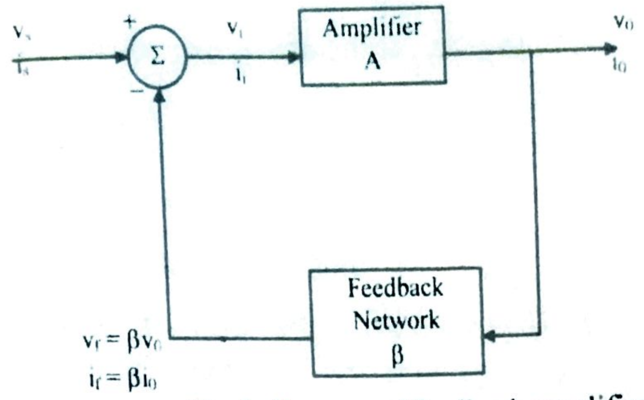


Block diagram of feedback amplifier

The transfer gains of the amplifier and the feedback network are A & β respectively,

i.e., $A = \dfrac{\upsilon_0}{\upsilon_i}$ & $\beta = \dfrac{\upsilon_f}{\upsilon_0}$

A is also known as ***open loop gain*** of the amplifier. The feedback network can contain passive as well as active elements. The fraction β is also known as the feedback ratio or factor.

The overall gain A_f of the feedback amplifier is the ratio of the o/p voltage υ_0 to the externally applied input voltage υ_s i.e., $A_f = \dfrac{\upsilon_0}{\upsilon_s}$

Now from fig 1 we have for –ve feedback, $\upsilon_i = \upsilon_s - \upsilon_f$

Then $\upsilon_0 = A\upsilon_i = A(\upsilon_s - \upsilon_f)$

Since $\upsilon_f = \beta\upsilon_o$

$\upsilon_0 = A(\upsilon_s - \beta\upsilon_0)$ or, $\upsilon_0(1 + A\beta) = A\upsilon_s$ or, $A_f = \dfrac{\upsilon_0}{\upsilon_s} = \dfrac{A}{1 + A\beta}$

The term βA is called ***loop gain***.

Input Impedance & Output Impedance

In **Voltage-series feedback amplifier** the input impedance with feedback.

$Z_{if} = \dfrac{V_s}{I_i} = Z_i(1 + \beta A_v)$ and

Output impedance with feedback, $Z_{of} = \dfrac{V_o}{I_o} = \dfrac{Z_o}{(1 + \beta A_v)}$

Stability

We know that the voltage gain of an amplifier with negative feedback, $A_v' = \dfrac{A_v}{1 + \beta A_v}$

Taking natural logarithm on both sides of the above expression, $\log_e A'_v = \log_e\left(\frac{A_v}{1+\beta A_v}\right)$

$= \log_e A_v - \log_e(1+\beta A_v)$

Differentiating both side, $\frac{dA'_v}{A'_v} = \frac{dA_v}{A_v} - \left(\frac{\beta.dA_v}{1+\beta.A_v} + \frac{A_v.d\beta}{1+\beta.A_v}\right)$

The derivative of β (i.e., $d\beta$) is zero, because the feedback network, usually, consists of stable elements such as resistor, capacitors and inductors. Therefore,

$$\frac{dA'_v}{A'_v} = \frac{dA_v}{A_v} - \frac{\beta.dA_v}{1+\beta.A_v} = dA_v\left(\frac{1}{A_v} - \frac{\beta}{1+\beta.A_v}\right) = \frac{1}{1+\beta.A_v} \times \frac{dA_v}{A_v} \approx \frac{1}{\beta A_v} \times \frac{dA_v}{A_v} \quad \text{if } \beta A_v >> 1$$

The term $\frac{dA'_v}{A'_v}$ represents the fractional change in amplifier voltage gain with feedback and $\frac{dA_v}{A_v}$ the fractional change in voltage gain without feedback. The term $\frac{1}{1+\beta.A_v}$ is called ***sensitivity***. It indicates the ratio of percentage change in voltage gain with feedback to the percentage change in voltage gain without feedback.

Mathematically, the sensitivity $\frac{\frac{dA'_v}{A'_v}}{\frac{dA_v}{A_v}} = \frac{1}{1+\beta.A_v} \approx \frac{1}{\beta A_v}$

In this way we can minimize the change in gain of the voltage amplifier. Thus negative feedback stabilizes the gain.

Bandwidth

Consider an amplifier, whose bandwidth is required to be found out when it is subjected to negative feedback.

Let BW = Bandwidth of an amplifier without feedback and

BW' = Bandwidth of an amplifier with feedback,

A_v = Voltage gain of the amplifier without feedback, and

β = Feedback ratio.

We know that negative feedback reduces the gain and gain-bandwidth product (GBW) must remain constant, so bandwidth of an amplifier must increase by a factor equal to $(1 + \beta A_v)$.

$$BW' = (1 + \beta A_v)\, BW$$

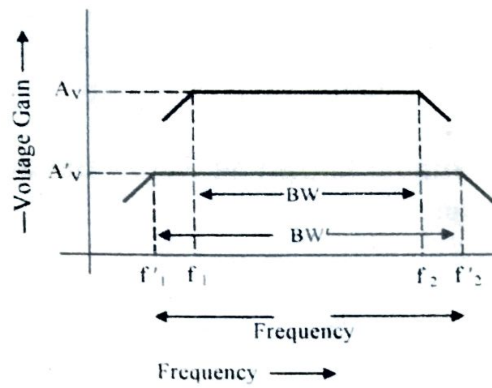
By introducing negative feedback we are sacrificing gain for bandwidth. We know that bandwidth of an amplifier is given by the separation between the upper and lower 3 dB frequencies.

Now let, f_1 = the lower 3 dB frequency, and f_2 = the upper 3dB frequency.

Bandwidth of the amplifier. $BW = f_2 - f_1$

It can be proved easily that with negative feedback the upper (f_2') and lower (f_1') 3dB frequencies of an amplifier are given by the relation.

$$f_2' = (1+\beta.A_v)f_2;\quad f_1' = \frac{f_1}{(1+\beta.A_v)}$$



It is evident from the above relations that the upper 3 dB frequency (f_2') is greater than f_2 by a factor of $(1+\beta A_v)$. Similarly, f_1' is smaller than f_1 by a factor of $(1+\beta A_v)$. Since the product of voltage gain and bandwidth is the same without feedback and with feedback, therefore

$$A_v' \times BW' = A_v \times BW$$

or, $A_v' \times (f_2' - f_1') = A_v(f_2 - f_1)$

The above facts are illustrated in the frequency response graph (*i.e.*, gain versus frequency graph) as shown in the figure.

2.2. With the help of a block diagram, explain the working principle of a feedback amplifier. Derive an expression for the voltage gain with feedback. [WBUT 2013]

Answer:

Refer to Question No. 2.1 and rest part is given below.

Different Conditions of Feedback

1) If $|1+A\beta| > 1$, we have $|A_f| < |A|$ which characterizes negative feedback.

2) If $|1+A\beta| < 1$, we obtain $|A_f| > |A|$ which gives positive feedback.

3) If $|1+A\beta| = 0$, $|A_f| = \infty$, implying that the amplifier gives an o/p signal even in the absence of an input signal. The amplifier is then behaves as an ***oscillator***.

Note: The amount of feedback introduced into an amplifier may also be expressed in decibels (dB) by the expression.

$$F = \text{Feedback in dB.} = 20\log\left(\frac{A_f}{A}\right) = 20\log\left(\frac{1}{1+\beta A}\right)$$

2.3. What is positive feedback? Name the different feedback topologies. [WBUT 2014]

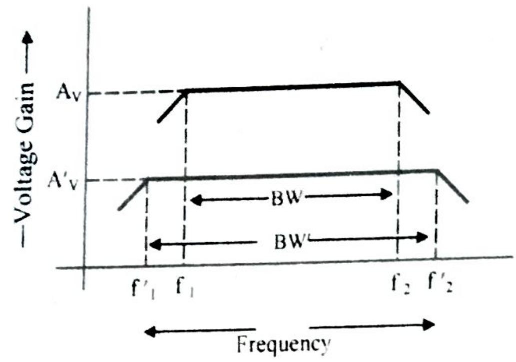
Answer:

When application of feedback signal increases the input signal i.e., the signal fed back is in phase with the input signal, it is called positive feedback. Positive feedback increases the gain of the amplifier, but it also increases distortion and instability of amplifier. So, positive feedback is normally not used in amplifier. If the positive feedback in an amplifier is sufficiently large, it leads to oscillation and hence it is used in oscillators.

