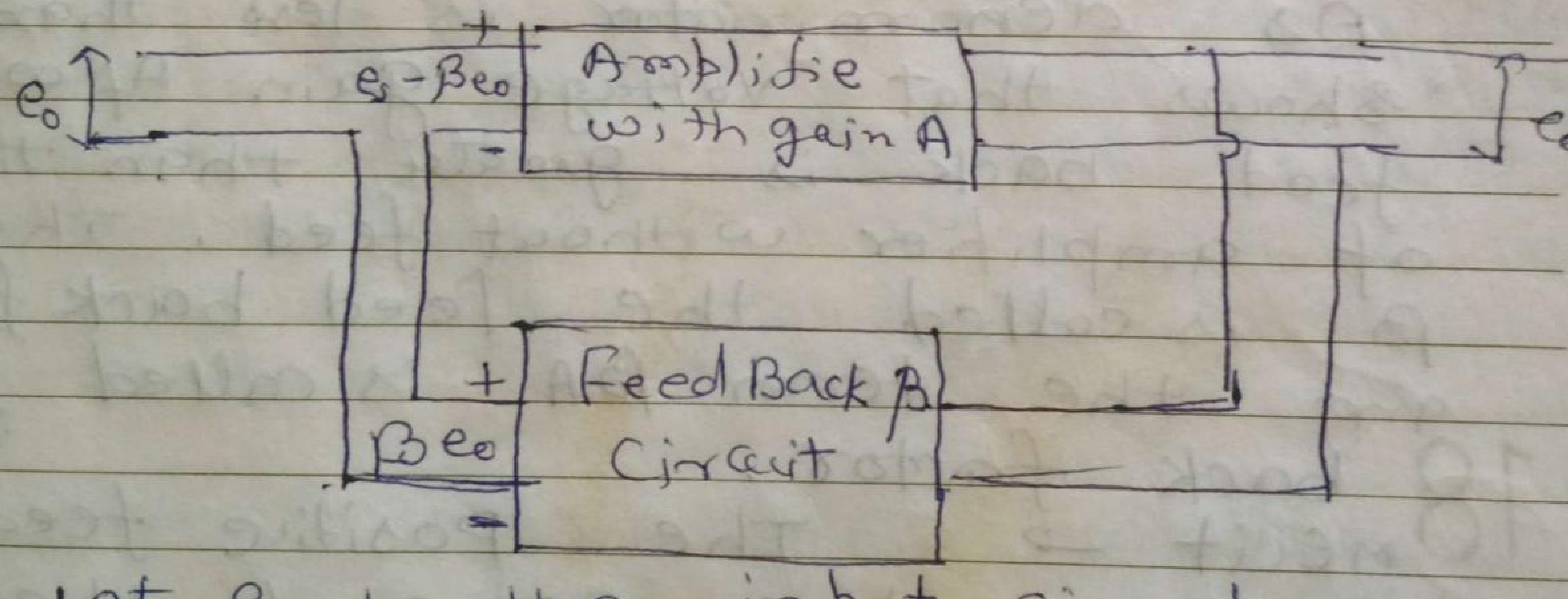
Feed Back Amplifier

A feedback amplifier is one in which a fraction of output energy (voltage or current) is fed back to the input by any mean. There are two basic types of feed back in amplifiers

1. Positive feed back
2. Negative feedback

Positive feedback → when the feed back energy (voltage or current) is in Phase with the input signal and thus aids it. the feed back is said to be positive or regenerative.



let e_s be the input signal voltage and e_o the output voltage

let β fraction of the output Votage e_o be feed back to the input in the same phase, then the actual input to the amplifier is $e_s + \beta e_o$. This input amplified by the gain A of the ~~amplier~~ amplifier must be equal to the output Voltage e_o

