



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Applications of Feedback in amplifier circuits

Flow of Discussion (Bottom-up)

– Sub-systems/Modules

- **System / Sub-systems** (*for specific application*)
 - **Modules** (*performing specific tasks*)
 - **Building blocks** (*having specific characteristics*) - Bias circuits
 - **Components** (*devices/circuit elements*)
- **Week 10 (Course Module 9):**
 - **Feedback System: Basic feedback theory**
 - **Four different feedback configurations and their characteristics**
 - **Effects of feedback on frequency response of an amplifier**
 - **Application of feedback in practical circuits**



CONCEPTS COVERED

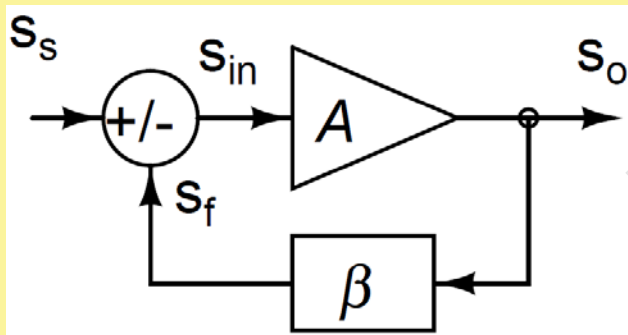
Concepts Covered:

- ☐ **How to apply feedback in BJT amplifiers**
 - ☐ Voltage-shunt (shunt-shunt) F.B.
 - ☐ Current-series (series-series) F.B.
 - ☐ Voltage-series (shunt-series) F.B.
- ☐ **Customization / extension of basic FB model**
- ☐ **Application of feedback in op-amp circuits**
 - ☐ Inverting amplifier
 - ☐ Integrator and Differentiator
 - ☐ Non-inverting amplifier
 - ☐ A circuit with two feedback loops



Summary of effects of negative feedback loop in amplifier

Configuration names	Sin	So	A ↓	Rin ↓	Rout ↓	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	↓	↓	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	↓	↑	-
Voltage-Series (Shunt-Series)	V	V	A_V	↑	↓	-
Current-Series (Series-Series)	V	I	G_m	↑	↑	Ohm

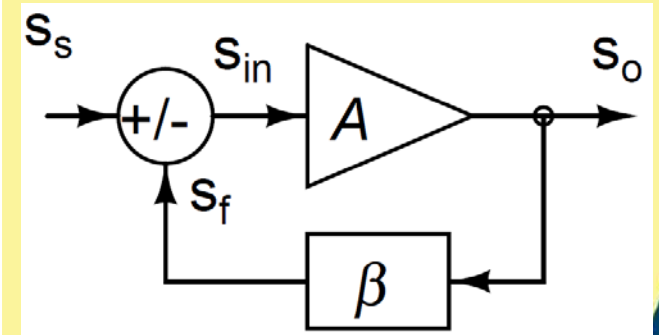


$$A_f = \frac{A}{(1 + \beta \cdot A)}$$

$$D = (1 + \beta \cdot A)$$

Summary of effects of negative feedback loop in amplifier (contd.)

Configuration names	S_{in}	S_o	$A \downarrow$	R_{in}	R_{out}	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	$\downarrow$	$\downarrow$	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	$\downarrow$	$\uparrow$	-
Voltage-Series (Shunt-Series)	V	V	A_v	$\uparrow$	$\downarrow$	-
Current-Series (Series-Series)	V	I	G_m	$\uparrow$	$\uparrow$	Ohm



$$A_f = \frac{A}{(1 + \beta \cdot A)}$$

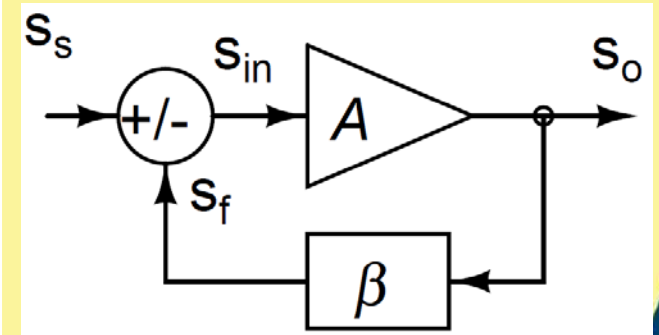
- Which configuration?
- Consequences !