Different feedback topologies are:
1. Voltage-series feedback amplifier
2. Voltage-Shunt Feedback Amplifier
3. Current-Series Feedback Amplifier
4. Current-Shunt Feedoack Amplifier

2.4. What is known as Gain – bandwidth product of an amplifier? **[WBUT 201**

Answer:



$$A'_v \times BW' = A_v \times BW$$

Frequency ⟶

$$\text{or, } A'_v \times (f'_2 - f'_1) = A_v(f_2 - f_1)$$

From the above expression, the gain bandwidth product of an amplifier is (Gain of t amplifier) × (Band-width of the amplifier) and it is constant.

2.5. What is oscillator? Which type of feedback is used to design an oscillato Draw the block diagram of an oscillator and explain its principle of operation.
[WBUT 201

Answer:
Oscillator is an electronic circuit which produces output signal without applying inp signal.
Positive feedback is used in an oscillator.
Fig. 1 shows the block diagram of a feedback amplifier consisting of a basic amplifi and a feedback network.

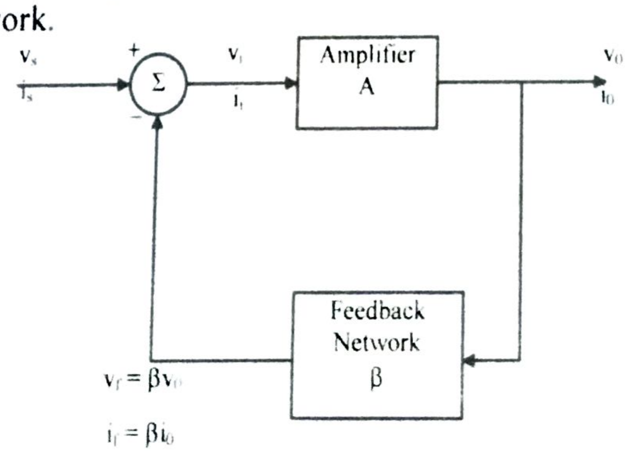


Fig. 1 Block diagram of feedback amplifier

Increase in input impedance
Without feedback the input impedance

$$Z_{in} = \frac{V_{in}}{I_{in}}$$

Now with feedback input voltage is

$v_s = v_{in} + v_f$

or, $v_s = v_{in} + \beta v_o$

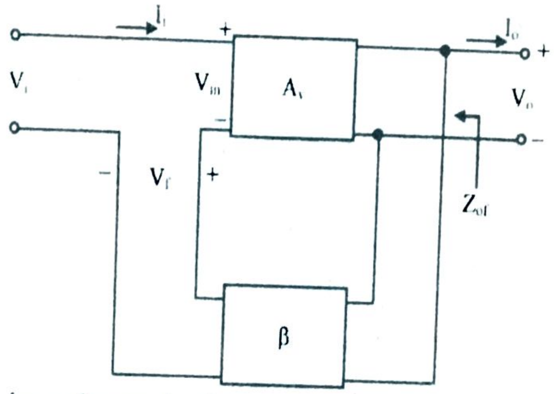
or, $v_s = v_{in} + \beta A v_{in}$

or, $v_s = v_{in}(1 + \beta A)$

Now with feedback input impedance

$$Z_{if} = \frac{v_s}{I_{in}} = \frac{v_{in}(1 + \beta A)}{I_{in}} = Z_{in}(1 + \beta A)$$

Decrease in output impedance



For measuring output impedance the input voltage is short circuited and we connect a source with value V_o at the output.

$$Z_{of} = \frac{V_o}{I_o}$$

Now without feedback if output impedance is Z_o then

$$A_v V_{in} = I_o Z_o + V_o$$

or, $$Z_o = \frac{A_v V_{in} - V_o}{I_o}$$

Now $V_{in} = V_i - V_f = -V_f = -\beta V_o$

$$\therefore \quad Z_o = \frac{-A_v \beta V_o - V_o}{I_o} = -\frac{V_o}{I_o}(1 + A_v \beta) = Z_{of}(1 + A_v \beta)$$

or, $$Z_{of} = \frac{Z_o}{(1 + A_v \beta)}$$

Long Answer Type Questions

3.1. a) Write short note on Advantages of negative feedback amplifier. **[WBUT 2007]**

OR,

What are the advantages of negative feedback? **[WBUT 2010]**

Answer:

If the feedback signal (*i.e.*, voltage or current) is applied in such a way that it is *out of phase with the input signal* and thus decreases it, then it is called a negative feedback. Sometimes, it is also called as degenerative feedback or inverse feedback.

The negative feedback reduces gain of the amplifier. However, it improves the amplifier performance in many other respects. Thus a negative feedback is frequently used in small-signal as well as with large-signal amplifier circuits.

Feedback factor: It is used to control the portion of output signal fed back to the input. It is denoted by β.

Advantages of Negative Feedback

1. Increased stability.
2. Increased bandwidth.
3. Less amplitude and harmonic distortion.
4. Decreased noise.
5. Less frequency distortion.
6. Less phase distortion.
7. Input and output resistances can be modified as desired.

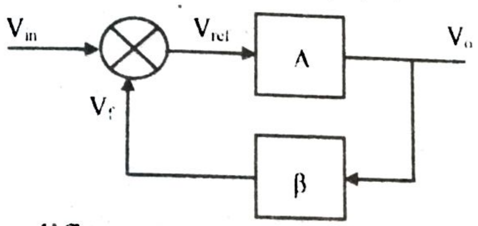
b) Write short note on 'Barkhausen Criterion'. **[WBUT 2007, 2008, 2013, 2015]**

OR,

State the Barkhausen criterion of sinusoidal oscillations. **[WBUT 2011, 2014]**

Answer:

Let amplifier gain is A and feedback factor is β..



The oscillation in any amplifier can occur if positive feedback with infinite gain exists,

i.e., $A_f = \infty$ Hence $A_f = \dfrac{A}{1 - A\beta}$

$1 - A\beta = 0$ So $\boxed{A\beta = 1}$

This relation is known as ***Barkhausen criterion***. But practically the gain of an amplifier and the feedback factor will be complex quantities and frequency dependent and is limited by the non-linearity of the circuit elements. The frequency of sinusoidal oscillation is determined by the condition that the loop gain phase shift is zero.