$$e_o = (e_s + \beta e_o) A$$

$$e_o = e_s A + \beta e_o A$$

$$e_o(1 - \beta A) = e_s A$$

∴ Gain of amplifier with positive feed back

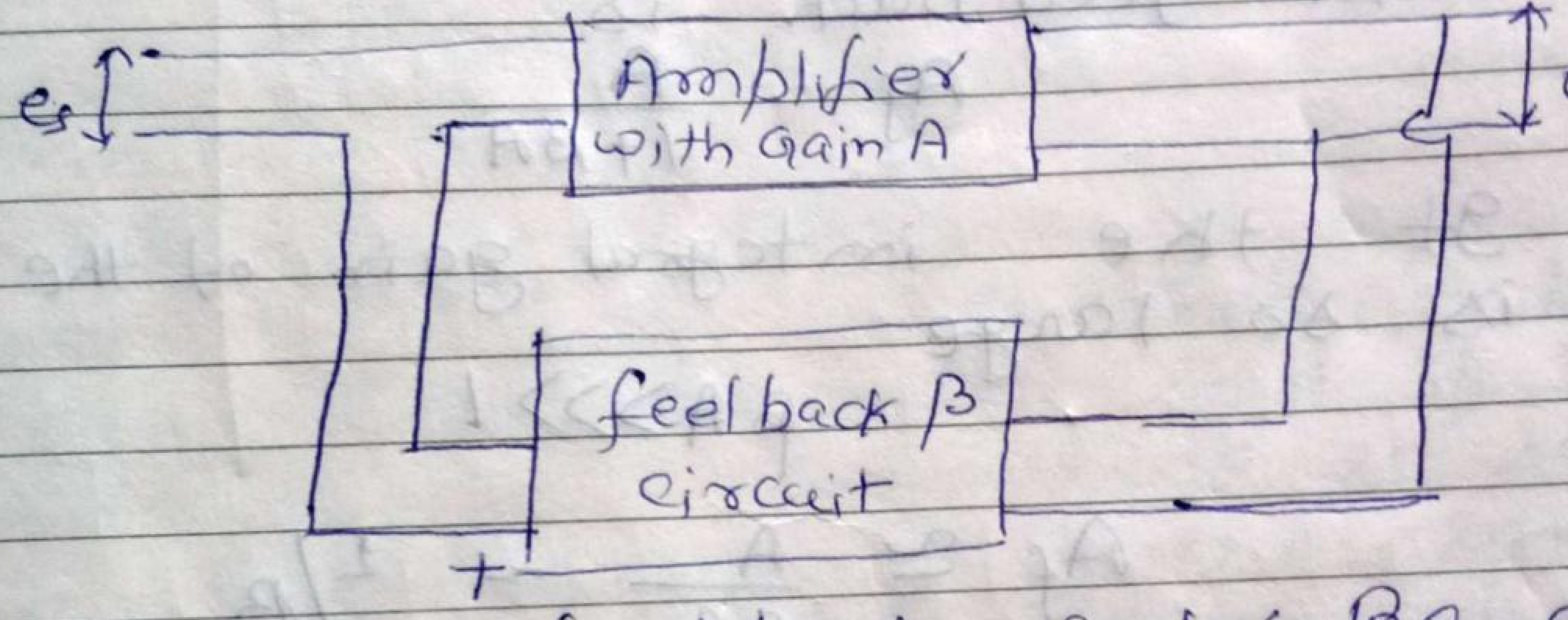
$$A_f = \frac{e_o}{e_s} = \frac{A}{1-\beta A}$$

$$\boxed{A_f = \frac{A}{1-\beta A}}$$

As denominator is less than unity shows that voltage gain A_f with positive feed back is greater than the gain A of amplifier without feed. The fraction β is called the feed back fraction and the term βA is called feed back factor.

Next → The positive feed back increases the gain of the amplifier but it increases the distortion by the same factor. If the positive feed back is sufficiently large, it leads to oscillations, Thus making the amplifier instable

Negative feed back when the feed back energy (voltage or current) is feed back in the opposite phase with the input signal and thus opposes it, The feedback is said to be Negative or degenerative.



The feed back factor βe_0 and input signal e_s are out of phase. The net input voltage is $(e_s - \beta e_0)$. This input amplified by the gain A of the amplifier must be equal to the output voltage e_0 Thus

$$e_0 = (e_s - \beta e_0)A$$

$$A_f = e_0/e_s = \frac{A}{1+\beta A}$$

The denominator is now greater than unity. Hence the voltage gain A_f with negative feed back is less than the gain A without feedback. The greater is the feed back factor βA, smaller is the gain but at the same time smaller is the distortion.

