Negative Feedback

Negative Feedback

Advantages

1-Stabilizes the gain of the amplifier against parameters changes in the active devices due to temperature .

2- Modifies the input and output impedance in any desired fashion.

3- Increases the Bandwidth .

Disadvantages

1. **Decreases the gain .**
2. **Oscillation .**

Negative Feedback

General Feedback equation

$S_O = AS_\epsilon$

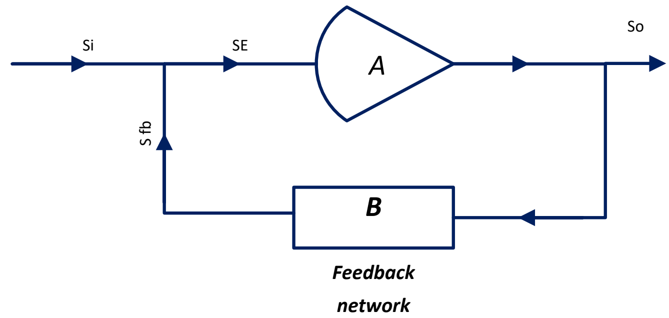
$S_\epsilon = S_i - S_{fb}$

$A_f = \frac{S_O}{S_i} = \frac{A}{1+AB}$

AB ≡ Loop gain

If AB≫ 1

$\therefore A_f = \frac{1}{B}$



Negative Feedback

General Feedback equation

$S_\epsilon = S_i - S_{fb}$

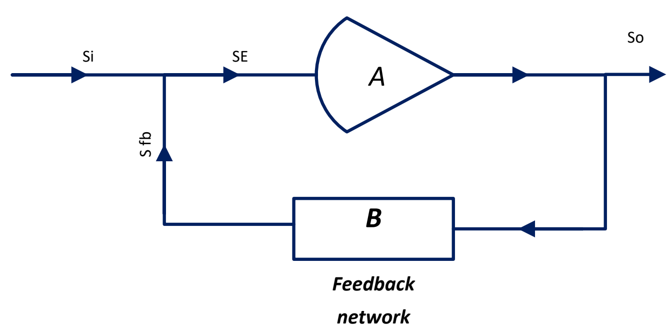
$S_\epsilon = S_i - BS_O$

$S_\epsilon = S_i - B\frac{A}{1+AB}S_i$

$S_\epsilon = S_i(1 - \frac{AB}{1+AB})$

If AB≫ 1

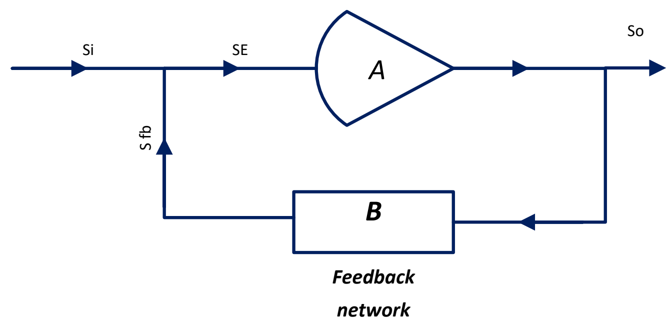
$S_\epsilon \approx S_i(1 - \frac{AB}{AB}) \approx 0$



Negative Feedback

Gain stabilization

$$let\ A = 10,000$$
$$B = 0.01$$
$$\therefore AB = 100$$
$$Af = \frac{A}{1 + AB} = 99$$
$$let\ A = 9000$$
$$B = 0.01$$
$$\therefore AB = 90$$
$$Af = \frac{A}{1 + AB} = 98.9$$



Change in A → change in Af

10% → 0.1%

Negative Feedback

Increasing the Bandwidth.

In high frequency

$$A(jw) = \frac{Am}{1 + \frac{jw}{w2}}$$

$$\therefore wH = w2$$

With Negative Feedback

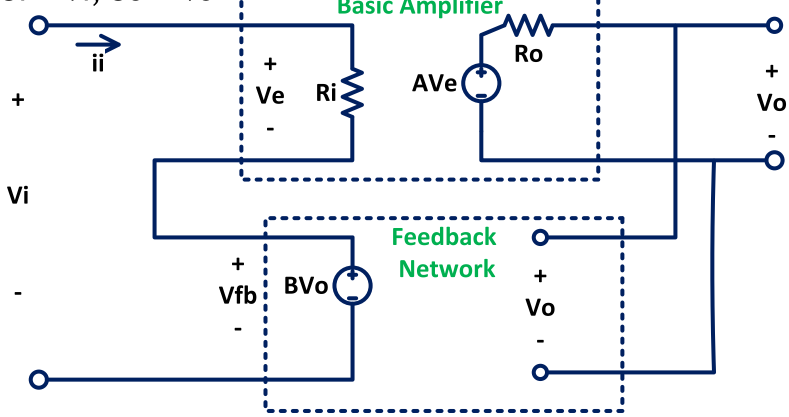
$$Af(jw) = \frac{Am}{1 + AmB} = \frac{1}{1 + \frac{jw}{w2(1 + AmB)}}$$

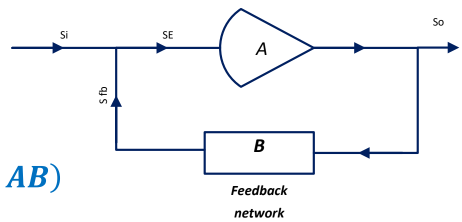
$$\therefore wH = w2(1 + AmB)$$

Types Of Negative Feedback

Negative Feedback

Si = Vi, So = Vo





1) Series – Shunt Feedback

$$Vo = AVe$$

$$Ve = Vi - Vfb$$

$$Vfb = BVo$$

$$\therefore \frac{Vo}{Vi} = \frac{A}{1 + AB} = Af$$

$$Zif = \frac{vi}{ii}$$

$$Vi = Ve + Vfb$$
$$= Ri\, ii + BV0$$
$$= Ri\, ii + BAVe$$
$$= Ri\, ii + B\, A\, Ri\, ii$$

$$\therefore Zif = \frac{Vi}{ii} = Ri(1 + AB)$$

1) Series – Shunt Feedback

Negative Feedback

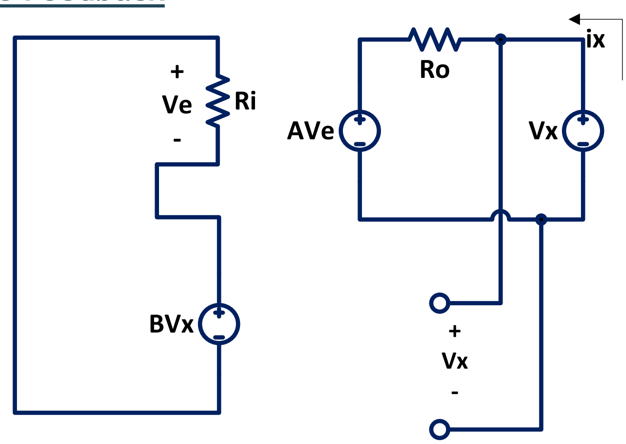
$$Zof = \frac{Vx}{ix}\bigg|\, vi = 0$$

$$ix = \frac{Vx - AVe}{Ro}$$

$$Ve = -BVx$$

$$ix = \frac{Vx + ABVx}{Ro}$$

$$\therefore \frac{Vx}{Ix} = \frac{Ro}{1 + AB}$$



Series Feedback at the input always raises the input impedance by (1+AB)

shunt Feedback at the output always lowers the output impedance by (1+AB)

Negative Feedback

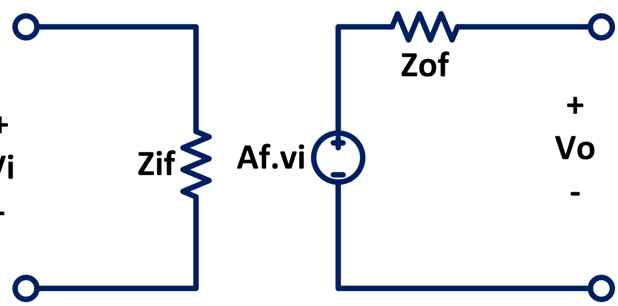
1) Series – Shunt Feedback

Equivalent ckt of Series - shunt amplifier

$$Zif = (1+AB)\,Ri$$

$$Zof = \frac{Ro}{1+AB}$$

$$Af = \frac{A}{1+AB} = \frac{Vo}{Vi}$$



Negative Feedback

1) Series – Shunt Feedback

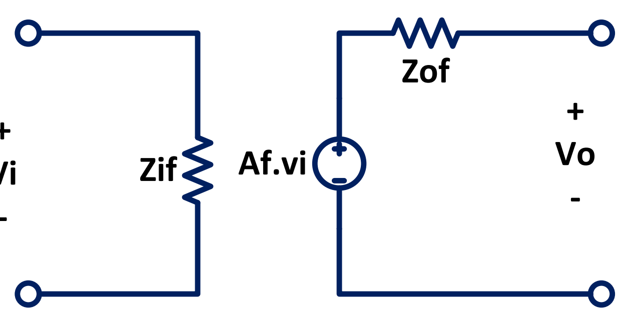
Equivalent ckt of Series _shunt amplifier

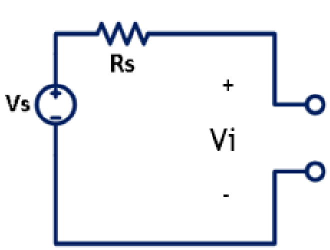
If A → ∞ ;

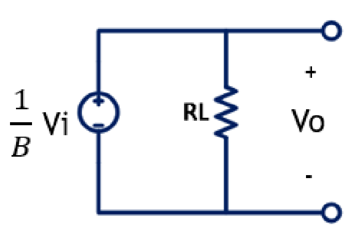
$Zif = \infty$;

$Zof = 0$;