This condition implies both:

1) $|A\beta| = 1$
2) Phase shift of Aβ is zero or integer multiples of 2π

c) Compare between voltage and current feedback mechanism. **[WBUT 2007]**

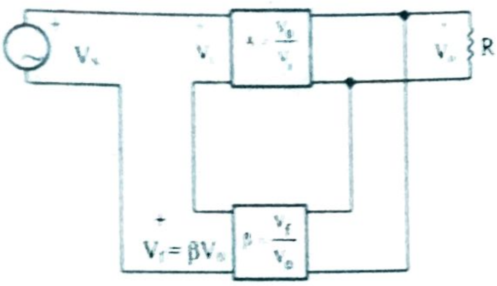
OR,

Explain with proper diagram the configuration of current series and current shunt feedback circuit. **[WBUT 2010]**

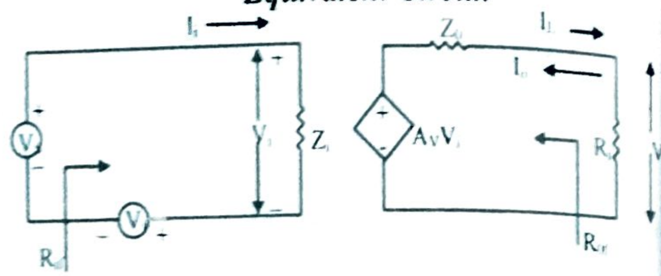
Answer:

Voltage-series feedback amplifier

Block Diagram



Equivalent Circuit



Voltage gain

Voltage gain of an amplifier without feedback is represented by,

$$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_i} \qquad (V_s \approx V_i)$$

voltage gain of an amplifier with feedback is represented by $A_{vf} = \dfrac{V_o}{V_s}$

If a feedback signal (V_f) is connected in series opposition (negative feedback condition) with the source signal (V_s), then $V_i = V_s - V_f$

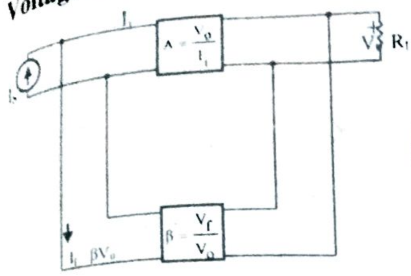
But $V_o = A_v V_i = A_v(V_s - V_f) = A_v V_s - A_v V_f = A_v V_s - A_v(\beta V_o)$

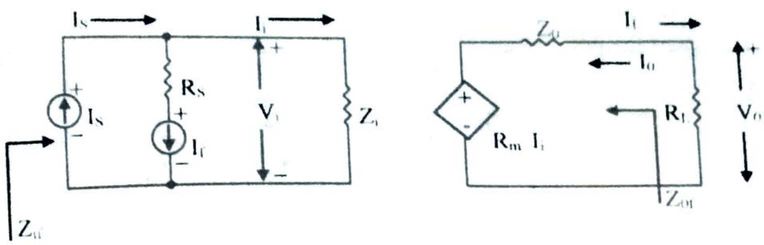
Where, feedback factor, $\beta = \dfrac{V_f}{V_o}$

Therefore, $(1 + \beta A_v)V_o = A_v V_s$

The overall voltage gain of an amplifier with feedback is given by, $A_{vf} = \dfrac{V_o}{V_s} = \dfrac{A_v}{(1 + \beta A_v)}$

Voltage-Shunt Feedback Amplifier **Equivalent Circuit**





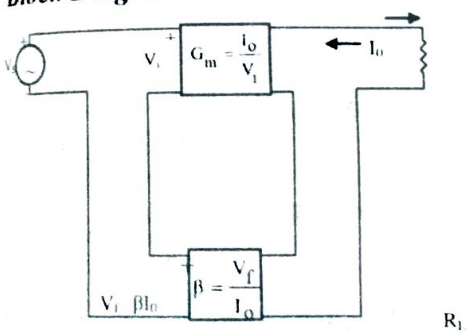
Trans-resistance ($R_m = \frac{V_o}{I_i}$)

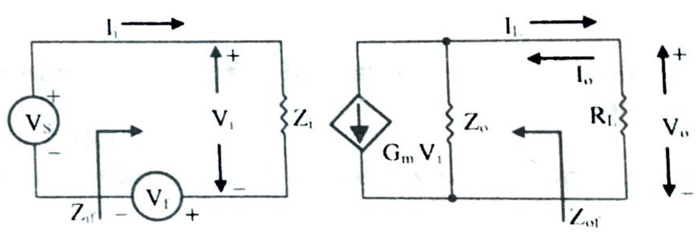
In case of voltage-shunt feedback amplifier, the feedback terms are defined in terms of trans-resistance. Therefore, trans-resistance can be defined as the ratio of output voltage (V_o) to input current (I_s) i.e.,

$$R_{mf} = \frac{V_o}{I_s} = \frac{R_m I_i}{I_i + I_f} = \frac{R_m I_i}{I_i + \beta V_o} = \frac{R_m I_i}{I_i + \beta R_m I_i} \quad \text{here, } \beta = \frac{I_f}{V_o} \text{ so} \quad R_{mf} = \frac{R_m}{1 + \beta R_m}$$

Current-Series Feedback Amplifier **Equivalent Circuit**

Block Diagram





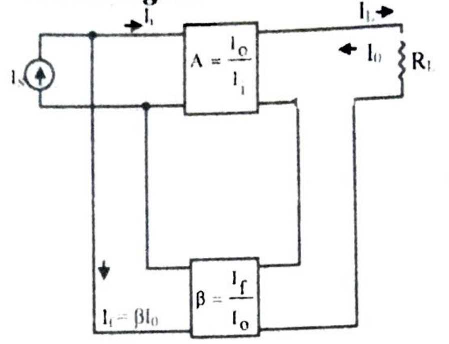
Trans-conductance **(** $\mathbf{G_m = \frac{I_0}{V_i}}$ **)**

In case of current-series feedback amplifier, the feedback terms are defined in terms of trans-conductance. Therefore, trans-conductance can be defined as the ratio of output current (I_0) to input voltage (V_i) i.e., $G_{mf} = \frac{I_o}{V_s} = \frac{G_m V_i}{V_i + V_f} = \frac{G_m V_i}{V_i + \beta I_o} = \frac{G_m V_i}{V_i + \beta G_m V_i}$

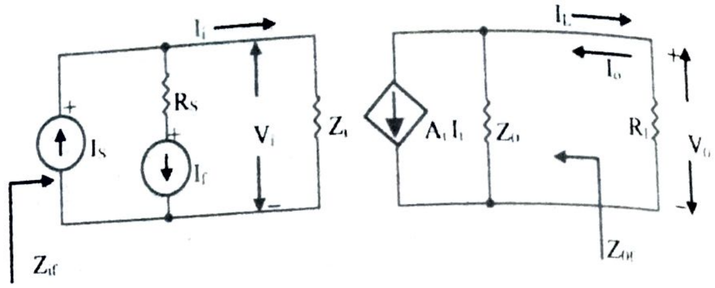
Where, feedback factor, $\beta = \frac{V_f}{I_0}$ so $G_{mf} = \frac{G_m}{1 + \beta G_m}$

Current-Shunt Feedback Amplifier

Block Diagram



Equivalent Circuit



Current gain (A_i)

In case of current-shunt feedback amplifier, the feedback terms are defined in terms of current gain. Therefore, current gain can be defined as the ratio of output current (I_o) to input current (I_i) i.e., $A_{if} = \frac{I_o}{I_s}$

In case of current-shunt feedback amplifier, the source current is equal to sum of input current and feedback current. Therefore, $I_s = I_i + I_f = I_i + \beta I_o = I_i + \beta(A_i I_i)$

Current gain with feedback can be written in terms of current gain without feedback as,

$$A_{if} = \frac{I_o}{I_s} = \frac{A_i I_i}{(1+\beta A_i)I_i} = \frac{A_i}{(1+\beta A_i)}.$$

3.2. Mention the advantage and disadvantage of a negative (–ve) feedback amplifier. **[WBUT 2007, 2010]**

OR,

Mention the advantages and disadvantages of negative feedback amplifier. **[WBUT 2012]**

Answer:

Advantages and Disadvantages of Negative Feedback Though there are numerous advantages of employing negative feedback in the amplifier, yet some of the important are given below:

1. Increased stability.
2. Increased bandwidth.
3. Less amplitude and harmonic distortion.
4. Decreased noise.
5. Less frequency distortion.
6. Less phase distortion.
7. Input and output resistances can be modified as desired.

