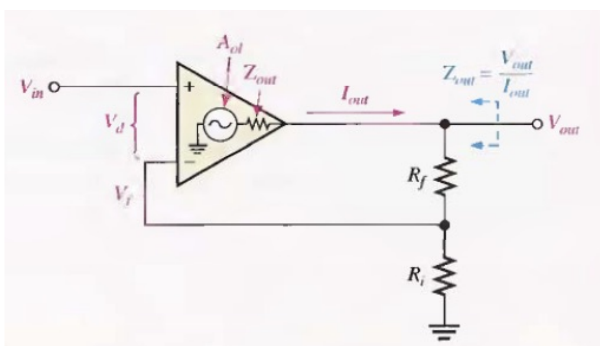

Figure 8: schematics for output impedance

From Fig.8, V_{out} = $A_{ol}V_d$ - $Z_{out}I_{out}$. The differential input voltage V_d = V_{in} - V_f, say $A_{ol}V_d$larger than the $Z_{out}I_{out}$.

$$V_{out} = A_{ol}(V_{in}V_f) \tag{28}$$

by putting V_f for BV_{out},

$$V_{out} = A_{ol}(V_{in} - BV_{out}) \tag{29}$$

by solving we get,

$$A_{ol}V_{in} = (1 + A_{ol}B)V_{out} \tag{30}$$

Since $Z_{out(NI)} = V_{out}/I_{out}$. So, $A_{ol}V_{in} = (1{+}A_{ol}B)I_{out}Z_{out(NI)}$ We get,

$$\frac{A_{ol}V_{in}}{I_{out}} = (1 + A_{ol}B)Z_{out(NI)} \tag{31}$$

$A_{ol}V_{in} = V_{out}$, So, $Z_{out} = (1{+}A_{ol}B)Z_{out(NI)}$ So,

$$Z_{out(NI)} = \frac{Z_{out}}{1 + A_{ol}B} \tag{32}$$

This equation shows that output impedance of the noninverting amplifier with -ve feedback is less than the internal output impedance Z_{out}.

For Impedance for voltage follower in Fig.4, $Z_{in(VF)} = (1{+}\ A_{ol})Z_{in}$ and $Z_{out(VF)} = Z_{out}/(1{+}A_{ol})$

input impedance

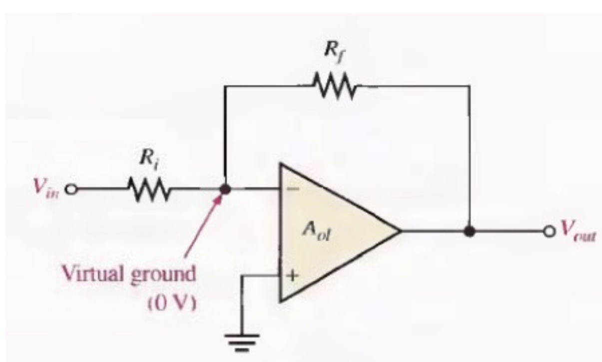

Figure 9: schematic for input impedance

As in Fig.9, $Z_{in(I)} = R_i$, since inverting input of op-amp is at virtual ground and input resistance is R_i.

- $Z_{out(I)} = \frac{Z_{out}}{1+A_{ol}B}$

Output impedance of both inverting and noninverting amplifier configuration is low, due to this near zero output impedance, any load impedance connected to the opamp output can vary greatly and not change the output votage .

Reference: Electronic Devices conventional current version by T. L. Floyd. and Electronic Devices & circuit Theory, R.L. Boylestad & L.D. Nashelsky, 2009, Pearson