	A_I	A_v	G_m	Z_m
A_I	1	R_{in}/R_{out}	R_{in}	$1/R_{out}$
A_v	R_{out}/R_{in}	1	R_{out}	$1/R_{in}$
G_m	$1/R_{in}$	$1/R_{out}$	1	$1/(R_{in} \cdot R_{out})$
Z_m	R_{out}	R_{in}	$(R_{in} \cdot R_{out})$	1



Procedure to incorporate feedback loop in amplifier

Configuration names	Sin	So	A ↓	Rin ↓	Rout ↓	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	↓	↓	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	↓	↑	-
Voltage-Series (Shunt-Series)	V	V	A_V	↑	↓	-
Current-Series (Series-Series)	V	I	G_m	↑	↑	Ohm



$$A_f = \frac{A}{(1 + \beta \cdot A)}$$

• Steps to follow:

- Select the right feedback configuration
- Be aware of consequences
- To make the loop effective and intuitive :
 - Consider the loading effect on “A” (i.e., use A')
 - Find useful range of β_{FB} providing $A'' \approx A'$, $\beta'_{FB} \approx \beta_{FB}$ and $(A' \beta_{FB}) \gg 1$



Procedure to incorporate feedback loop in amplifier (*contd.*)

- To make the loop effective and intuitive :
 - Consider the loading effect on “A” (i.e., use A')
 - Find useful range of β_{FB} providing

$$A'' \approx A' \quad \text{and} \quad \beta'_{FB} \approx \beta_{FB}$$

$$R_{in_ \beta} \gg R_{out} \quad \text{for voltage sampling}$$

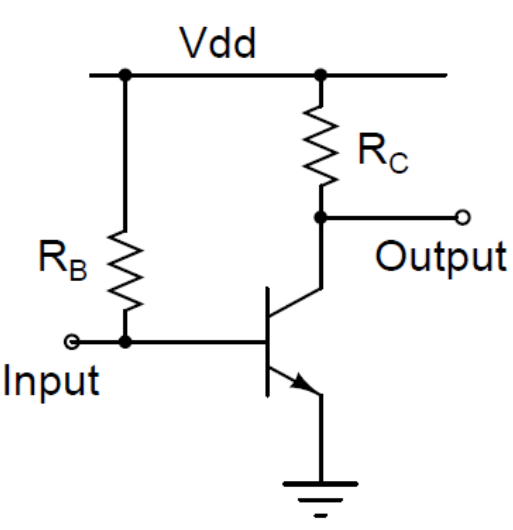
$$R_{out_ \beta} \gg R_{in} \quad \text{for current mixing}$$

and

$$A' \cdot \beta_{FB} \gg 1$$



Application circuit-1



Configuration names	Sin	So	A ↓	Rin ↓	Rout ↓	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	↓	↓	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	↓	↑	-
Voltage-Series (Shunt-Series)	V	V	A_v	↑	↓	-
Current-Series (Series-Series)	V	I	G_m	↑	↑	Ohm

We want stable Z_m defined by feedback network

Feedback configuration: *Voltage-Shunt (Shunt-shunt) feedback*

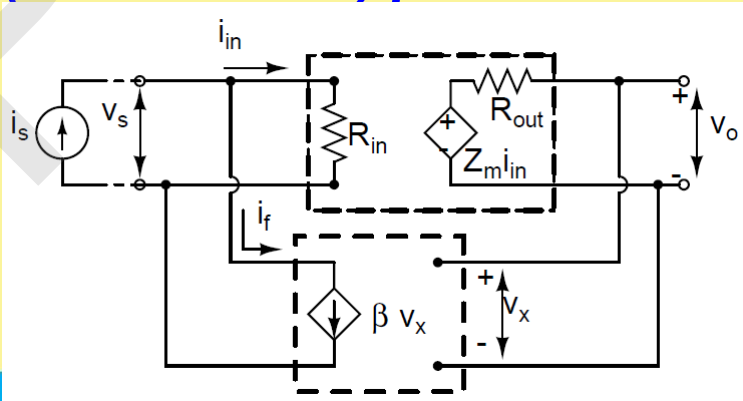
Input signal:

Output signal:

Forward amplifier gain:

T.F. of F.B. Network :

Rin: Rout:



Application circuit-1 (contd.)

Feedback configuration: *Voltage-Shunt (Shunt-shunt) feedback*

S_s :