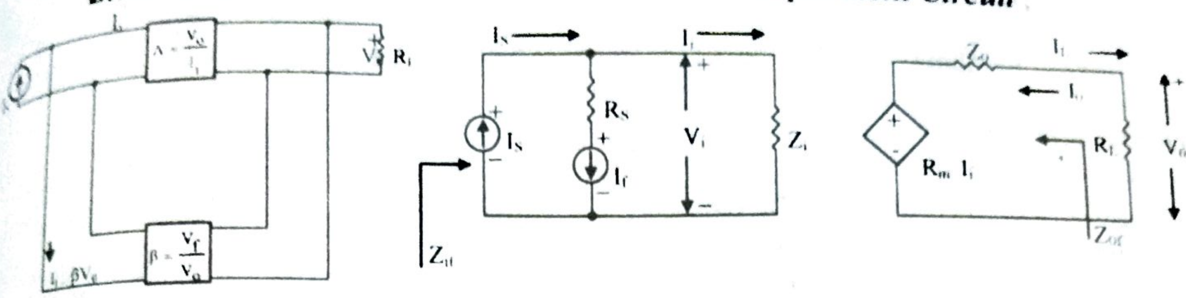
The only disadvantage of negative feedback is that it reduces the amplifier gain. However, this disadvantage is outweighed due to numerous advantages obtained through negative feedback.

3.3. Write down the effect of negative feedback in an amplifier in terms of gain, bandwidth, input resistance and output resistance with respect to voltage series configuration. **[WBUT 2009]**

Answer:

Voltage-series feedback amplifier

Block Diagram ***Equivalent Circuit***



Voltage gain

Voltage gain of an amplifier without feedback is $A_v = \frac{V_o}{V_s} = \frac{V_o}{V_i} \quad (V_s \approx V_i)$

voltage gain of an amplifier with feedback is $A_{vf} = \frac{V_o}{V_s}$

If a feedback signal (V_f) is connected in series opposition (negative feedback condition) with the source signal (V_s), then $V_i = V_s - V_f$

But $V_o = A_v V_i = A_v(V_s - V_f) = A_v V_s - A_v V_f = A_v V_s - A_v(\beta V_o)$

Where, feedback factor, $\beta = \frac{V_f}{V_o}$

Therefore, $(1+\beta A_v)V_o = A_v V_s$

The overall voltage gain of an amplifier with feedback is given by,

$$A_{vf} = \frac{V_o}{V_s} = \frac{A_v}{(1+\beta A_v)}$$

Bandwidth

Consider an amplifier, whose bandwidth is required to be found out when it is subjected to negative feedback.

Let BW = Bandwidth of an amplifier without feedback and
BW' = Bandwidth of an amplifier with feedback,
A_v = Voltage gain of the amplifier without feedback, and
β = Feedback ratio.

We know that negative feedback reduces the gain and gain-bandwidth product (GBW) must remain constant, so bandwidth of an amplifier must increase by a factor equal to $(1+\beta A_v)$. $BW' = (1+\beta A_v)\, BW$

Input impedance
To find the input impedance of voltage-series feedback amplifier,

$I_i = \frac{V_i}{Z_i} = \frac{V_s - V_f}{Z_i} = \frac{V_s - \beta V_o}{Z_i} = \frac{V_s - \beta A_v V_i}{Z_i}$; $\qquad I_i Z_i = V_s - \beta A_v V_i$

$V_s = I_i Z_i + \beta A_v V_i$; $\qquad V_s = I_i Z_i + \beta A_v (I_i Z_i)$; $\qquad V_s = I_i Z_i \times (1 + \beta A_v)$

The input impedance with feedback, $Z_{if} = \frac{V_s}{I_i} = Z_i (1 + \beta A_v)$

Output impedance
To find output impedance of voltage-series feedback amplifier, short-circuit the source voltage V_s i.e., $V_s = 0$. Apply a voltage (V_o), which results in a current (I_o) at the output terminal, disconnect the load resistance.

$$V_o = I_o Z_o + A_v V_i; \qquad V_i = V_s - V_f$$

For,

$V_s = 0, \quad V_i = -V_f, \qquad V_o = I_o Z_o + A_v(-V_f)$

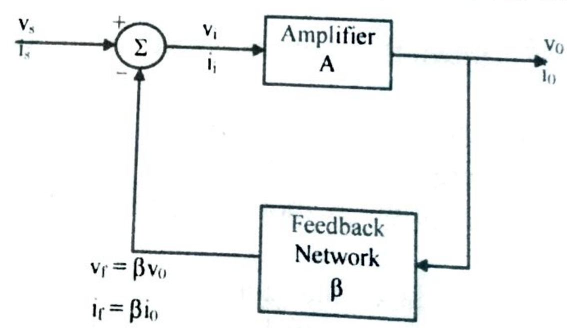
$V_o = I_o Z_o - A_v(\beta V_o)$; $\qquad V_o + A_v \beta_v V_o = I_o Z_o$; $\qquad V_o(1 + A_v \beta) = I_o Z_o$

Output impedance with feedback, $Z_{of} = \frac{V_o}{I_o} = \frac{Z_o}{(1 + \beta A_v)}$

3.4. a) What do you mean by negative feedback? **[WBUT 2011, 2015]**
b) Why is it used in designing an amplifier? **[WBUT 2011, 2015]**
c) The variation of the open-loop gain of an amplifier having internal gain 1000 is 10%, but for a specific use only 1% gain variation is allowed. Design a feedback amplifier for this purpose and find the corresponding feedback fraction and overall gain. **[WBUT 2011]**

Answer:

a) If the feedback signal (*i.e.*, voltage or current) is applied in such a way that it is *out of phase with the input signal* and thus decreases it, then it is called a negative feedback. Sometimes, it is also called as degenerative feedback or inverse feedback.



Block diagram of feedback amplifier

The negative feedback reduces gain of the amplifier. However, it improves the amplifier performance in many other respects. Thus a negative feedback is frequently used in small-signal as well as with large-signal amplifier circuits.

b) There are numerous advantages of employing negative feedback in the amplifier, yet some of the important are given below:

1. Increased stability
2. Increased bandwidth
3. Less amplitude and harmonic distortion
4. Decreased noise
5. Less frequency distortion
6. Less phase distortion
7. Input and output resistances can be modified as desired

The only disadvantage of negative feedback is that it reduces the amplifier gain. However, this disadvantage is outweighed due to numerous advantages obtained through negative feedback.

c) We know, the closed loop gain $A_f = \dfrac{A}{1+AB}$

where,
$A \rightarrow$ open loop gain
$B \rightarrow$ feedback fraction

Given, $(dA_f/A_f)\times 100 = 1 \quad \Rightarrow \quad \dfrac{dA_f}{A_f} = 0.01$

and $\left(\dfrac{dA}{A}\right)\times 100 = 10 \quad \Rightarrow \quad \dfrac{dA}{A} = 0.1$

We know, $A_f = \dfrac{A}{1+AB}$

Differentiate both sides, $dA_f = \dfrac{(1+AB)\,dA - AB\,dA}{(1+AB)^2} = \dfrac{dA}{(1+AB)^2}$

Now, $\dfrac{dA_f}{A_f} = \dfrac{dA/(1+AB)^2}{A/(1+AB)} = \dfrac{dA}{A(1+AB)}$

$$\Rightarrow \quad \frac{dA_f/A_f}{dA/A} = \frac{1}{1+AB}$$

$$\Rightarrow \quad 1+AB = \frac{dA/A}{dA_f/A_f} = \frac{0.1}{0.01} = 10$$

We know, $A = 1000$

Therefore, $B = \dfrac{10-1}{A} = 0.009$

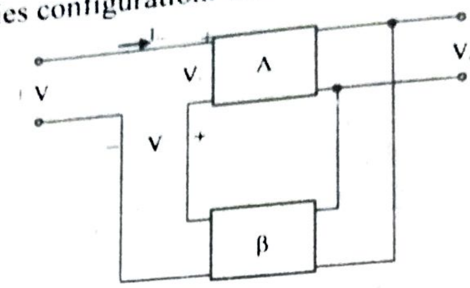
Overall gain, $A_f = \dfrac{A}{1+AB} = \dfrac{1000}{1+1000\times 0.009} = 100$

$\therefore$ Feedback fraction $B = 0.009$ and overall gain $A_f = 100$.