$Af = \frac{1}{B}$







$$Zif = (1+AB)\,Ri$$

$$Zof = \frac{Ro}{1+AB}$$

$$Af = \frac{A}{1+AB} = \frac{Vo}{Vi}$$

Negative Feedback

1) Series – Shunt Feedback

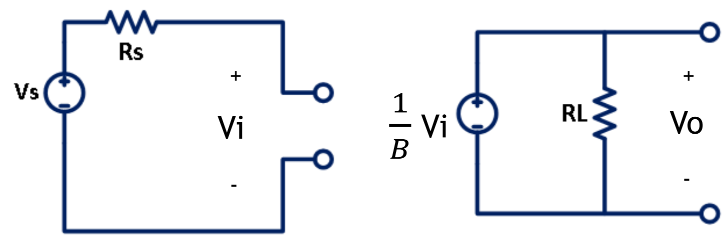
Equivalent ckt of Series _ shunt amplifier

If we have R_s and R_L

$$Vo = \frac{1}{B} Vi$$

$$Vi = Vs$$

$$\therefore \frac{Vo}{Vs} = \frac{1}{B}$$



Negative Feedback

2) Shunt - Shunt Feedback

Si = ii , So = Vo

$$Vo = Aie$$

$$ie = ii - ifb$$

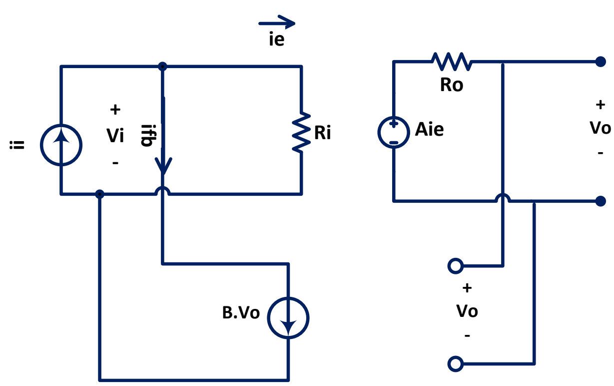
$$ifb = BVo$$

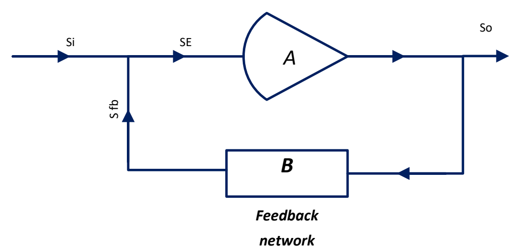
$$Vo = A(ii - BVo)$$

$$\therefore \frac{Vo}{ii} = Af = \frac{A}{1 + AB}$$

$$A = \frac{Vo}{ie}$$

$$B = \frac{ifb}{Vo}$$





AB is dimensionless

2) Shunt - Shunt Feedback

Negative Feedback

The input impedance

$$Zif = \frac{Vi}{ii}$$

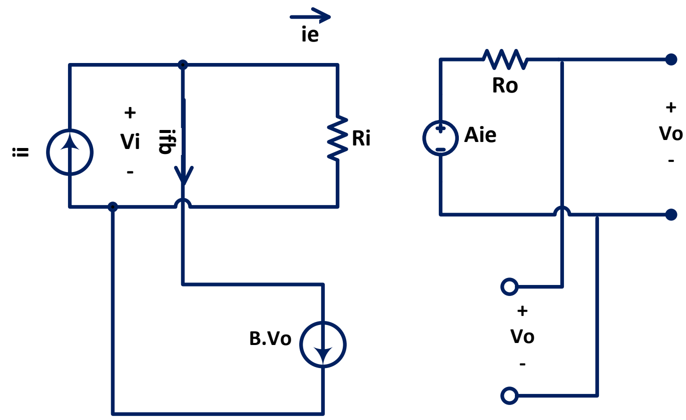
$$Vi = Ri\ ie$$

$$ie = ii - ifb$$

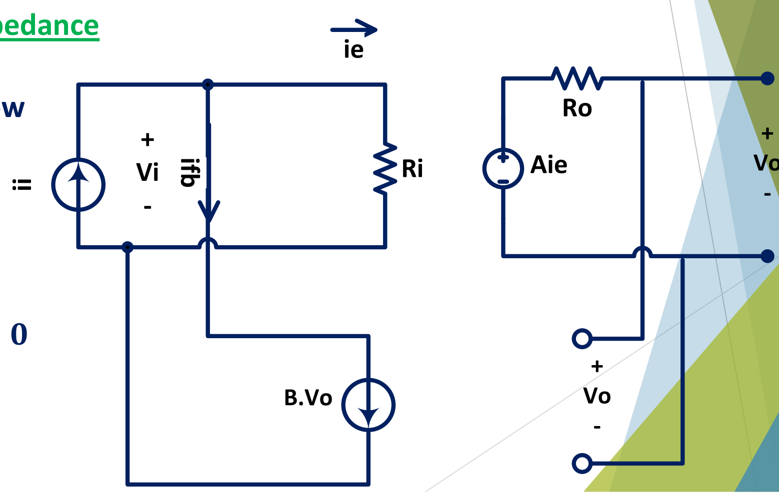
$$ifb = BVo$$

$$Vo = \frac{A}{1+AB} ii$$

$$\therefore Zif = \frac{Ri}{1+AB}$$



- **The output impedance**
- it is easy to show
- $Zof = \frac{Ro}{1+AB}$
- using :
- $Zof = \frac{Vt}{it}\Big| ii = 0$



Negative Feedback

2) Shunt - Shunt Feedback

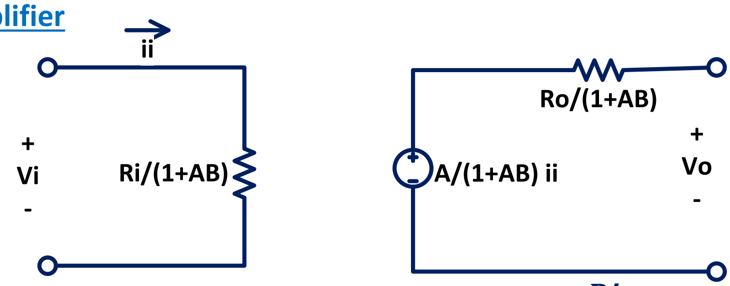
Equivalent ckt of Shunt _Shunt amplifier

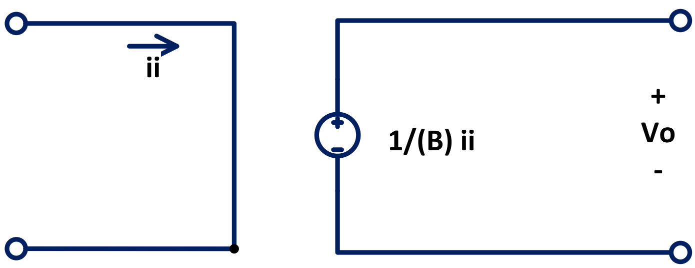
If A → ∞ ;

$Zif = 0$;

$Zof = 0$;