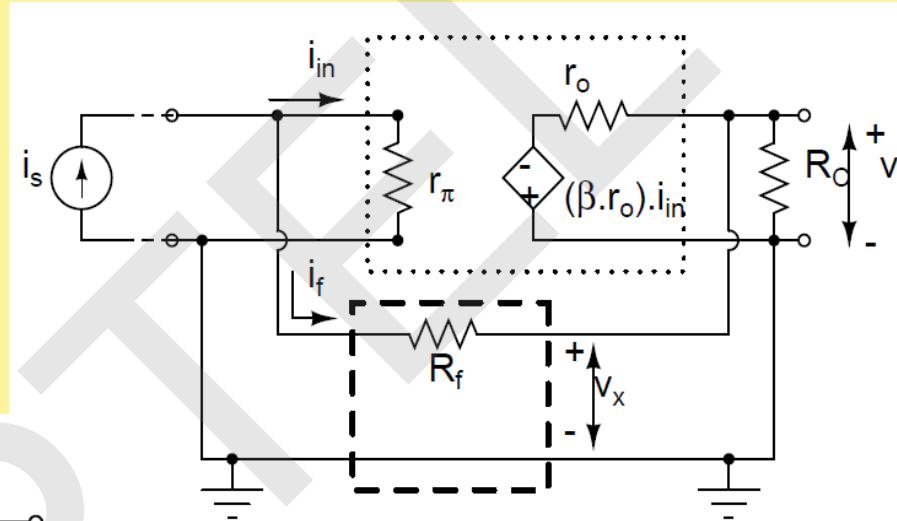
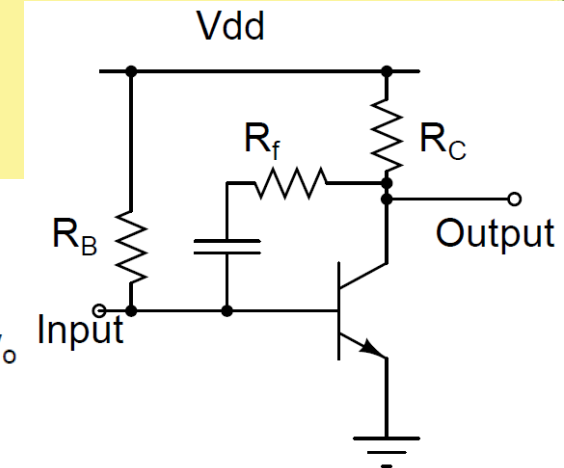
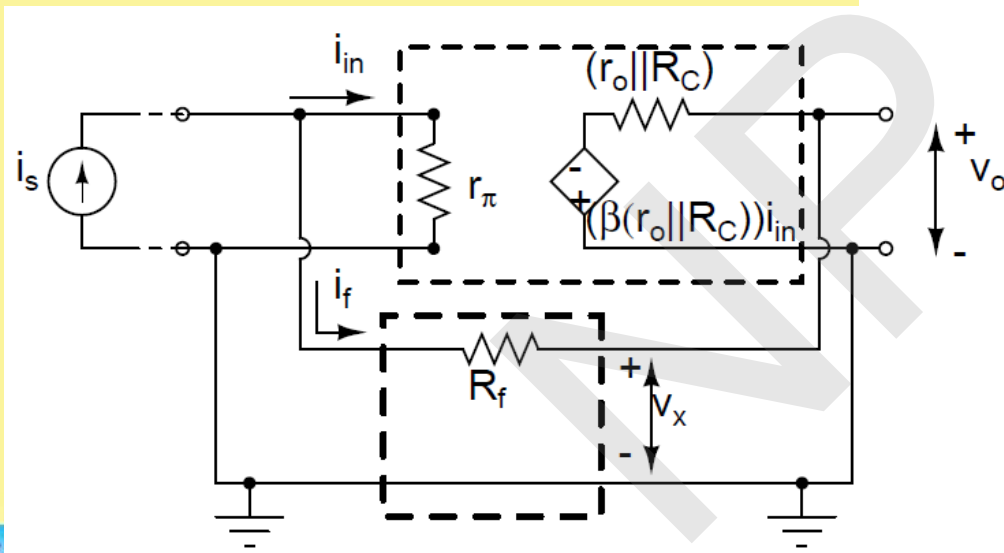
S_o :

A :

β_{FB} :

R_{in} :

R_{out} :



Application circuit-1 (contd.)

Feedback configuration: *Voltage-Shunt (Shunt-shunt) feedback*

A : $Z_m =$

R_{in} =

R_{out} =

$\beta_{FB} = 1/R_f$

Suitable range of R_f

$R_{in_f} \gg R_{out}$

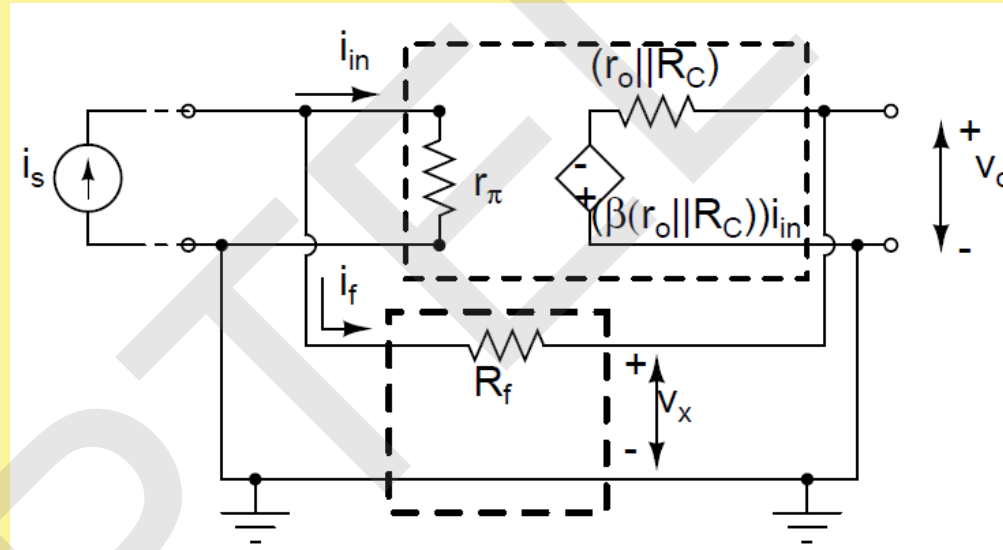
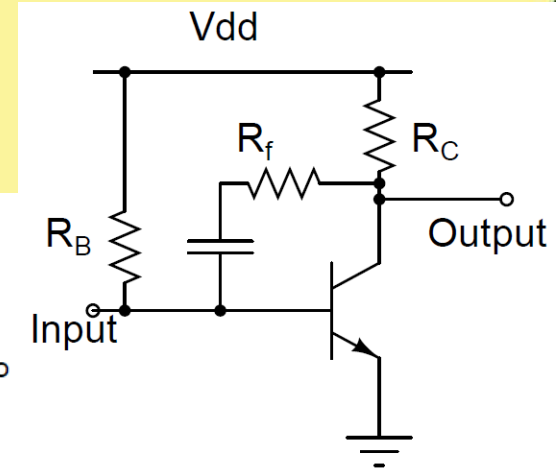
$R_{out_f} \gg R_{in}$