3.5. a) What is the effect of negative feedback on output impedance and phase distortion? [WBUT 2012]

Answer:

The negative feedback has the following effects on the performance of amplifier. Here it is shown for Voltage-series configuration. This will depend on the type of connection.



Increase in input impedance

Without feedback the input impedance, $Z_{in} = \dfrac{V_{in}}{I_{in}}$

Now with feedback input voltage is

$v_s = v_{in} + v_f$

or, $v_s = v_{in} + \beta v_o$

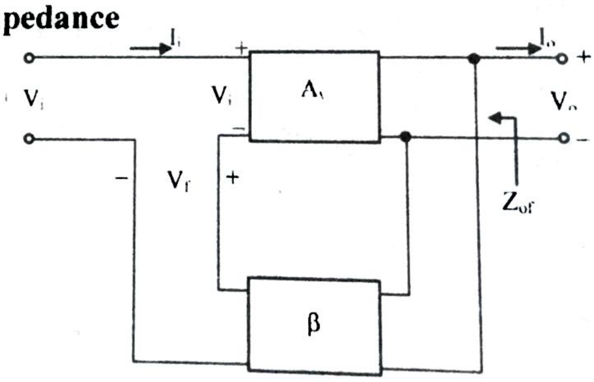
or, $v_s = v_{in} + \beta A v_{in}$

or, $v_s = v_{in}(1+\beta A)$

Now with feedback input impedance

$$Z_{if} = \frac{v_s}{I_{in}} = \frac{v_{in}(1+\beta A)}{I_{in}} = Z_{in}(1+\beta A)$$

Decrease in output impedance



For measuring output impedance the input voltage is short circuited and we connect a source with value V_o at the output.

$Z_{of} = \dfrac{V_o}{I_o}$

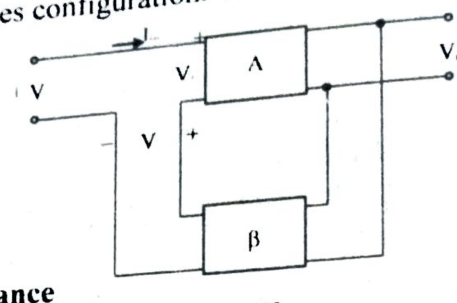
Now without feedback if output impedance is Z_o then

$A_v V_{in} = I_o Z_o + V_o$

3.5. a) What is the effect of negative feedback on output impedance and phase distortion? **[WBUT 2012]**

Answer:

The negative feedback has the following effects on the performance of amplifier. Here it is shown for Voltage-series configuration. This will depend on the type of connection.



Increase in input impedance

Without feedback the input impedance, $Z_{in} = \frac{V_{in}}{I_{in}}$

Now with feedback input voltage is

$v_s = v_{in} + v_f$

or, $v_s = v_{in} + \beta v_o$

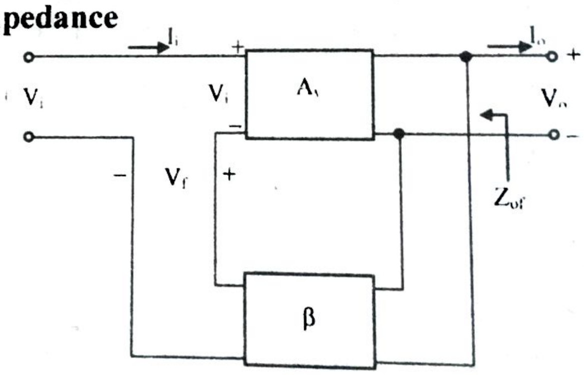
or, $v_s = v_{in} + \beta A v_{in}$

or, $v_s = v_{in}(1+\beta A)$

Now with feedback input impedance

$$Z_{if} = \frac{v_s}{I_{in}} = \frac{v_{in}(1+\beta A)}{I_{in}} = Z_{in}(1+\beta A)$$

Decrease in output impedance



For measuring output impedance the input voltage is short circuited and we connect a source with value V_o at the output.

$$Z_{of} = \frac{V_o}{I_o}$$

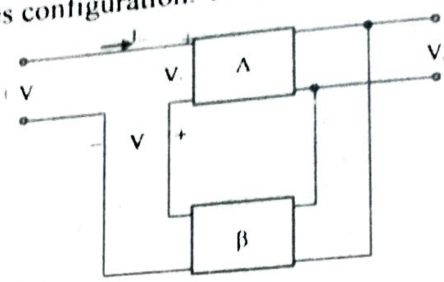
Now without feedback if output impedance is Z_o then

$$A_v V_{in} = I_o Z_o + V_o$$

3.5. a) What is the effect of negative feedback on output impedance and phase distortion? **[WBUT 2012]**

Answer:

The negative feedback has the following effects on the performance of amplifier. Here it is shown for Voltage-series configuration. This will depend on the type of connection.



Increase in input impedance

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Now with feedback input voltage is

$v_s = v_{in} + v_f$

or, $v_s = v_{in} + \beta v_o$

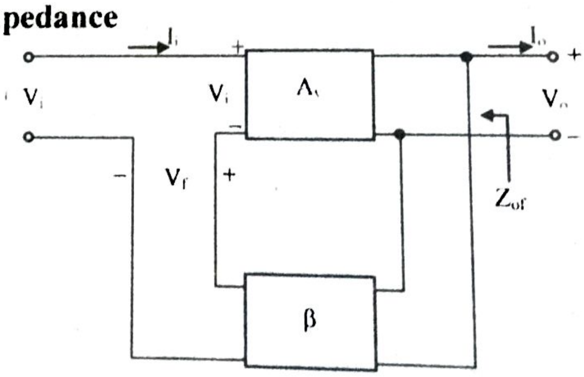
or, $v_s = v_{in} + \beta A v_{in}$

or, $v_s = v_{in}(1 + \beta A)$

Now with feedback input impedance

$$Z_{if} = \frac{v_s}{I_{in}} = \frac{v_{in}(1+\beta A)}{I_{in}} = Z_{in}(1+\beta A)$$

Decrease in output impedance



For measuring output impedance the input voltage is short circuited and we connect a source with value V_o at the output.

$$Z_{of} = \frac{V_o}{I_o}$$

Now without feedback if output impedance is Z_o then

$A_v V_{in} = I_o Z_o + V_o$

or, $Z_o = \frac{A_v V_{in} - V_o}{I_o}$

Now $V_{in} = V_i - V_f = -V_f = -\beta V_o$

$$Z_o = \frac{-A_v \beta V_o - V_o}{I_o} = -\frac{V_o}{I_o}(1 + A_v\beta) = Z_{of}(1 + A_v\beta)$$

or, $Z_{of} = \frac{Z_o}{(1 + A_v\beta)}$

Phase Distortion:

If the feedback network contains reactive components then overall gain is a function of frequency. So, the gain A of the amplifier without feedback can be written as

$$A = |A|.\text{angle}(\Theta)$$

With feedback, the gain is

$$A_f = A/(1+A\beta)$$

The β can be either complex or real quantity. Taking β to be real for simplicity, we obtain

$$\begin{aligned} A_f &= |A|.\text{angle}(\Theta)/(1+ \beta.|A|.\text{angle}(\Theta)) \\ &= |A|.\text{angle}(\Theta)/(1+ \beta.|A|.(\cos\Theta + j\sin\Theta)) \\ &= |A|.\text{angle}(\Theta)/(|B|.\text{angle}(\Phi)) \end{aligned}$$

Where, $B = \sqrt{(1 + \beta.|A|.\cos\Theta)^2 + (\beta.|A|.\sin\Theta)^2}$

And $\Phi = tan^{-1}\frac{\beta|A|\sin\Theta}{1-\beta|A|\cos\Theta}$

Writing, $A_f = |A_f|.\text{angle}(\Theta_f)$

Therefore, the magnitude of A_f is; $|A_f| = \frac{|A|}{|B|}$

And phase angle of A_f is; $\Theta_f = \Theta - \Phi$

So, clearly negative feedback decreases the phase angle of the gain by Φ. Since the phase angle by which the output signal leads the input signal diminishes, the phase distortion is reduced.