$Af = \frac{1}{B}$





$$Zif = \frac{Ri}{1 + AB}$$

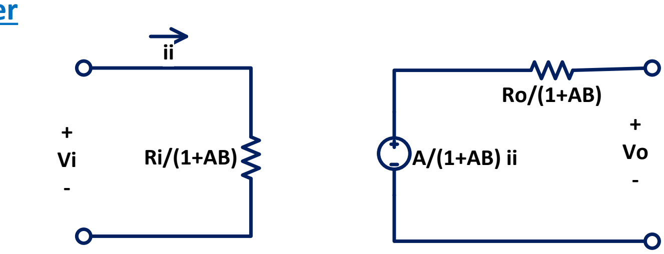
$$Zof = \frac{Ro}{1 + AB}$$

$$Af = \frac{A}{1 + AB}$$

Negative Feedback

2) Shunt - Shunt Feedback

Equivalent ckt of Shunt _Shunt amplifier

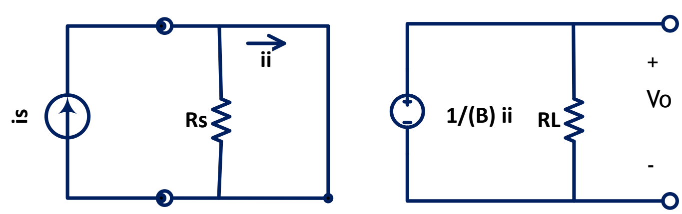


If we have R_s and R_L

$$Vo = \frac{1}{B} ii$$

$$ii = is$$

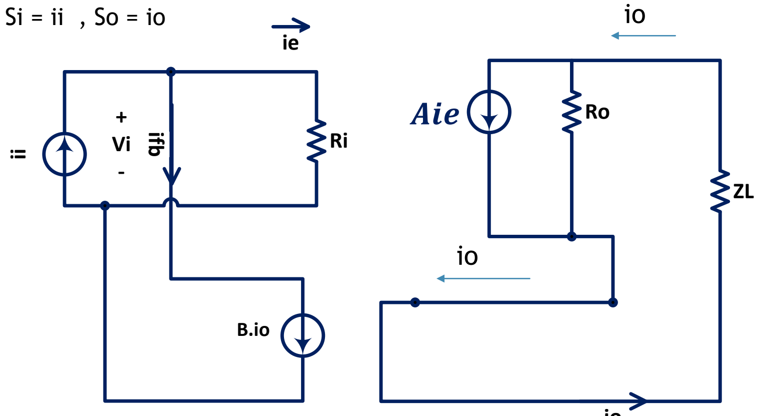
$$\frac{Vo}{is} = \frac{1}{B}$$



Negative Feedback

3) Shunt - Series Feedback

Si = ii , So = io



$$io = Aie\frac{Ro}{Ro + Zl}$$

$$if\ Zl \ll Ro$$

$$io = A\,ie$$

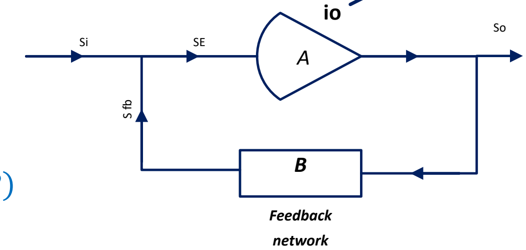
$$ie = ii - ifb$$

$$ifb = B\,io$$

$$\therefore \frac{io}{ii} = Af = \frac{A}{1 + AB}$$

$$Zif = \frac{Ri}{1 + AB}$$

$$Zof = Ro(1 + AB)$$



Negative Feedback

4) Series - Series Feedback

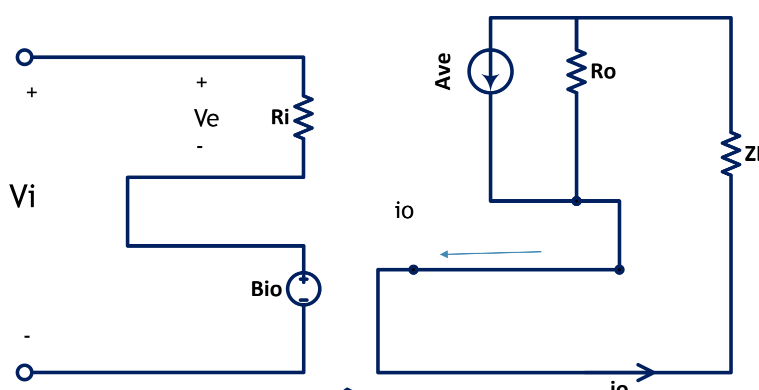
Si = Vi , So = io

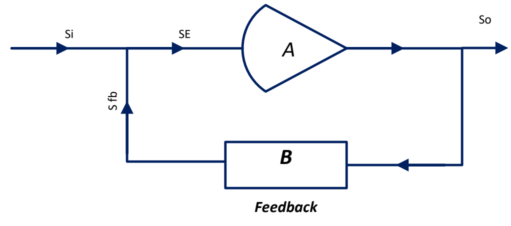
$$if\ Zl \ll Ro$$

$$\frac{io}{Vi} = Af = \frac{A}{1 + AB}$$

$$Zif = Ri(1 + AB)$$

$$Zof = Ro(1 + AB)$$





Negative Feedback

Practical configuration and the effect of loading

1) Shunt - Shunt Feedback

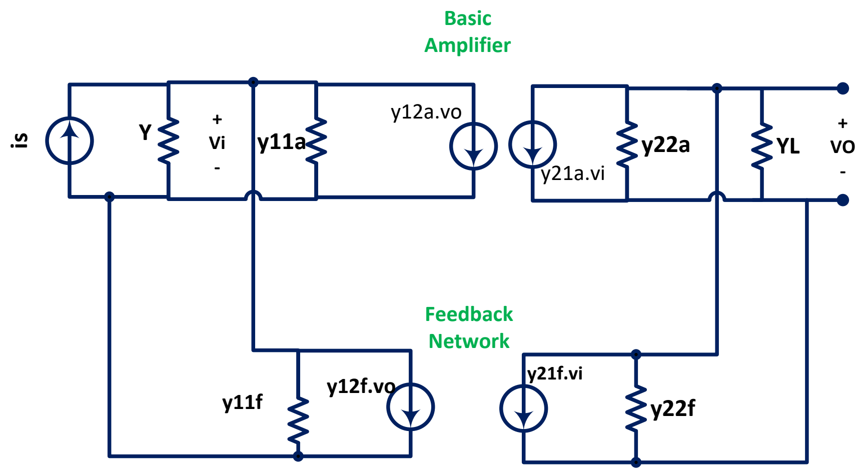
Si = is

So = Vo

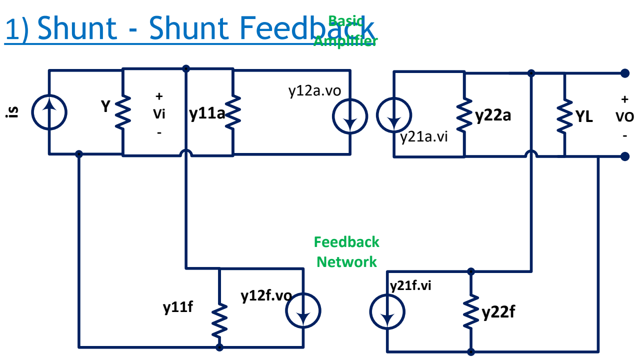
$$Af = \frac{Vo}{is} = \frac{A}{1 + AB}$$

$$|Y12\ a| \ll |Y12\ f|$$

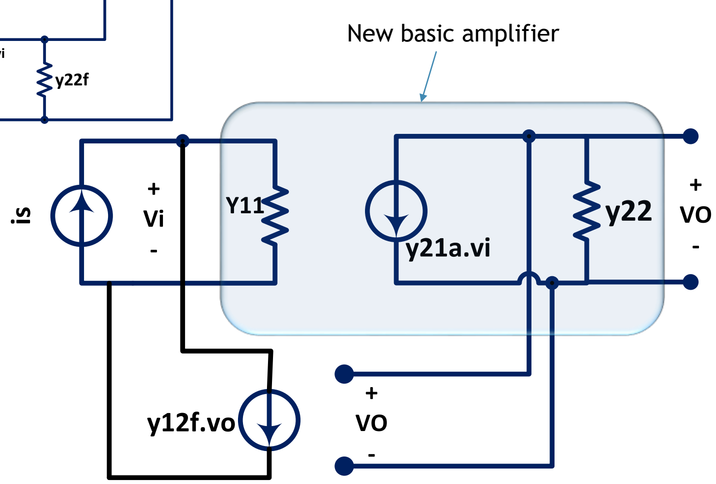
$$|Y21\ a| \gg |Y21\ f|$$



1) Shunt - Shunt Feedback



New basic amplifier = basic amplifier + loading



$$Y11 = y11\ a + y11f + Y$$
$$Y22 = y22\ a + y22f + Yl$$

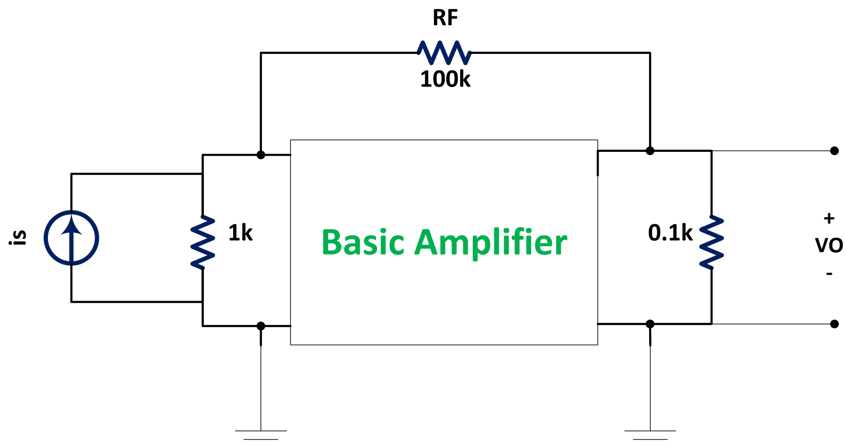
$$\therefore\ y12\ f = B$$

Negative Feedback

Practical configuration and the effect of loading

1) Shunt - Shunt Feedback

Example:

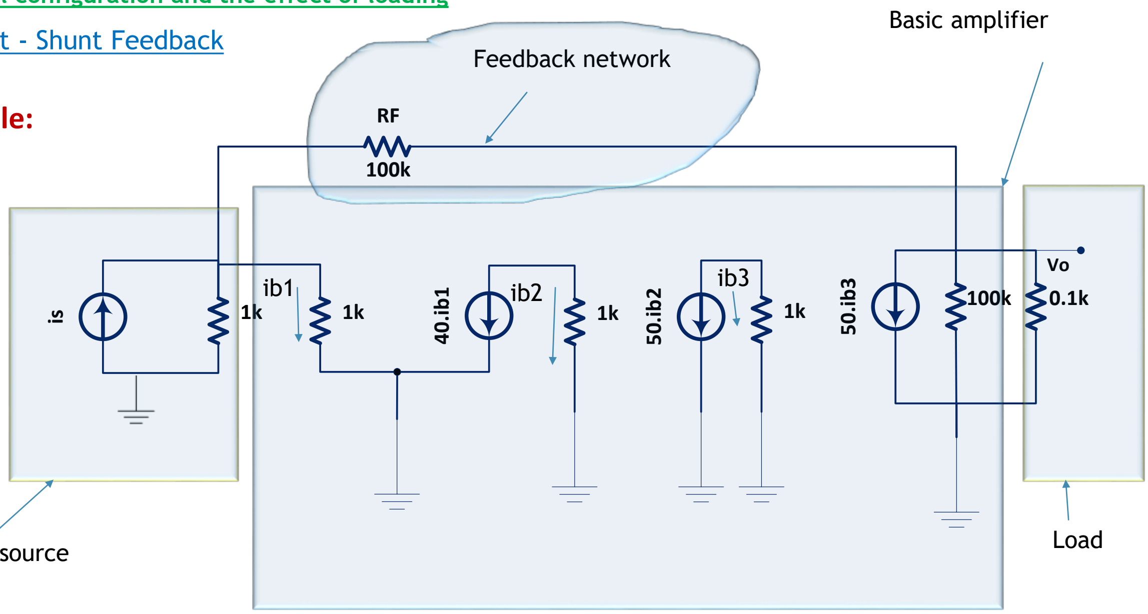


Negative Feedback

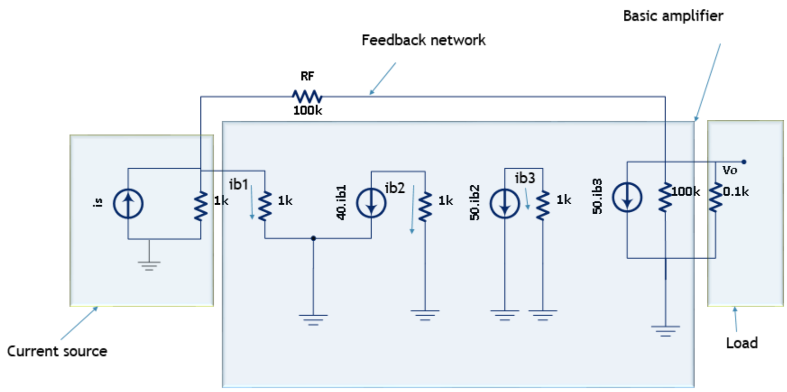
Practical configuration and the effect of loading