$A' \cdot \beta_{FB} \gg 1$

A_f : $Z_{m_f} =$

R_{in_f} :

R_{out_f} :



Application circuit-1 (contd.)

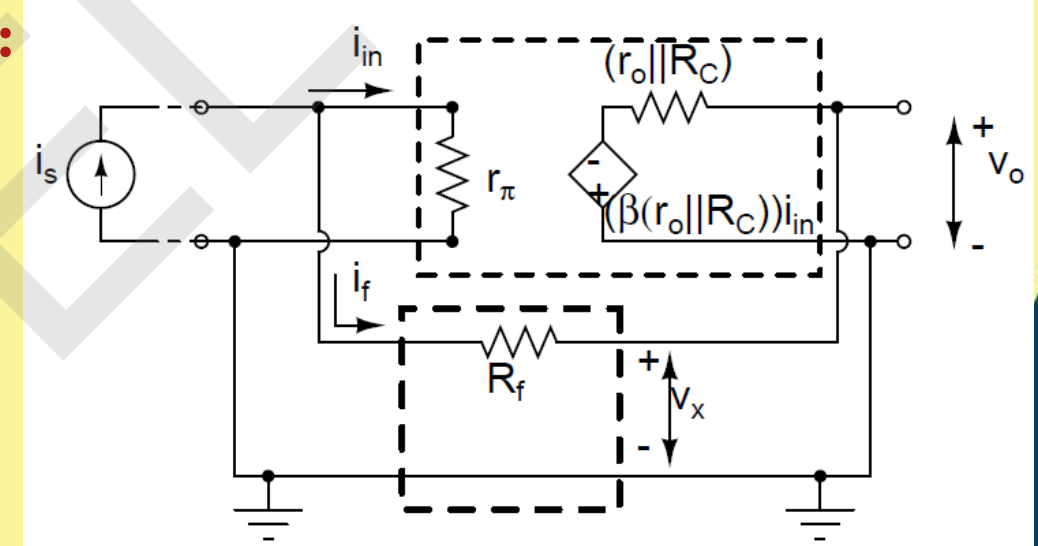
Feedback configuration: *Voltage-Shunt (Shunt-shunt) feedback*

Consequences of the F.B on other parameters:

A_v :

A_i :

G_m :



	A_i	A_v	G_m	Z_m
A_i	1	R_{in}/R_{out}	R_{in}	$1/R_{out}$
A_v	R_{out}/R_{in}	1	R_{out}	$1/R_{in}$
G_m	$1/R_{in}$	$1/R_{out}$	1	$1/(R_{in} \cdot R_{out})$
Z_m	R_{out}	R_{in}	$(R_{in} \cdot R_{out})$	1

Application circuit-1 : Numerical example

Feedback configuration: *Voltage-Shunt (Shunt-shunt) feedback*

$R_C = 5\text{ k}\Omega$; $R_B = 940\text{ k}\Omega$ $V_{DD} = 10\text{ V}$; $V_{BE(on)} = 0.6\text{ V}$; $V_A = 100\text{ V}$, $\beta = 100$