b) An amplifier has a voltage gain of -100. The feedback ratio is -0.04. Find
i) the voltage gain with feedback
ii) the amount of feedback in dB
iii) the output voltage of the feedback amplifier for an input voltage of 40 mV
iv) the feedback factor
v) the feedback voltage. **[WBUT 2012]**

Answer:

i) voltage gain $= \frac{A}{1+\beta A} = \frac{-100}{1+(-100)\times(-0.04)} = \frac{-100}{1+4} = -20$

ii) amount of feedback in db: $F = 20\log\left(\frac{A_f}{A}\right) = 20\log\left(\frac{-20}{-100}\right) \approx -14dB$

iii) output voltage; $V_{out} = A_f \times V_{in} = (-20) \times 40 \times 10^{-3} = -800 \times 10^{-3} = -0.8V$

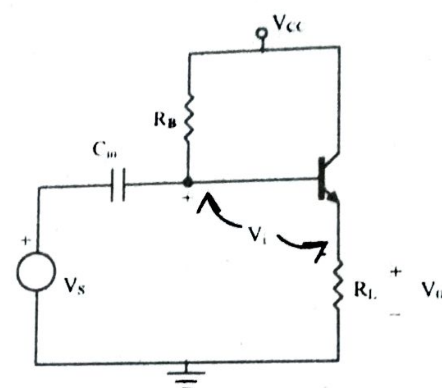
iv) feedback factor $= \dfrac{1}{1+A\beta} = \dfrac{1}{1+(-100)\times(-0.04)} = \dfrac{1}{5}$

v) feedback voltage $V_f = \beta \times V_{out} = (-0.04)\times(-0.8) = 0.032V$ considering $V_{out} = -0.8V$

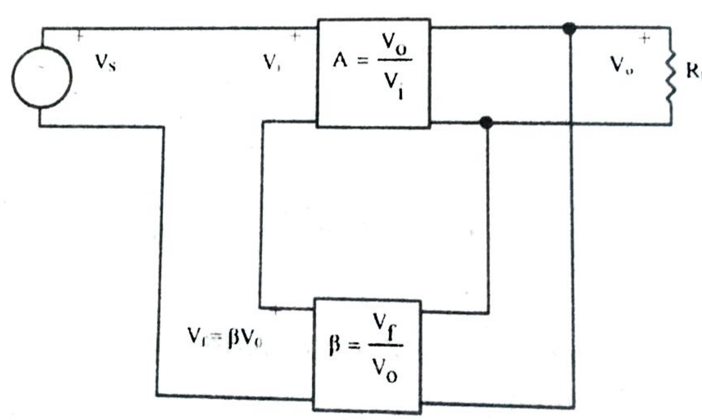
3.6. a) Draw the circuit diagram of an emitter follower and explain the nature of feedback in this circuit. What is the feedback topology of emitter follower?
b) The open loop gain of an amplifier changes by 20% due to the changes in the parameters of the active amplifier device. If a change of gain by 2% is allowable, what type of feedback has to be applied? If the amplifier gain with feedback is 10, find the minimum value of the feedback ratio and the open loop gain. [WBUT 2013]

Answer:

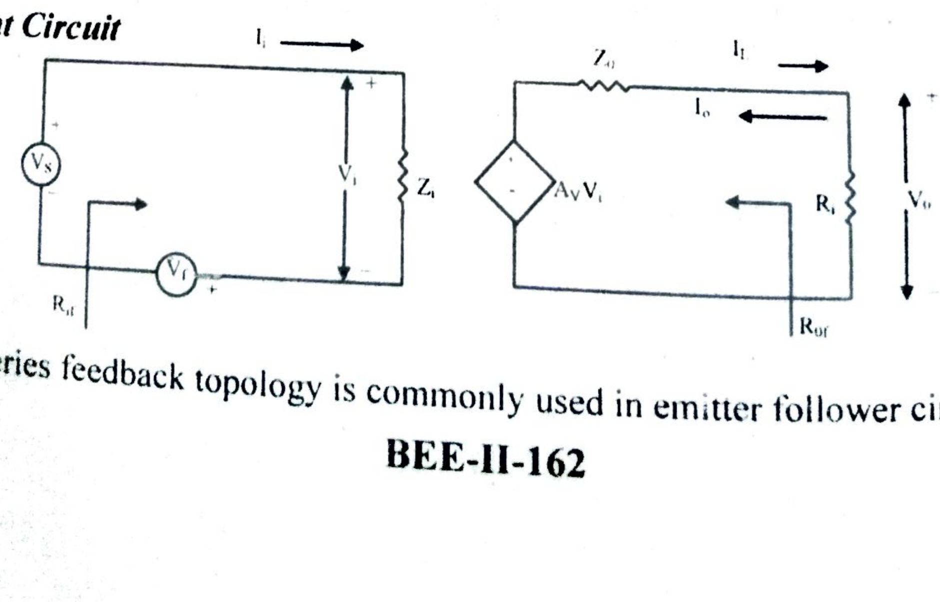
a) Emitter Follower



Block Diagram



Equivalent Circuit



Voltage-Series feedback topology is commonly used in emitter follower circuit.

b) Given $\frac{dA}{A} = 20\%$ and $\frac{dA_f}{A_f} = 2\%$

We know, $\frac{dA_f}{A_f} = \frac{1}{1+\beta A}\frac{dA}{A}$

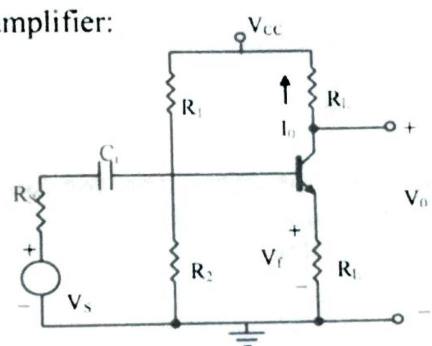
$\frac{2}{100} = \frac{1}{1+\beta \times A} \times \frac{20}{100}$ or $1+\beta \times A = \frac{20}{2}$ or $\beta = \frac{10-1}{A} = \frac{9}{A}$

Two unknown values can not be computed from a single equation. Some value is missing in the problem given here.

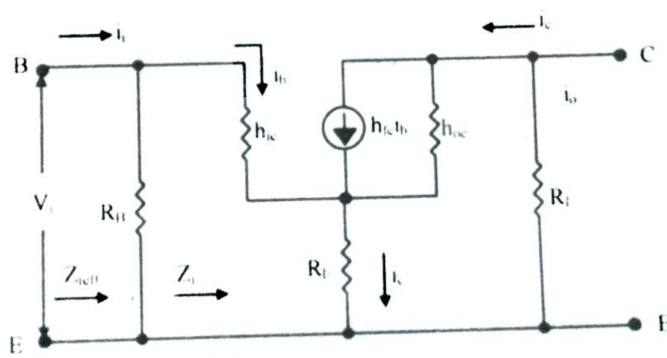
3.7. A current series feedback amplifier has the following circuit parameters: $R_L = 1K\Omega, R_E = 100\Omega, R_2 = 20k\Omega, R_1 = 30k\Omega$ and $h_{fe} = 100$. Calculate A, β, R_{if}, A_f and loop gain in *dB*. **[WBUT 2015]**

Answer:

Current-Series feedback amplifier:



Equivalent Circuit



Trans-conductance without feedback is

$$A = \frac{I_0}{V_i} = I_c/V_{be} = h_{fe}I_b/V_{be} = h_{fe}/R_i$$
$$= h_{fe}/(R_B \| h_{ie}) \approx h_{fe}/(R_1 \| R_2)$$
$$= 100/952 = 0.105\text{mho}$$

The feedback factor is

$$B = V_f/I_0 = R_E = 100\Omega$$

Trans-conductance with feedback is

$$A_f = A/(1+AB) = 9.1\text{milimho}$$

Input Impedance without feedback is

$$R_i = V_i/I_i$$

$$R_i = R_B \| h_{ie} \approx R_B = R_1 \| R_2 = 0.952K\Omega$$

Input Impedance with feedback is

$$R_{if} = R_i(1+AB) \approx 10.95K\Omega$$

3.8. a) What is negative feedback? Draw the block diagram of different types of feedback topologies. **[WBUT 2016]**

Answer:

1st Part:

If the feedback signal (*i.e.*, voltage or current) is applied in such a way that it is *out of phase with the input signal* and thus decreases it, then it is called a negative feedback. Sometimes, it is also called as degenerative feedback or inverse feedback.