1) Shunt - Shunt Feedback

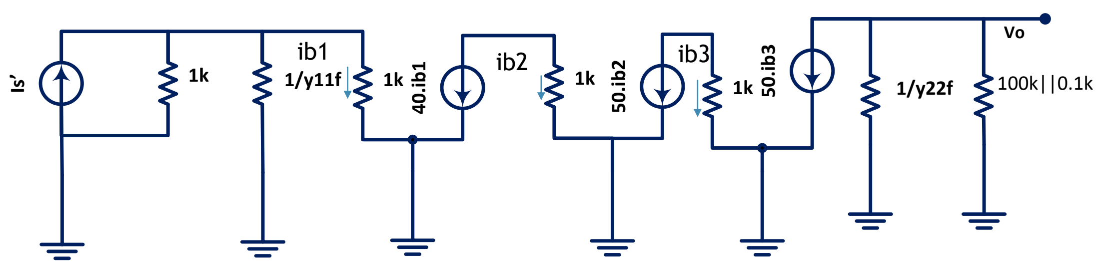
Example:



1) Shunt - Shunt Feedback



New Basic Amplifier: $A = \frac{Vo}{i\acute{s}}$



Negative Feedback

Practical configuration and the effect of loading

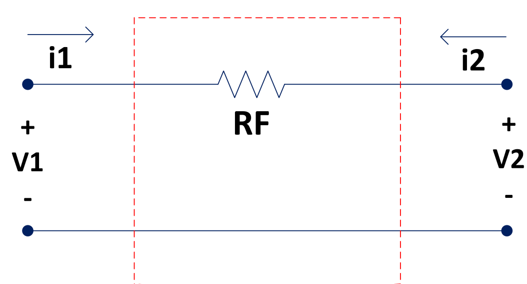
1) Shunt - Shunt Feedback

The Feedback network

$$y11 = \frac{1}{RF} = \frac{1}{100k}$$

$$y22 = \frac{1}{RF} = \frac{1}{100k}$$

$$y12 = \frac{-1}{RF} = \frac{-1}{100k}$$

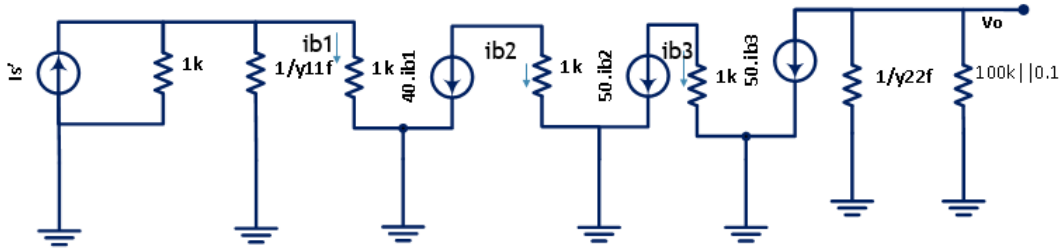


$$B = y12\,f$$

Negative Feedback

1) Shunt - Shunt Feedback

To calculate A : New basic amplifier



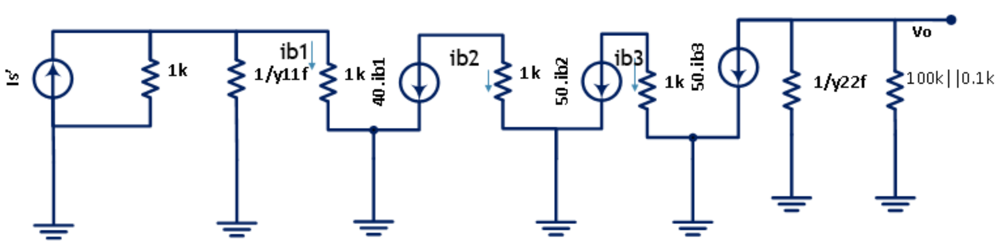
$$A = \frac{Vo}{\acute{is}}$$

$$ib2 = -40ib1$$

$$V0 = -50ib3\left(100k||0.1K||\frac{1}{y22\,f}\right)$$

$$ib3 = -50ib2$$

$$ib1 = is\,\frac{1K||\frac{1}{y11\,f}}{1k||\frac{1}{y11\,f} + 1k}$$



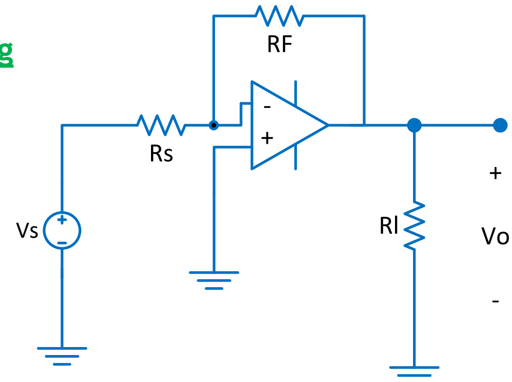
- $\therefore A = -4965\ k\,\Omega$
- $B = -0.01\ m\mho$
- $AB = 49.65$
- $Af = \frac{Vo}{is} = \frac{A}{1+AB} = -98K\ \Omega$
- $\frac{1}{B} = -100k\Omega$

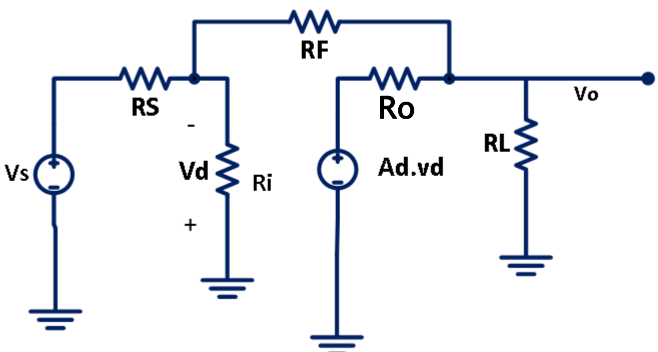
Negative Feedback

Practical configuration and the effect of loading

1) Shunt - Shunt Feedback

Example: Inverting Amplifier





$$Rs = 100k\Omega$$
$$Rf = 1M\Omega$$
$$Rl = 10k\Omega$$
$$Ro = 75\ \Omega$$
$$Ri = 2\ M\ \Omega$$
$$Ad = 200,000$$

Negative Feedback

Practical configuration and the effect of loading

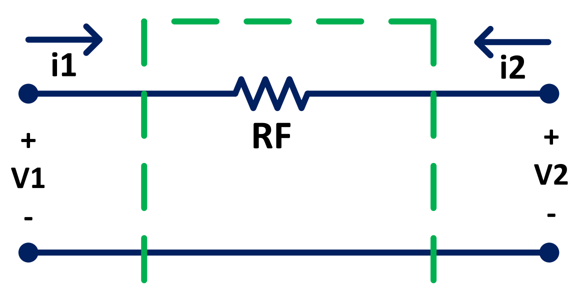
1) Shunt - Shunt Feedback

The Feed-Back Network:

$$y11\ f = \frac{1}{RF};$$

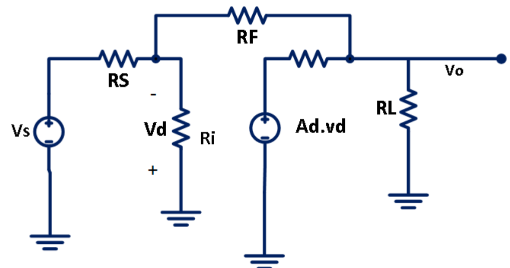
$$y22\ f = \frac{1}{RF}$$

$$y12f = -\frac{1}{RF} = \beta$$



Practical configuration and the effect of loa

1) Shunt - Shunt Feedback

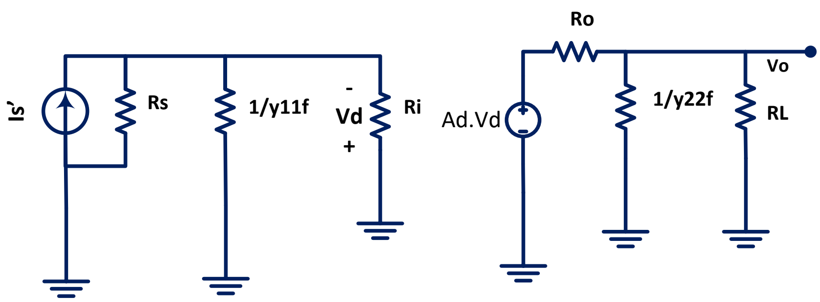


New Basic Amplifier : $A = \frac{Vo}{\acute{is}}$

$$V0 = \frac{Rl||\frac{1}{y22\,f}}{Rl||\frac{1}{y22\,f} + Ro} AdVd$$

$$Vd = -is'(Rs||\frac{1}{y11\,f}||Ri)$$

$$A = \frac{Vo}{\acute{is}} = -1.726 \times 10^{10}$$



$$To\ find\ Av = \frac{Vo}{Vs}$$

$$\frac{Vo}{Vs} = \frac{Vo}{is} \cdot \frac{is}{Vs} = Af \cdot \frac{1}{Rs}$$

$$Av = -9.9994$$

$$B = \frac{-1}{RF} = -1 \times 10^{-6}$$

$$AB = 17260$$

$$Af = \frac{Vo}{is} = \frac{A}{1+AB} = -999.94k\,\Omega$$

If the Op.amp is ideal

$Av = -\frac{RF}{RS} = -10$

Negative Feedback

Practical configuration and the effect of loading

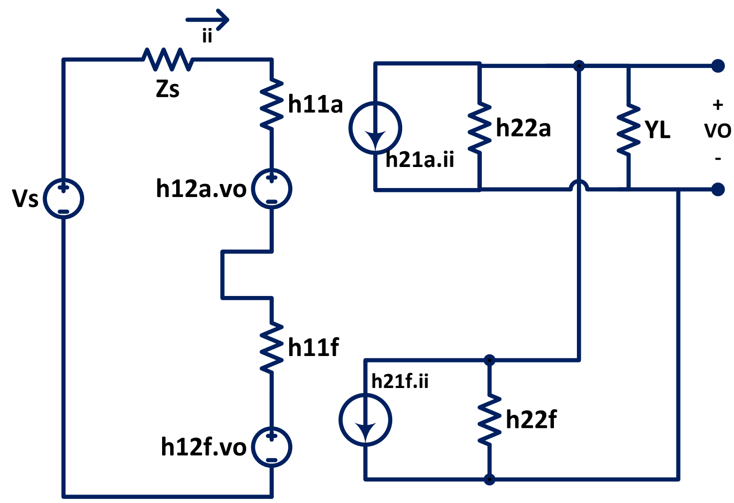
2) Series - Shunt Feedback

$$V1 = h11i1 + h12V2$$

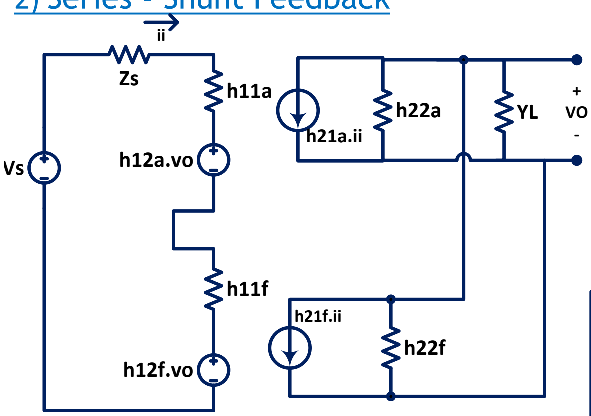
$$i2 = h21i1 + h22V2$$

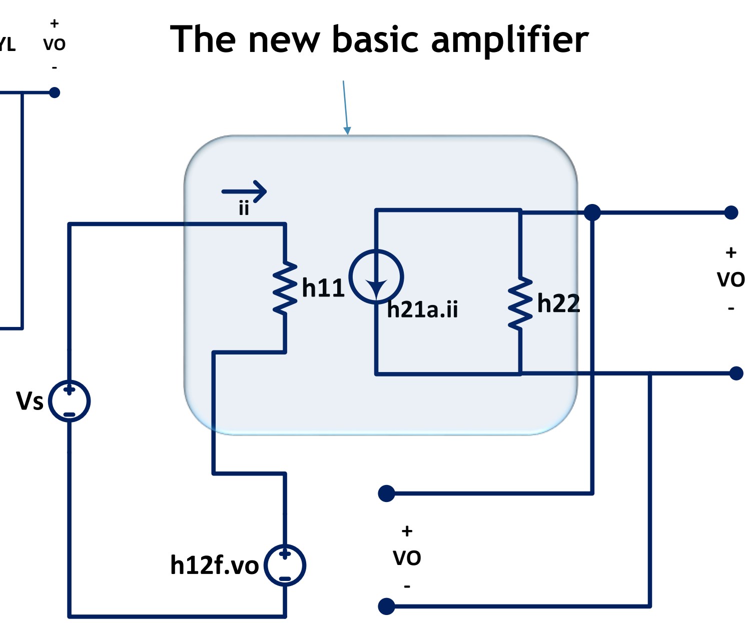
$$|h12_a| \ll |h12_f|;$$

$$|h21_a| \gg |h21_f|;$$



2) Series - Shunt Feedback





$$B = h12_f\ ;$$

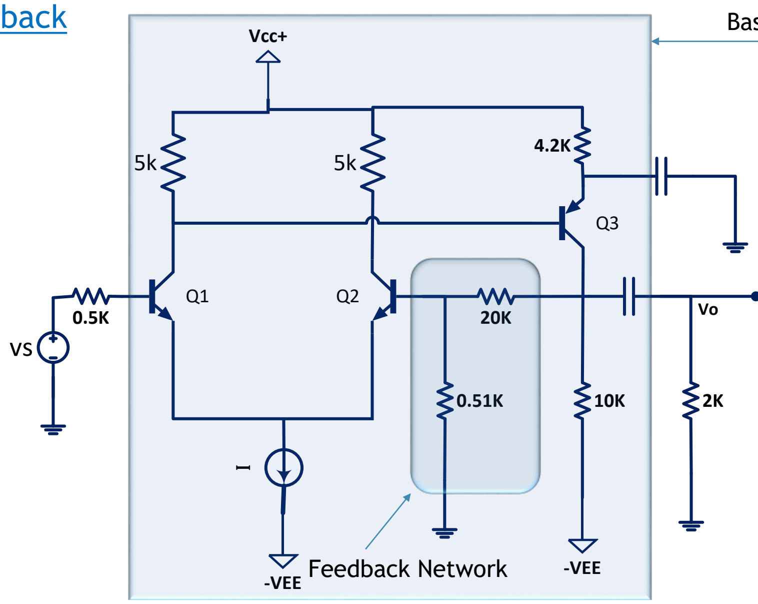
$$Af = \frac{Vo}{Vs} = \frac{A}{1 + AB}$$

Negative Feedback

Practical configuration and the effect of loading

2) Series - Shunt Feedback

Example:



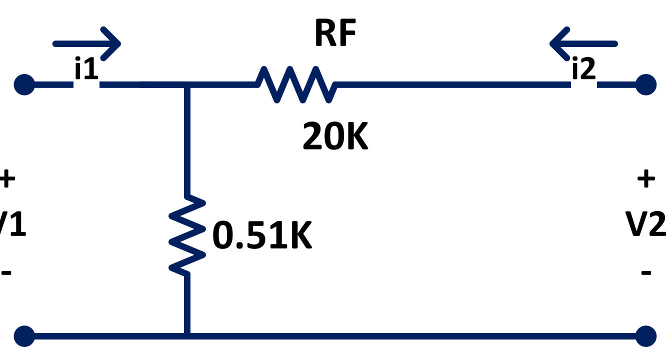
Negative Feedback

Practical configuration and the effect of loading

2) Series - Shunt Feedback

The Feed-Back Network:

Example:



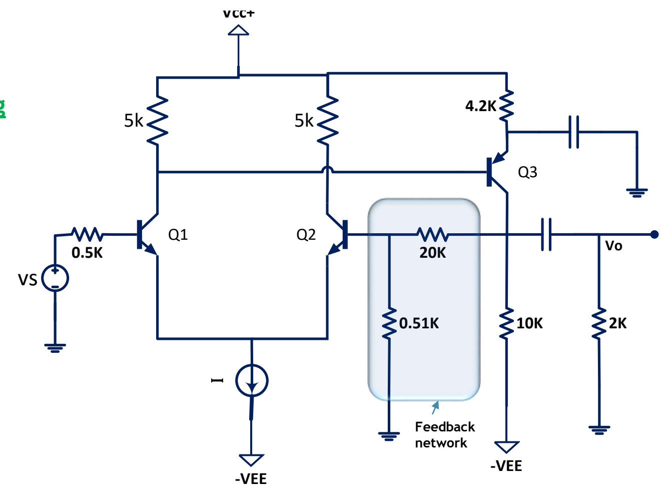
$$h11_f = 0.51||20k$$

$$h22_f = \frac{1}{20k + 0.51k}$$

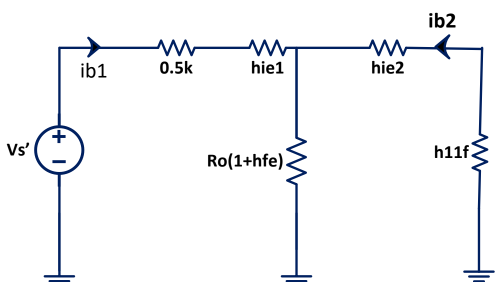
$$h12_f = \frac{0.51k}{0.51k + 20k} = B$$

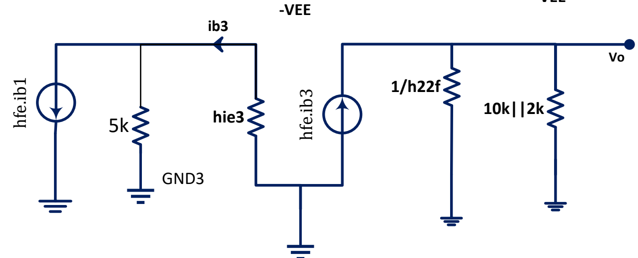
Practical configuration and the effect of loading

2) Series - Shunt Feedback



New Basic Amplifier : $A = \frac{Vo}{V\acute{s}}$





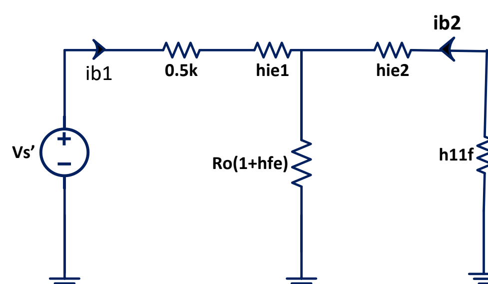
$$hfe = 100\ , hie = 3k$$

Negative Feedback

Practical configuration and the effect of loading

2) Series - Shunt Feedback

Differential Mode Analysis:

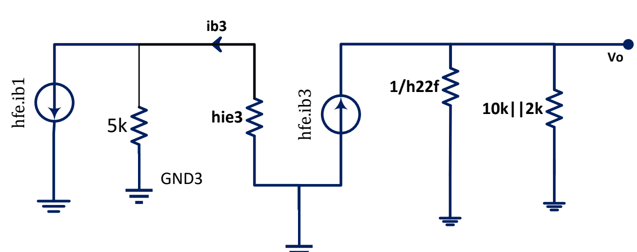


$$Vo = hfe\ ib3 \left(\frac{1}{h22_f} \| 10k \| 2k\right)$$

$$ib3 = hfe\ ib1 \frac{5k}{5k + 3k}$$

$$ib1 = -ib2$$

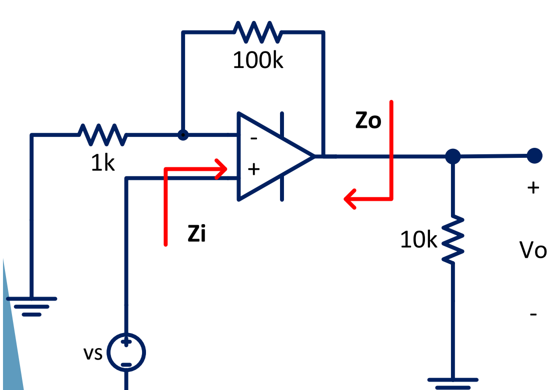
$$ib1 = \frac{V\acute{s}}{0.5k + hie1 + hie2 + h11f}$$