$A : Z_m =$

$R_{in} =$ $R_{out} =$

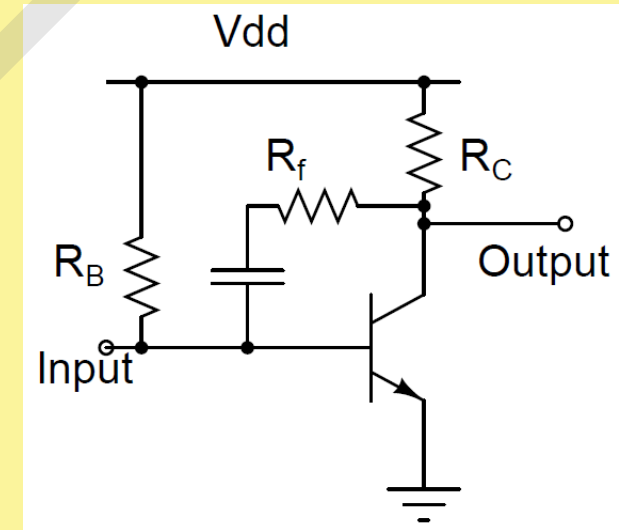
$\beta_{FB} = 1/R_f$

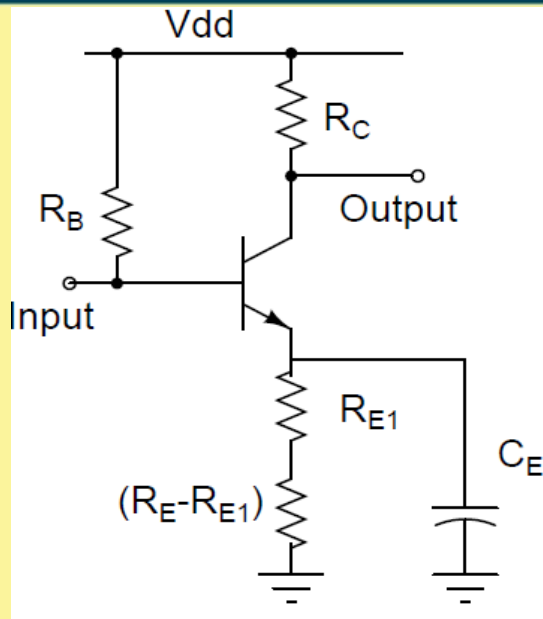
Suitable range of R_f

$A_f : Z_{m_f} =$

$R_{in_f} :$

$R_{out_f} :$





Application circuit-2

Configuration names	Sin	So	A ↓	Rin ↓	Rout ↓	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	↓	↓	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	↓	↑	-
Voltage-Series (Shunt-Series)	V	V	A_v	↑	↓	-
Current-Series (Series-Series)	V	I	G_m	↑	↑	Ohm

We want stable G_m defined by feedback network

Feedback configuration: *Current-Series (Series-Series) feedback*

Input signal:

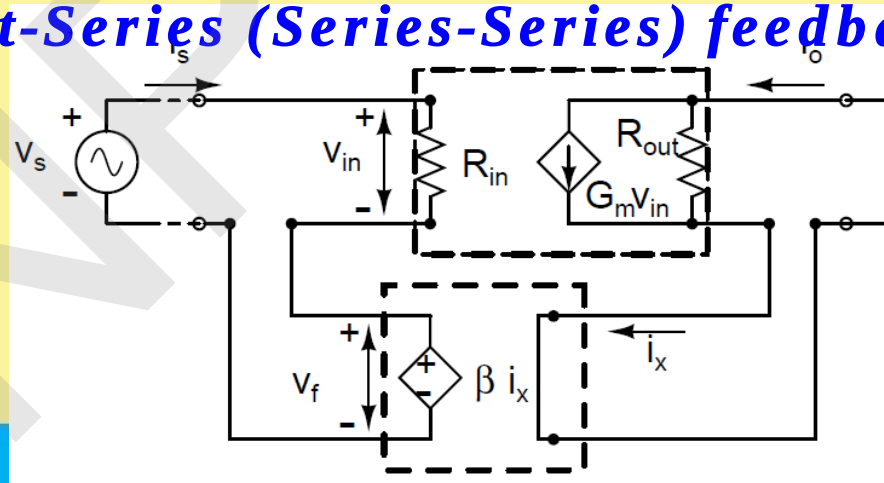
Output signal:

Forward amplifier gain:

T.F. of F.B. Network :

R_{in} :

R_{out} :



Application circuit-2 (contd.)

Feedback configuration: *Current-Series (Series-Series) feedback*

S_s :