The negative feedback reduces gain of the amplifier. However, it improves the amplifier performance in many other respects. Thus a negative feedback is frequently used in small-signal as well as with large-signal amplifier circuits.

2nd Part: ***Refer to Question No. 3.10.***

b) An amplifier has a voltage gain of –100. The feedback ratio is –0.04. Find (i) voltage gain with feedback, (ii) amount of voltage gain, (iii) the output voltage of the feedback amplifier for an input voltage of 40 mV. **[WBUT 2016]**

Answer:

i) We know, $A_f = \dfrac{A}{1+\beta A} = \dfrac{-100}{1+(-0.04)(-100)} = \dfrac{-100}{1+4} = -20$

ii) The amount of feedback introduced into an amplifier may also be expressed in decibels (dB) by the expression.

$$F = 20\log\left(\frac{A_f}{A}\right) = 20\log\left(\frac{20}{100}\right) \approx -14\,dB$$

$$V_o = Af \times V_i = -20 \times 40 = -800mV$$

3.9. a) State and explain the Barkhausen criteria. **[WBUT 2017]**

b) Derive an expression for the gain of an amplifier using positive feedback.

c) A negative feedback of $\beta = 0.002$ is applied to an amplifier of gain 1000. Calculate the change in the overall gain of the feedback amplifier if the internal gain of the amplifier is subjected to gain reduction of 15%.

d) How does negative feedback affects the bandwidth of an amplifier?

Answer:

a) Let amplifier gain is A and feedback factor is β.

The oscillation in any amplifier can occur if positive feedback with infinite gain exists, i.e., $A_f = \infty$ Hence $A_f = \dfrac{A}{1-A\beta}$

Input Impedance without feedback is

$R_i = V_i/I_i$

$R_i = R_B \| h_{ie} \approx R_B = R_1 \| R_2 = 0.952K\Omega$

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3.9. a) State and explain the Barkhausen criteria. **[WBUT 2017]**

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d) How does negative feedback affects the bandwidth of an amplifier?

Answer:

a) Let amplifier gain is A and feedback factor is β.

The oscillation in any amplifier can occur if positive feedback with infinite gain exists,

i.e., $A_f = \infty$ Hence $A_f = \dfrac{A}{1-A\beta}$

$1 - A\beta = 0 = 0$

So $\boxed{A\beta = 1}$

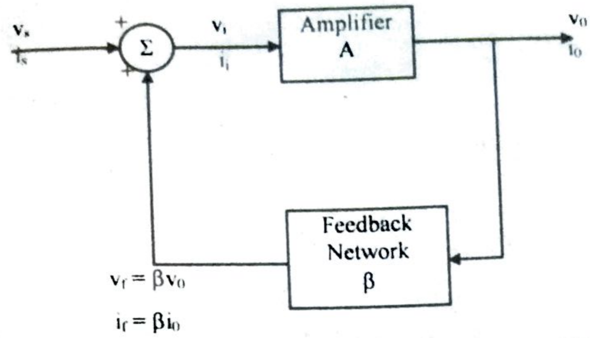


Fig. Block diagram of feedback amplifier

This relation is known as **Barkhausen criterion**. But practically the gain of an amplifier and the feedback factor will be complex quantities and frequency dependent and is limited by the non-linearity of the circuit elements.. The frequency of sinusoidal oscillation is determined by the condition that the loop gain phase shift is zero.

This condition implies both;

1) $|A\beta| = 1$

2) Phase shift of $A\beta$ is zero or integer multiples of 2π

b) The open loop gain of the amplifier and the feedback network are A & β respectively,

i.e., $A = \dfrac{\upsilon_0}{\upsilon_i}$ & $\beta = \dfrac{\upsilon_f}{\upsilon_0}$

The feedback network can contain passive as well as active elements. The fraction β is also known as the feedback ratio or factor.

The overall gain A_f of the feedback amplifier is the ratio of the o/p voltage υ_0 to the externally applied input voltage υ_s i.e., $A_f = \dfrac{\upsilon_0}{\upsilon_s}$

Now from fig, we have for +ve feedback

$$v_i = v_s + v_f$$

Then

$$V_0 = A(v_s + v_f)$$

Since $\upsilon_f = \beta\upsilon_o$

$$v_0 = A\, v_i = A(v_s + v_f)$$

$$v_0 = A(v_s + \beta\, v_0)$$

$$v_0 / v_s = A/(1 - A\,\beta)$$

$A_f = A/(1 - \beta A)$ This is the expression of the gain for positive feedback amplifier.

c) Assume for a negative feedback amplifier,

A→ open loop gain

A_f→ closed loop gain

$\beta \rightarrow$ feedback factor

Given data,

$A = 1000$

$\beta = 0.002$

$dA/A = 0.15$

We have to calculate the value of (dA_f/A_f)

Again we know that,

$dA_f/A_f = \{1/(1+A\beta)\}(dA/A) \times 100\%$

$= (1/3)\times(0.15) \times 100\%$

$= 5\%$

Therefore, if internal gain of the amplifier is reduced by 15% then overall gain will be reduced by 5%.

d) Bandwidth variation with negative feedback

Consider an amplifier, whose bandwidth is required to be found out when it is subjected to negative feedback.

Let BW = Bandwidth of an amplifier without feedback and

BW' = Bandwidth of an amplifier with feedback,

A_v = Voltage gain of the amplifier without feedback, and

β = Feedback ratio.

We know that negative feedback reduces the gain and gain-bandwidth product (GBW) must remain constant, so bandwidth of an amplifier must increase by a factor equal to $(1 + \beta A_v)$.

$$BW' = (1 + \beta A_v)\, BW$$

By introducing negative feedback we are sacrificing gain for bandwidth. We know that bandwidth of an amplifier is given by the separation between the upper and lower 3 dB frequencies.

Now let, f_1 = the lower 3 dB frequency, and f_2=the upper 3dB frequency.

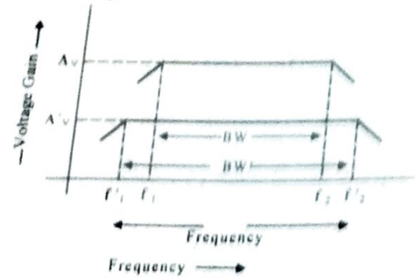
Bandwidth of the amplifier, $BW = f_2 - f_1$

It can be proved easily that with negative feedback the upper (f_2') and lower (f_1') 3 dB frequencies of an amplifier are given by the relation,

$$f_2' = (1 + \beta.A_v)\, f_2$$

$$f_1' = \frac{f_1}{(1 + \beta.A_v)}$$

... are illustrated in the frequency response graph (i.e., gain versus ... as shown in Figure below.



... on the following:

...ck amplifier **[WBUT 2012]**

[WBUT 2014]

...ologies **[WBUT 2017]**

...s of connecting the feedback signal. Both voltage and current ...d back to the input either in services or parallel.