- $A = \frac{Vo}{\acute{V}s} = 1379$
- $AB = 34.3$
- $Af = \frac{Vo}{Vs} = \frac{A}{1+AB} = 39$
- $\frac{1}{B} = 40.2$

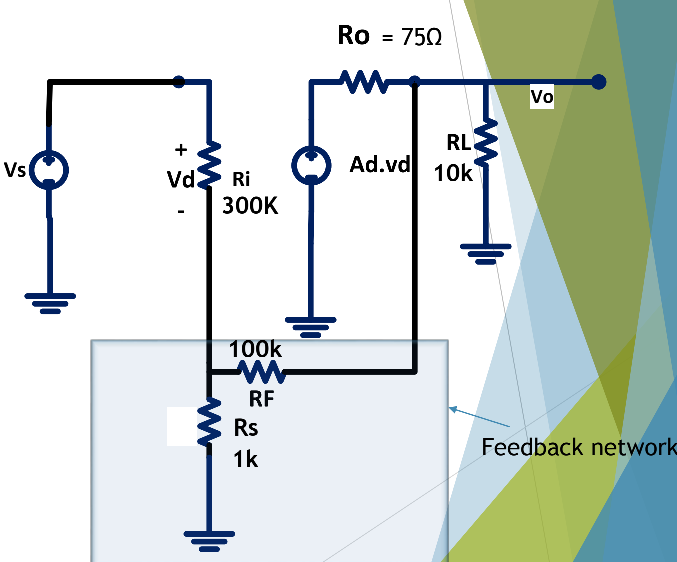
2) Series - Shunt Feedback

Example: Non-Inverting Amplifier



For op amp
R_i = 300k

R_O= 75 ohm
A_d =20000



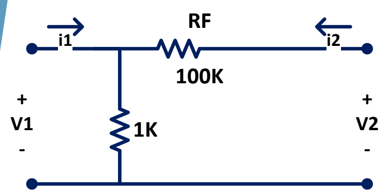
Negative Feedback

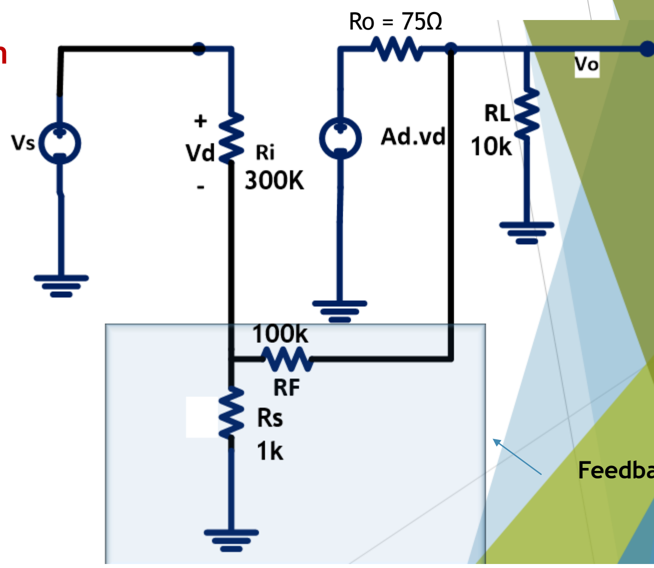
Practical configuration and the effect of loading

2) Series - Shunt Feedback

Example: Non-Inverting Am

The Feed-Back Network:



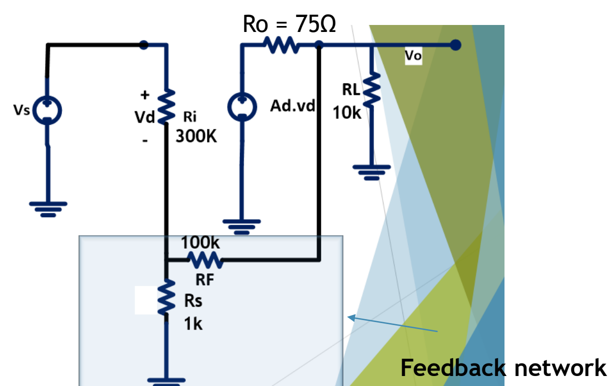


$$h11f = 100k||1k$$

$$h22f = \frac{1}{1k + 100k}$$

$$h12f = \frac{1}{1k + 100k} = B$$

2) Series - Shunt Feedback



Example: Non-Inverting Amplifier

$$A = \frac{Vo}{V\acute{s}}$$

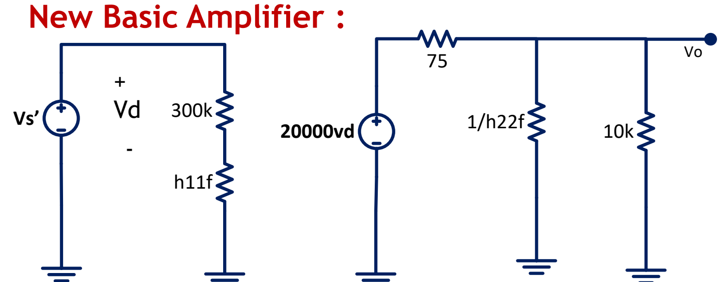
$$Vo = \frac{\left(10k \,||\, \frac{1}{h22f}\right)(20000\,Vd)}{\left(10k \,||\, \frac{1}{h22f}\right) + 75}$$

$$Vd = \frac{300k}{300k + h11f} Vs$$

$$A = 19771$$

$$AB = 195.75$$

New Basic Amplifier :



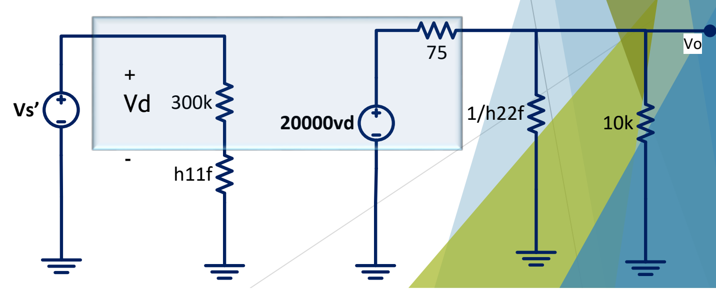
- $Af = \frac{Vo}{Vs} = \frac{A}{1+AB} = 100.487$
- $\frac{1}{B} = 101$