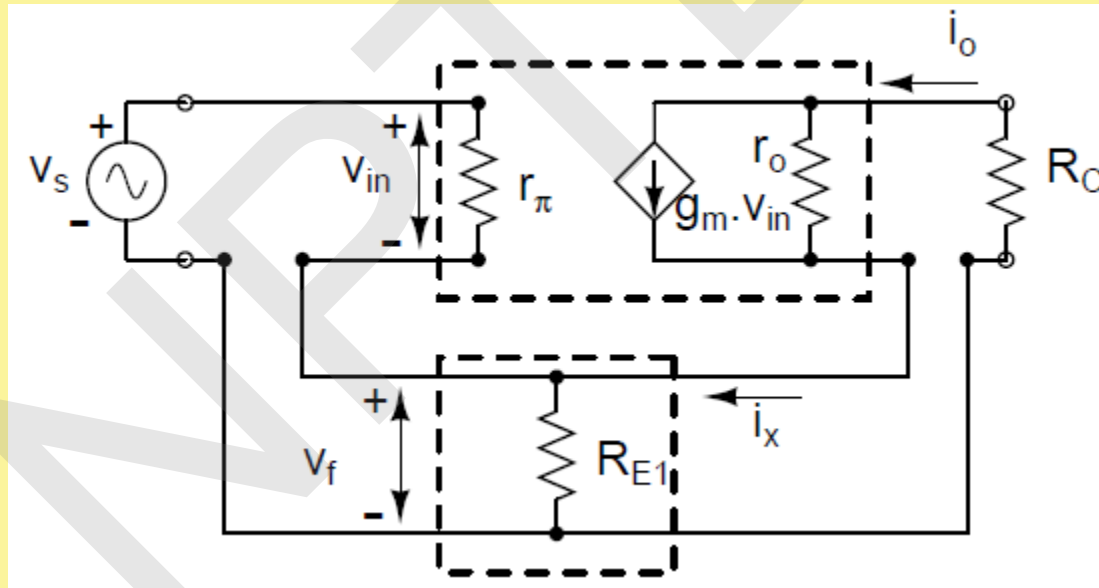
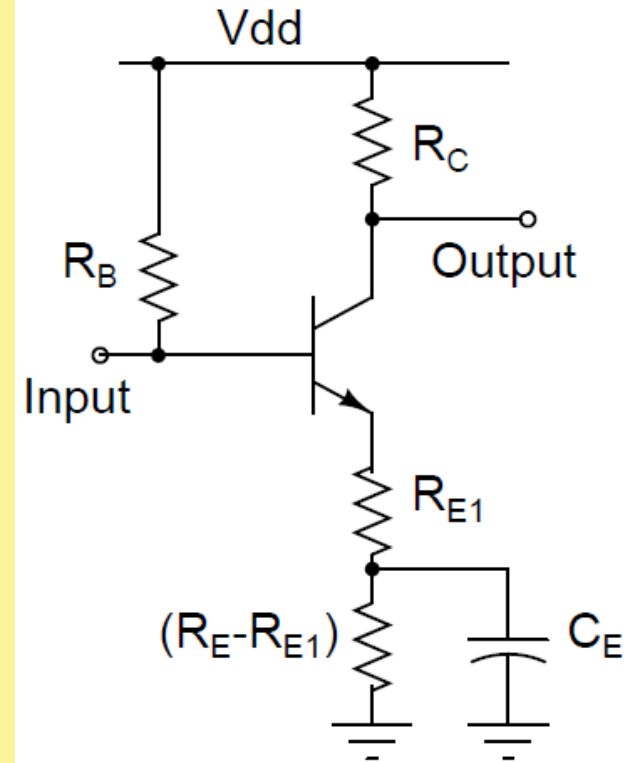
S_o :

A :

β_{FB} :

R_{in} :

R_{out} :



Application circuit-2 (contd.)

Feedback configuration: *Current-Series (Series-Series) feedback*

$$A : G_m =$$

$$R_{in} = \quad R_{out} =$$

$$\beta_{FB} = R_{E1}$$

Suitable range of R_{E1}

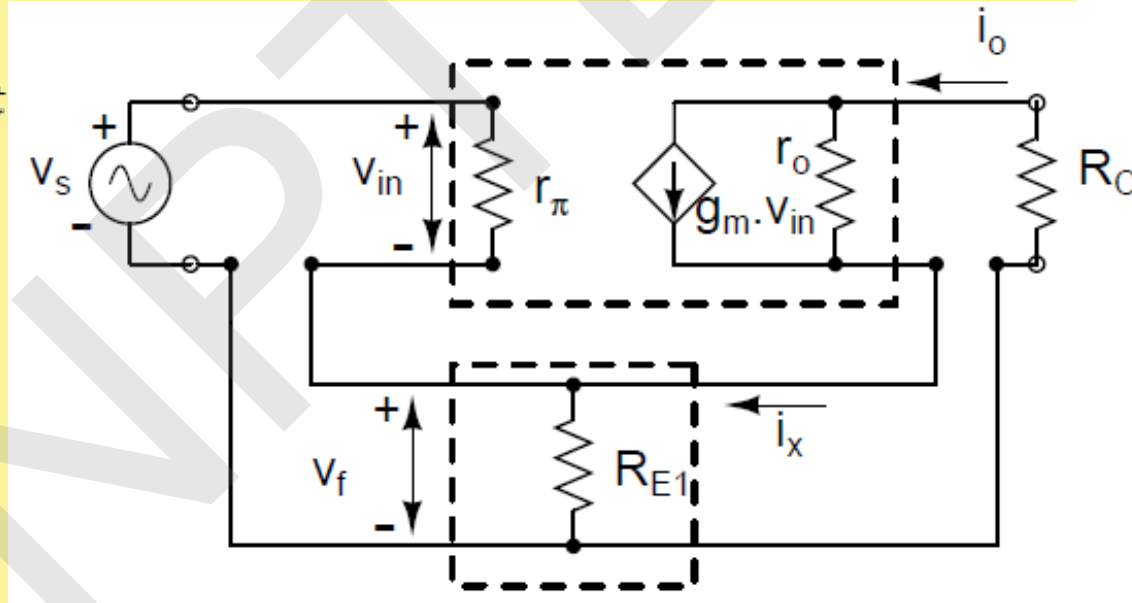
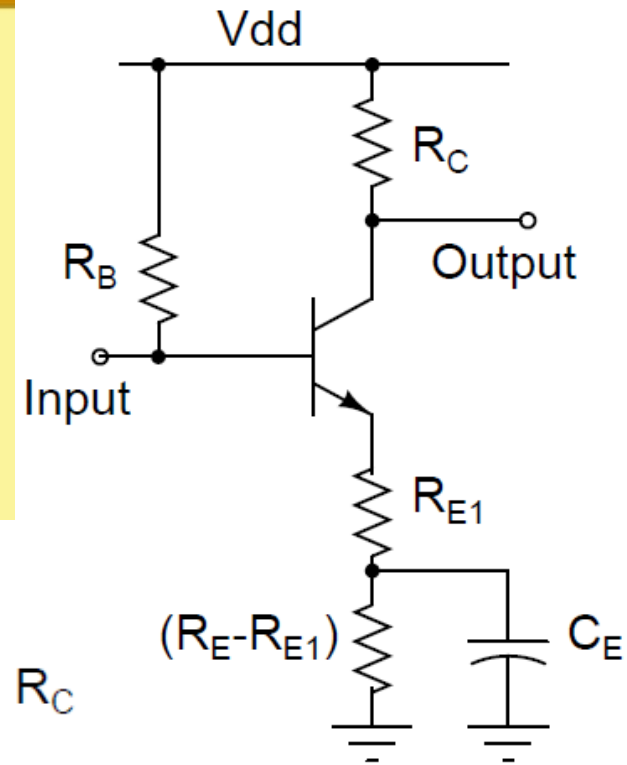
$$R_{out_\beta} \ll R_{in} \quad R_{in_\beta} \ll R_{out}$$