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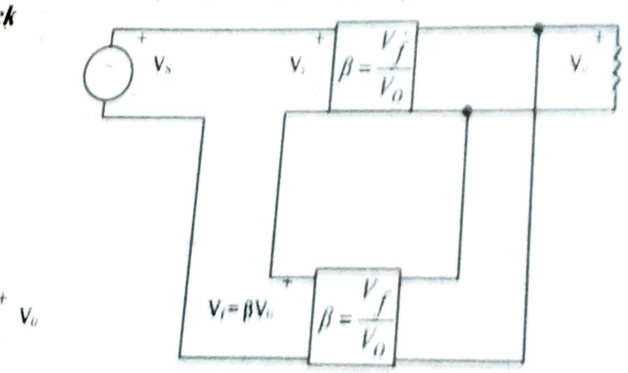
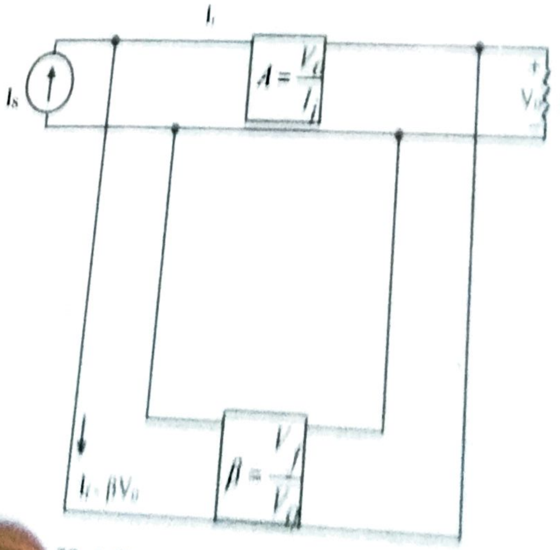
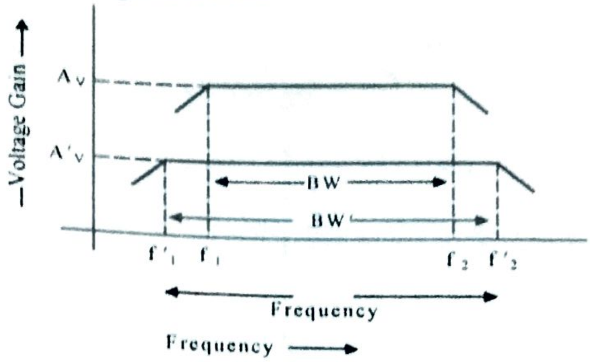




The above facts are illustrated in the frequency response graph (*i.e.*, gain versus frequency graph) as shown in Figure below.

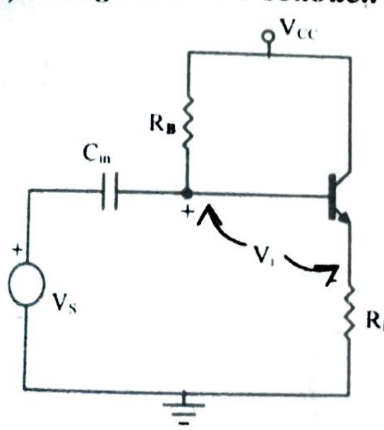


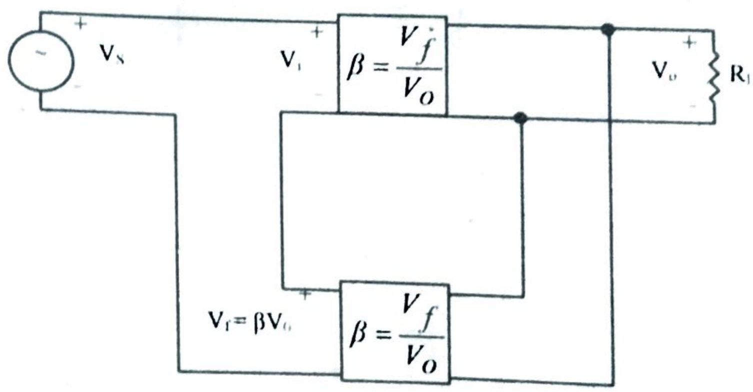
3.10. Write short note on the following:
Topologies of feedback amplifier **[WBUT 2012]**
OR,
Feedback Amplifier **[WBUT 2014]**
OR,
Feedback amplifier topologies **[WBUT 2017]**

Answer:

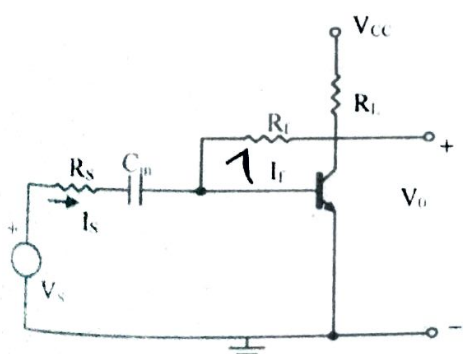
There are four basic ways of connecting the feedback signal. Both voltage and current from the output can be feed back to the input either in services or parallel.

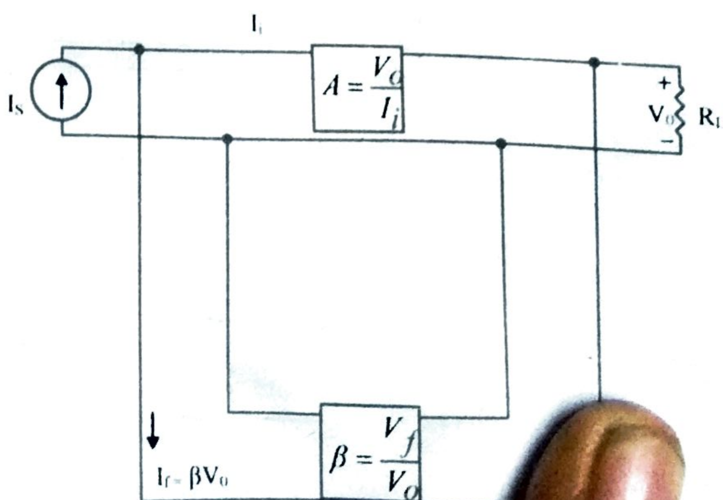
1) Voltage-Series Feedback



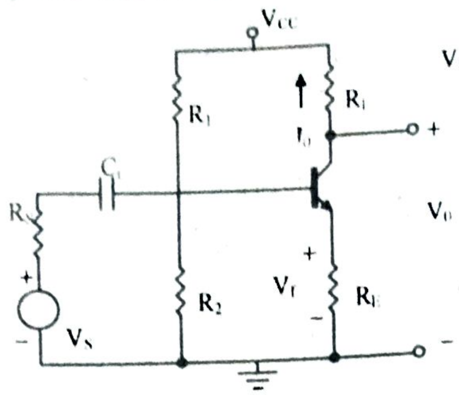


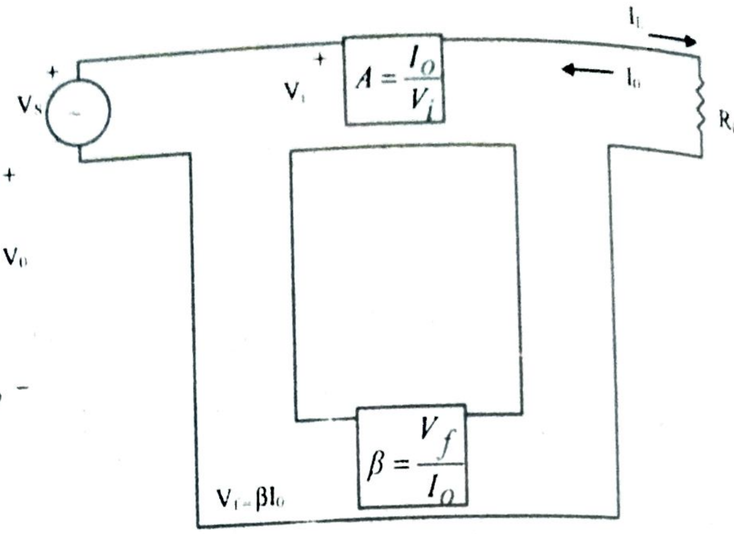
2) Voltage-Shunt Feedback





3) Current Series Feedback





4) Current-Shunt Feedback