Advantages of Negative feedback

(i) Negative feed back increases the stability of gain of Amplifier → The gain of the amplifier with feed back is

$$A_f = \frac{A}{1+\beta A}$$

If the integral gain of the Amplier is so large

$$\beta A >>> 1$$

$$A_f \simeq \frac{A}{\beta A} = 1/\beta$$

The gain of the amplifer depends on the properties of the negative feed back. The feed back circuit consists of stable elements like resistors and capacitors, Therefore with negative feed back gain does not change with transistor parameters.

(ii) Negative feed back reduces non linear distortion → The non-linear distortion arises due to curvature of output characteristics of the transistor. A large input signal has a non linear distortion because its gain changes at various points of the cycle. the negative feed back reduces the non-linear distortion in large signal amplifiers.

let e_1 & e_0 be the amplitude of first and nth harmonic in the output voltage without feed back, then fractional nth harmonics distortion is

$$D_n = e_n/e_1$$

If a fraction β of output voltage is fed back into input voltage out of phase and if the applied signal amplitude is so adjusted that the output has the same fundamental component e' as before then if e_n' is the amplitude of nth harmonic $\beta' e_n$ will appear into the input 180° out of phase with the applied signal and will be amplified by the amplifier to a value $A\beta e_n$ in opposite phase with initial nth harmic e_n then

$$e_n' = e_n - A\beta e_n$$

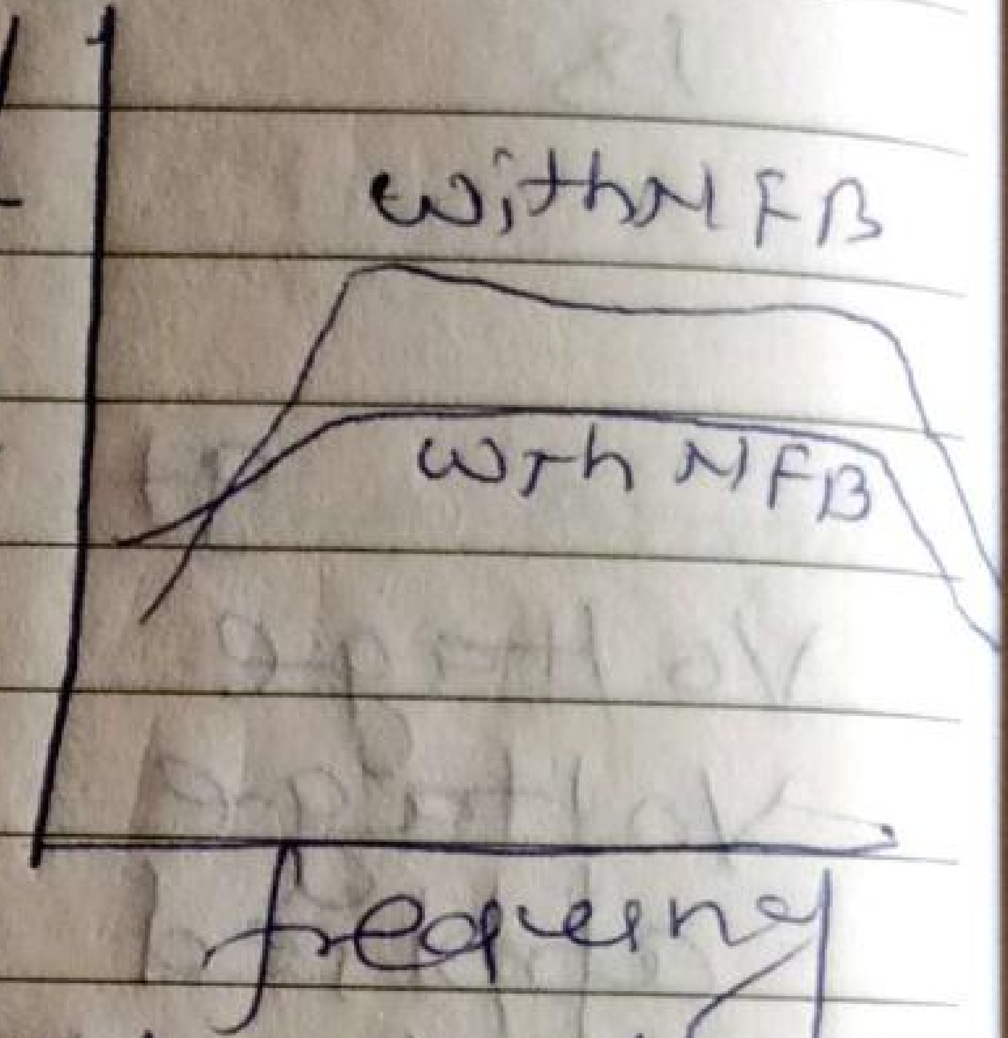
$$\frac{e_n'}{e_n} = \frac{1}{1+A\beta}$$