$$A' \cdot \beta_{FB} \gg 1$$

A_f :

R_{in_f} :

R_{out_f} :



Application circuit-2 (contd.)

Feedback configuration: *Current-Series (Series-Series) feedback*

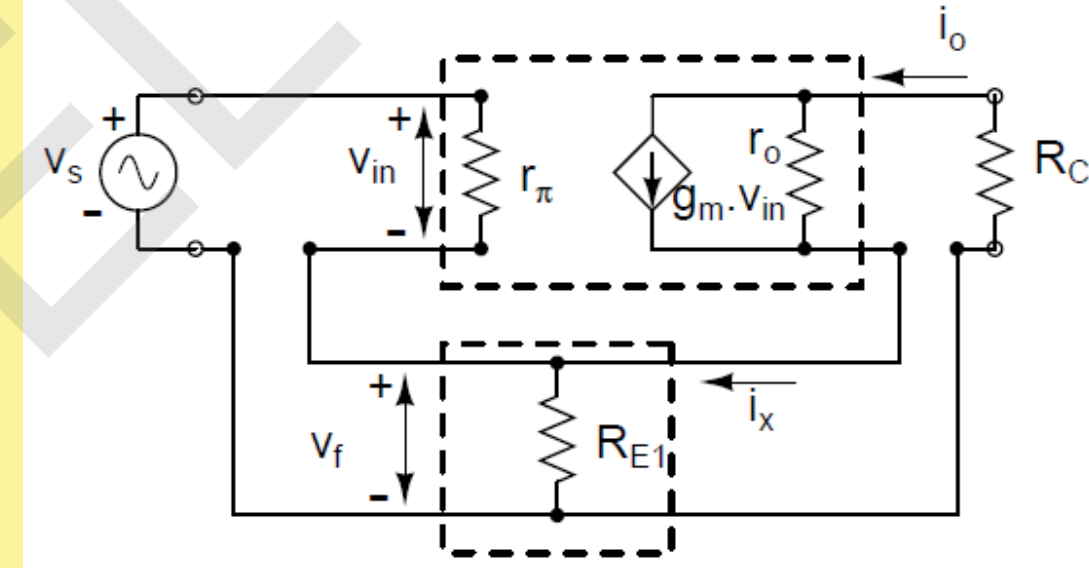
Consequences of the F.B on other parameters:

A_v :

A_i :

Z_m :

	A_i	A_v	G_m	Z_m
A_i	1	R_{in}/R_{out}	R_{in}	$1/R_{out}$
A_v	R_{out}/R_{in}	1	R_{out}	$1/R_{in}$
G_m	$1/R_{in}$	$1/R_{out}$	1	$1/(R_{in}.R_{out})$
Z_m	R_{out}	R_{in}	$(R_{in}.R_{out})$	1



Application circuit-2 : Numerical example

Feedback configuration: *Current-Series (Series-Series) feedback*

$R_C = 5\text{k}\Omega$, $R_B = 840\text{k}\Omega$, $V_{dd} = 10\text{V}$, $R_E = 1\text{k}\Omega$,