If the op amp is ideal ∴ Av = (1+Rf/Rs) =101

$$Zif = Ri(1 + AB);$$

$$Ri = 300k + h11f$$

$$\therefore Zif = 59.221M\,\Omega$$



Negative Feedback

2) Series - Shunt Feedback

Example: Non-Inverting Amplifier

$$Zof = \frac{Ro}{1 + AB}$$

$$Ro = 10k||101k||75$$

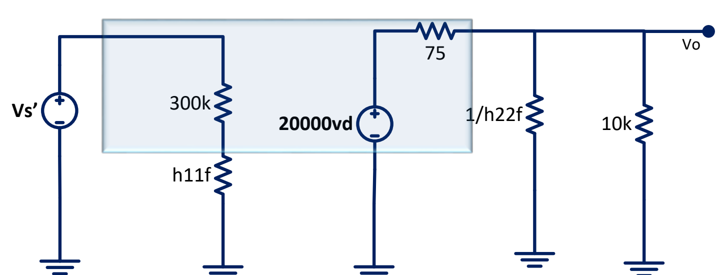
$$Ro = 74.4\,\Omega$$

$$\therefore Zof = 0.377\,\Omega$$

$$Zof = Zo||10k$$

$$\therefore Zo = 0.378\,\Omega$$

New Basic Amplifier



Negative Feedback

Practical configuration and the effect of loading

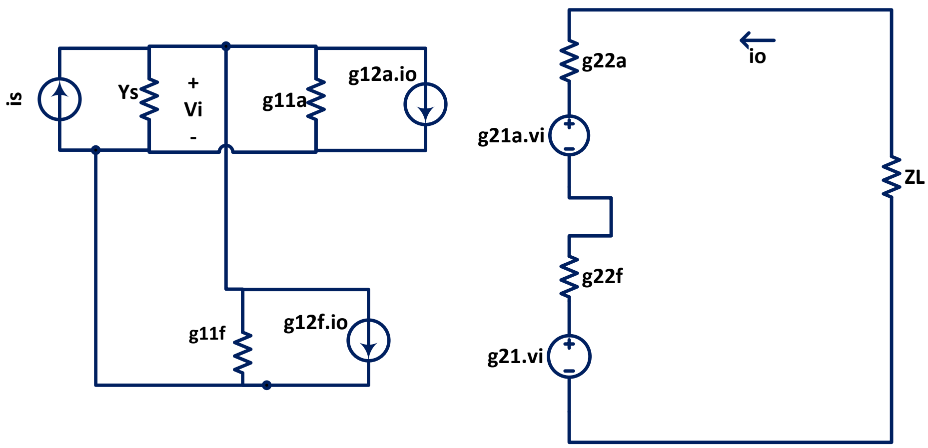
3) Shunt - Series Feedback

$$i1 = g11V1 + g12i2$$

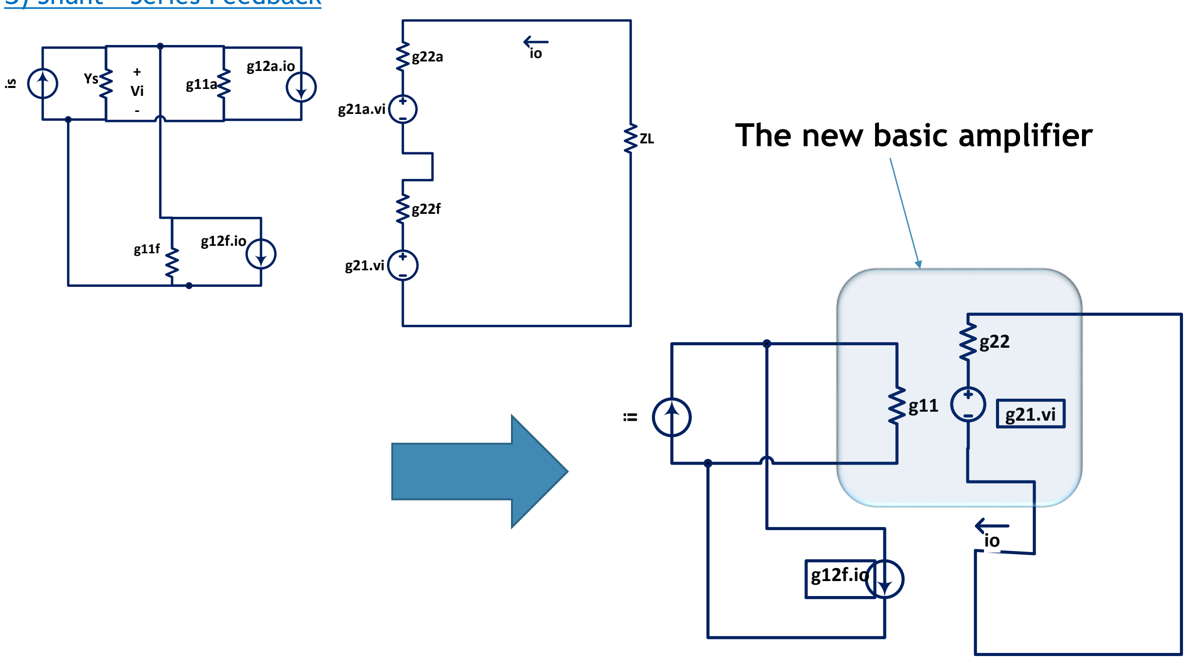
$$V2 = g21V1 + g22i2$$

$$|g12f| \gg |g12a|;$$

$$|g21a| \gg |g21f|$$



3) Shunt - Series Feedback



Negative Feedback

3) Shunt - Series Feedback

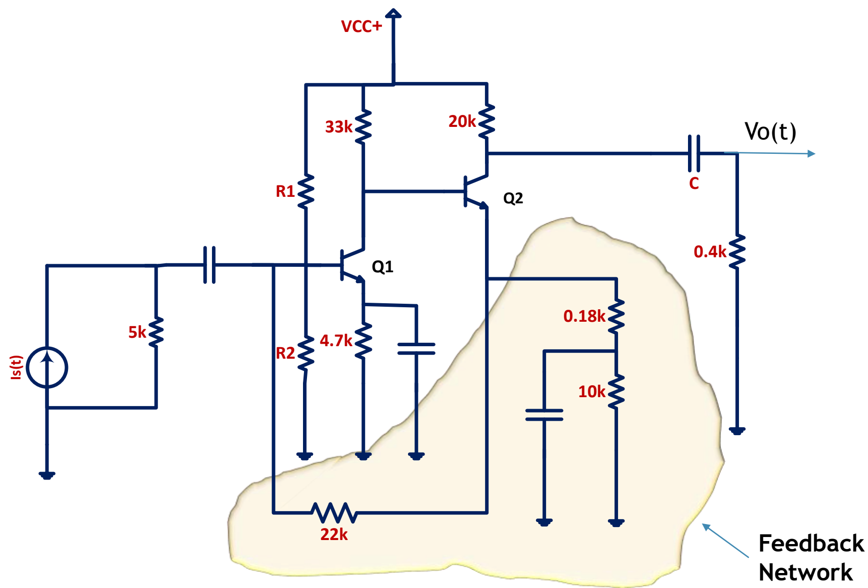
Example:

$$R1||R2 = 24k$$

$$hfe = 50$$

$$hie1 = 1.3k\ ;$$

$$hie2 = 1k$$



Negative Feedback

Practical configuration and the effect of loading

3) Shunt - Series Feedback

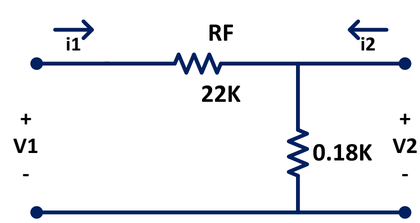
Example:

$$g11f = \frac{1}{22k + 0.18k}$$

$$g22f = 22k||0.18k$$

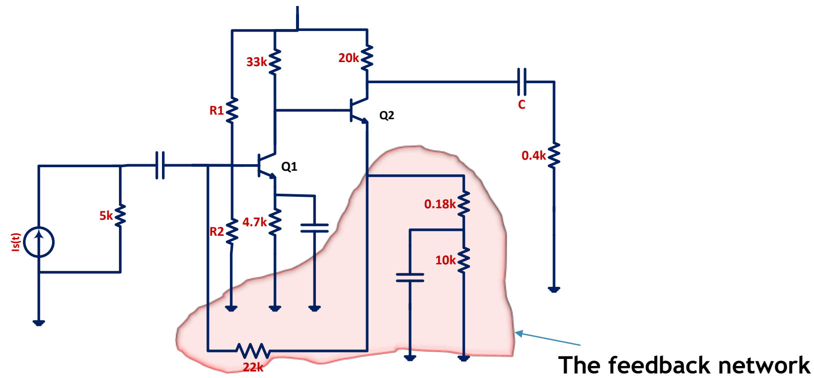
$$g12f = -\frac{0.18k}{0.18k + 22k} = B$$

The Feed-Back Network:

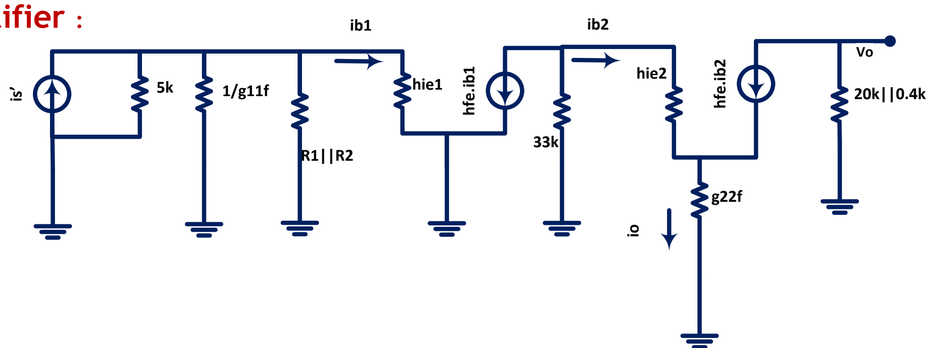


3) Shunt - Series Feedback

Example:



New Basic Amplifier :

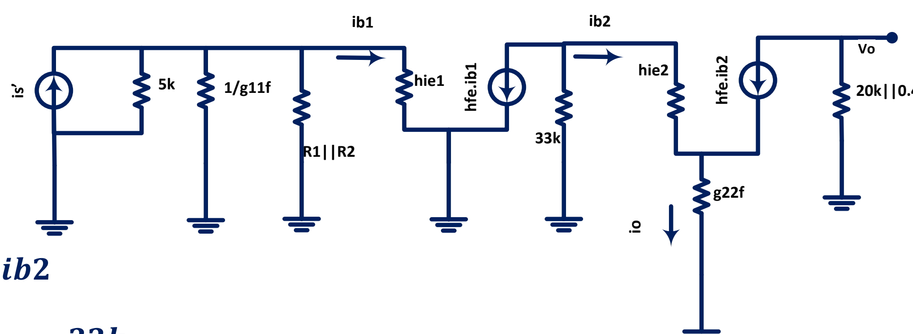


Negative Feedback

Practical configuration and the effect of loading

3) Shunt - Series Feedback

Example:



$$A = \frac{io}{is'}$$

$$io = (1 + hfe)ib2$$

$$ib2 = -hfe\ ib1\ \frac{33k}{33k + hie2 + g22f(1 + hfe)}$$

$$ib1 = is'\ \frac{5k\,||\frac{1}{g11f}||\ R1||R2}{5k\,||\frac{1}{g11f}||\ R1||R2 + hie1}$$