$$\frac{e_n'}{e_n} = \frac{e_n'/e_1}{e_n/e_1} = \frac{D_n'}{D_n} = \frac{1}{1+A\beta}$$

Therefore the application of negative feedback reduces non linear distortion.

(III) Negative feedback reduces frequency distortion.

This distortion is due to the variation in the gain of an amplifier with frequency. If $A\beta >> 1$, $A_f = 1/\beta$, β is independent of frequency then overall gain becomes independent of frequency over the range of frequencies for which this condition is satisfied.



(IV) Negative feedback reduces phase distortion →

Negative feedback reduces the phase-shift through an amplifier.

let $A = |A| \angle \theta$

Then the gain A_f with feedback

$$A_f = |A_f| \angle \theta_f = \frac{A}{1+\beta A}$$

$$= \frac{|A| \angle \theta}{1+\beta |A| \angle \theta} = \frac{|A| \angle \theta}{1+\beta |A| \cos\theta + j \cdot \beta |A| \sin\theta}$$

Hence $\theta_f = \theta - \tan^{-1} \frac{\beta |A| \sin\theta}{1+\beta |A| \cos\theta}$

Thus by the application of Negative feedback, the phase-shift is reduced by the angle $\tan^{-1}\{(\beta |A| \sin\theta)/(1+\beta |A| \cos\theta)\}$

Negative feed back Increasing the Input Impedance →

let e_s be the input signal and Z_i the input impedance without feed back. If I_1 is the current flowing in the input circuit with Negative feed back then

input impedance with feed back

$$Z_{if} = e_s / I_s$$

If e_o is the output voltage when negative feedback is applied then, the feed back voltage is βe_o and therefore, the net input voltage with negative feedback is $(e_s - \beta e_o)$

$$\therefore j_1 = \frac{e_s - \beta e_o}{Z_i}$$

gain Amplifier $A = \frac{e_o}{e_s - \beta e_o}$

$$e_o = \frac{A e_s}{1 + \beta A}$$

$$j_1 = \left(e_s - \frac{\beta A e_s}{1 + \beta A}\right) \cdot \frac{1}{Z_i}$$

$$= e_s \left(\frac{1 + \beta A - \beta A}{1 + \beta A}\right) \cdot 1/Z_i$$

$$\boxed{j_1 = e_s \left(\frac{1}{1 + \beta A}\right) \cdot \frac{1}{Z_i}}$$

$$Z_{if} = e_s / j_1 = Z_i (1 + \beta A)$$

$$\boxed{\frac{Z_{if}}{Z_i} = 1 + \beta A}$$

(15) Negative feedback reduces the output Impedance →

let e_s be the input signal and z_i the input impedance without feedback. If i_i is the current flowing in the input circuit with negative feedback

input Impedance with feedback

$$z_{if} = e_s / I_i$$

If e_o is the output voltage when negative feedback is applied, then the feedback voltage is βe_o.

The net input voltage with negative feedback $(e_s - \beta e_o)$

$$\therefore i_1 = \frac{e_s - \beta e_o}{z_i}$$

Gain Amplifier $A = \dfrac{e_o}{e_s - \beta e_o}$

$$e_o = \frac{A e_s}{1 + \beta A}$$

$$i_1 = \left(e_s - \frac{\beta A e_s}{1 + \beta A}\right) \cdot \frac{1}{z_i}$$

$$= e_s \left(\frac{1}{1 + \beta A}\right) \cdot 1/z_i$$

$$e_s / i_1 = z_i \cdot (1 + \beta A)$$

output Impedance $Z_{of} = Z_o / 1 + \beta A$