$$A = -1429$$

$$AB = 11.5$$

$$Af = \frac{io}{is} = \frac{A}{1 + AB} = -113.45$$

Negative Feedback

Practical configuration and the effect of loading

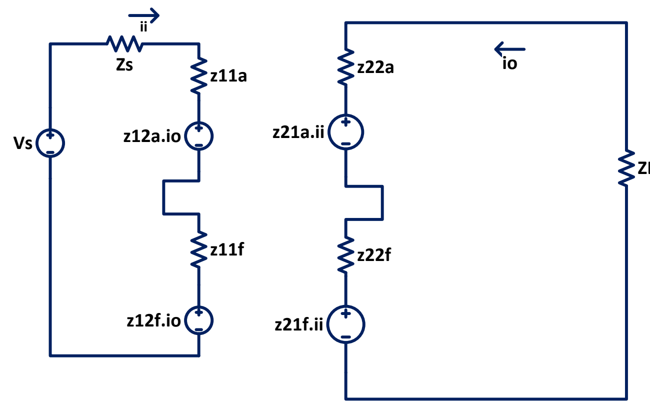
4) Series - Series Feedback

$$V1 = Z11\ i1 + Z12\ i2$$

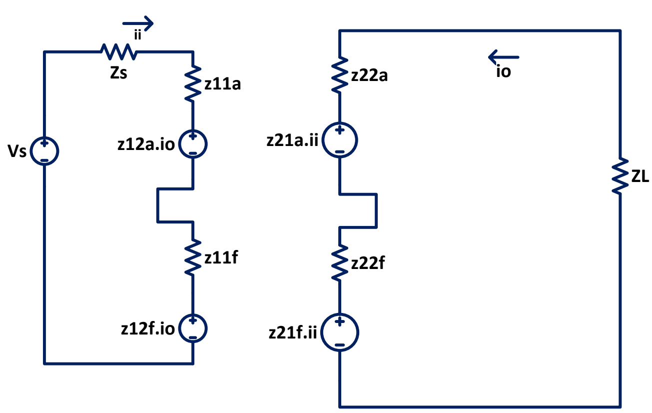
$$V2 = Z21\ i1 + Z22\ i2$$

$$|Z12f| \gg |Z12a|$$

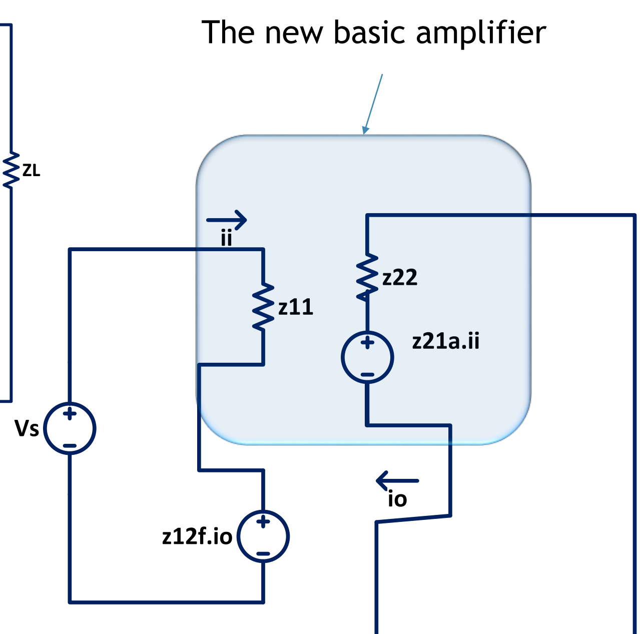
$$|Z21a| \gg |Z21f|$$



4) Series - Series Feedback



$$Z12f = B$$



Z12f= B

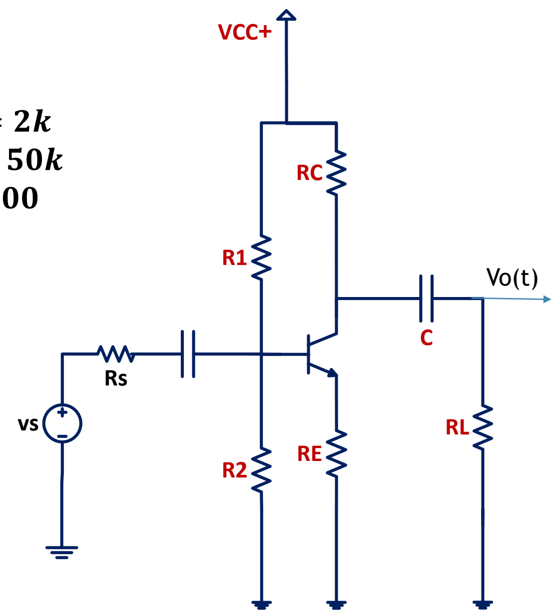
Negative Feedback

Practical configuration and the effect of loading

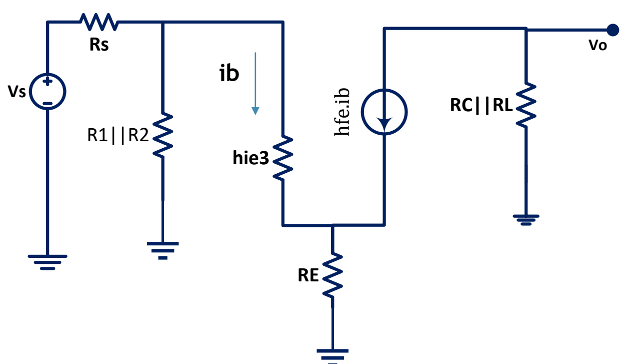
4) Series - Series Feedback

Example:

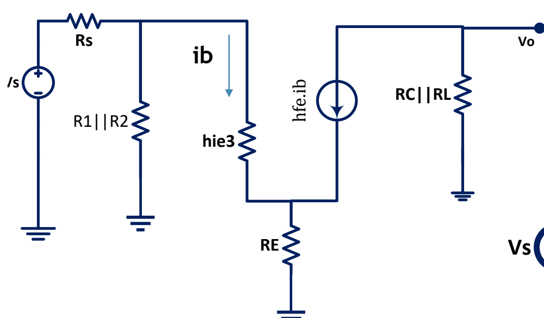
$$Rs = 0.6k \quad ,, Rc||Rl = 2k$$
$$Re = 0.2k \,,, R1||R2 = 50k$$
$$hie = 1k \quad ,, hfe = 100$$

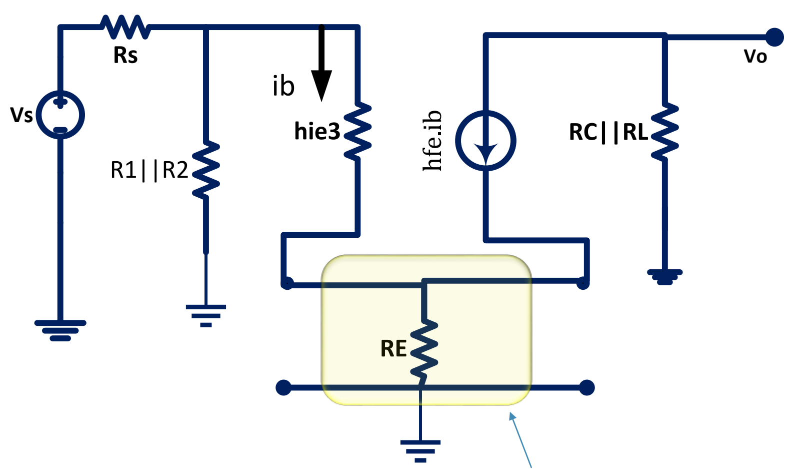


Ac small signal equivalent circuit



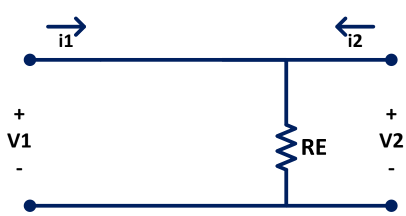
Negative Feedback



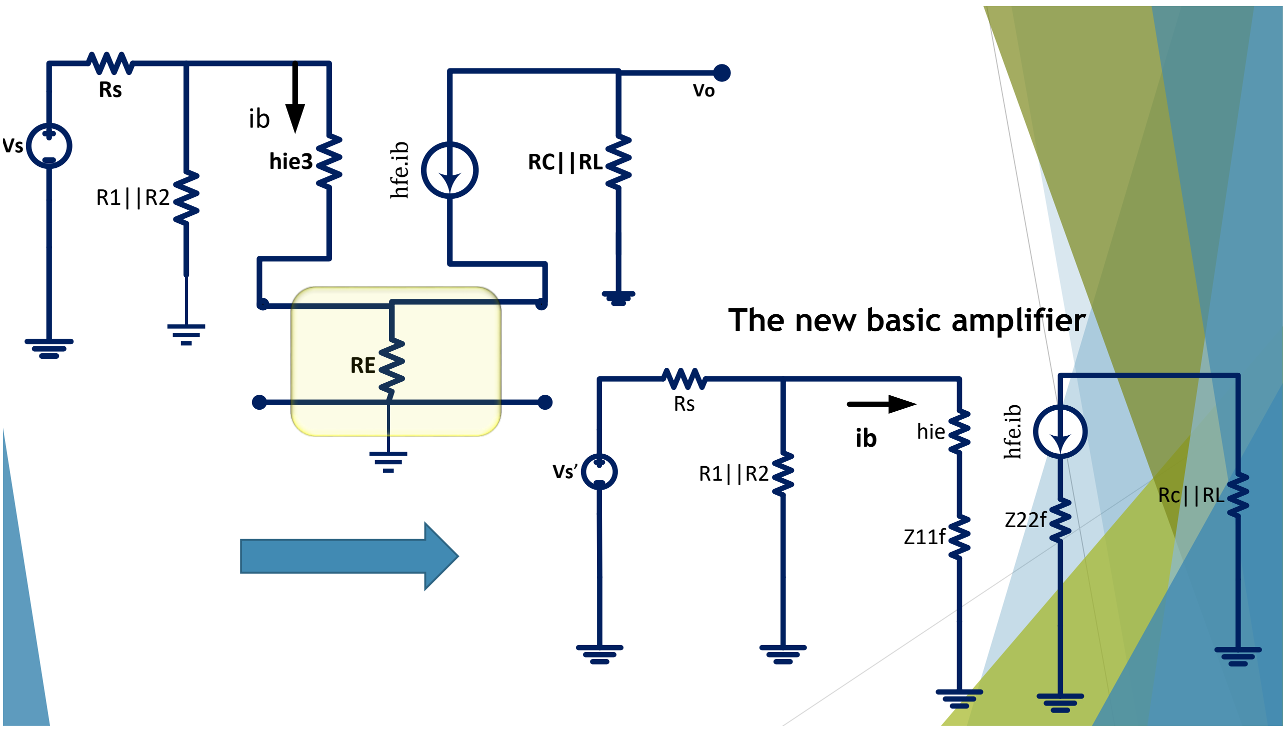


Feedback network

The Feed-Back Network:



$$Z11f = Re$$
$$Z22f = Re$$
$$Z12f = Re = B$$



4) Series - Series Feedback

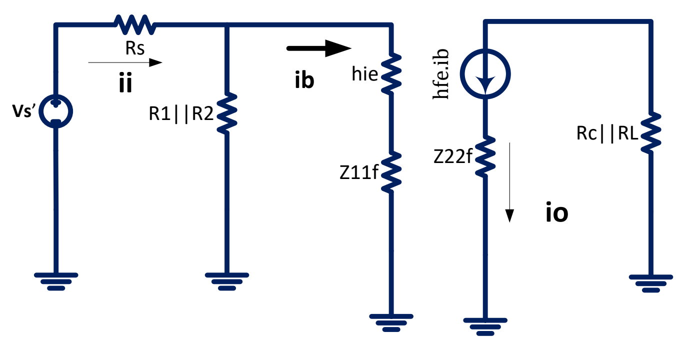
$$A = \frac{io}{Vs'}$$

$$io = (hfe)ib$$

$$ib = ii \frac{R1||R2}{R1||R2 + hie + Z11f}$$

$$ii = \frac{\acute{V}s}{RS + R1||R2||(hie + Z11f)}$$

New Basic Amplifier :



$$A = 56.4$$

$$AB = 11.29$$

$$Af = \frac{io}{Vs} = \frac{A}{1 + AB} = 4.59$$

$$Av = \frac{Vo}{Vs} = \frac{io}{Vs} \cdot \frac{Vo}{io}$$
$$= -\ Af.(Rl||Rc)$$
$$Av = -9.18$$