$V_{BE(on)} = 0.6\text{V}$, $V_A = 100\text{V}$, $\beta = 100$

A : $G_m =$

$R_{in} =$

$R_{out} =$

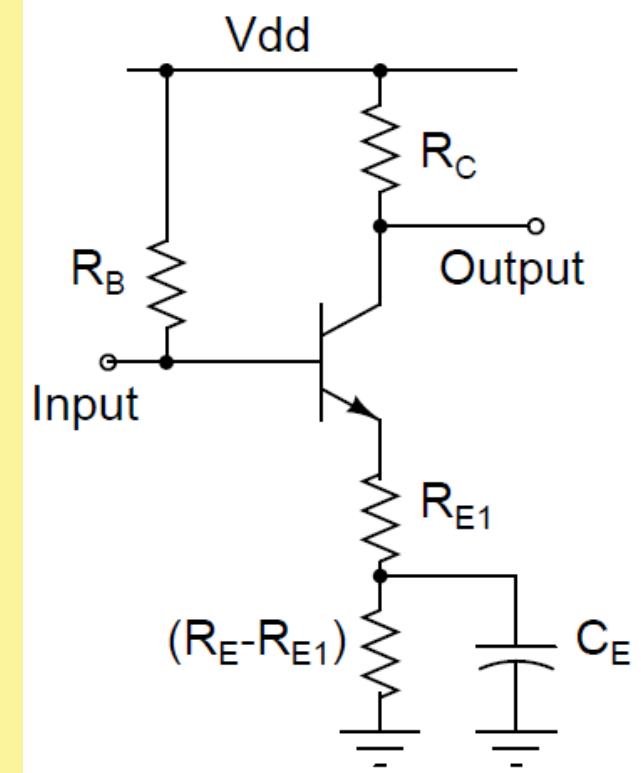
$\beta_{FB} = R_{E1}$

Suitable range of R_{E1}

A_f : $G_{m_f} =$

$R_{in_f} =$

$R_{out_f} =$



Application circuit-2 (contd.)

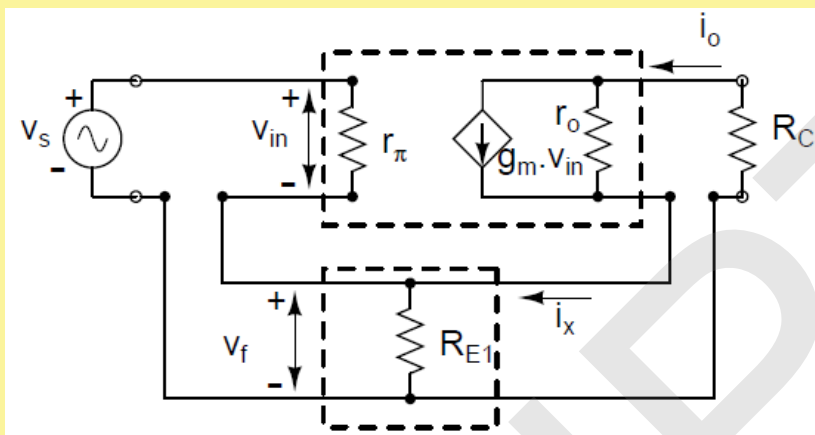
Feedback configuration: *Current-Series (Series-Series) feedback*

Consequences of the F.B on other parameters:

A_v :

A_i :

Z_m :



	A_i	A_v	G_m	Z_m
A_i	1	R_{in}/R_{out}	R_{in}	$1/R_{out}$
A_v	R_{out}/R_{in}	1	R_{out}	$1/R_{in}$
G_m	$1/R_{in}$	$1/R_{out}$	1	$1/(R_{in} \cdot R_{out})$
Z_m	R_{out}	R_{in}	$(R_{in} \cdot R_{out})$	1

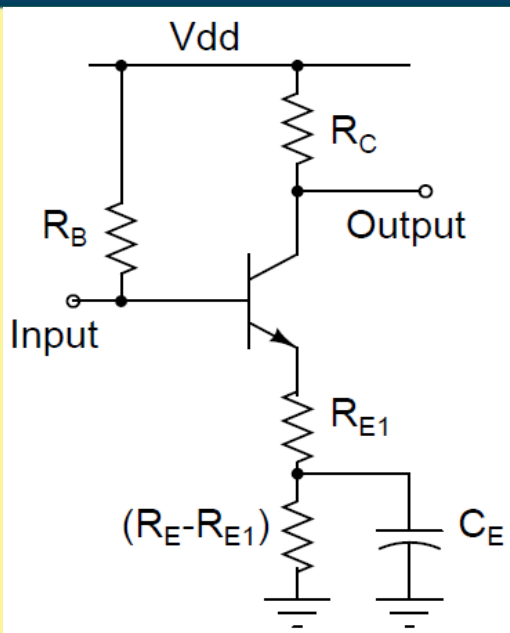
Consequences of the F.B on other parameters (considering R_C):

A_v :

A_i :

Z_m :





Application circuit-3

Configuration names	Sin	So	A ↓	Rin ↓	Rout ↓	Unit of β_{FB}
Voltage-Shunt (Shunt-Shunt)	I	V	Z_m	↓	↓	Mho
Current-Shunt (Series-Shunt)	I	I	A_I	↓	↑	-
Voltage-Series (Shunt-Series)	V	V	A_v	↑	↓	-
Current-Series (Series-Series)	V	I	G_m	↑	↑	Ohm

We want stable A_v defined by feedback network

Feedback configuration: **Voltage-Series (Shunt-Series) feedback**

Input signal:

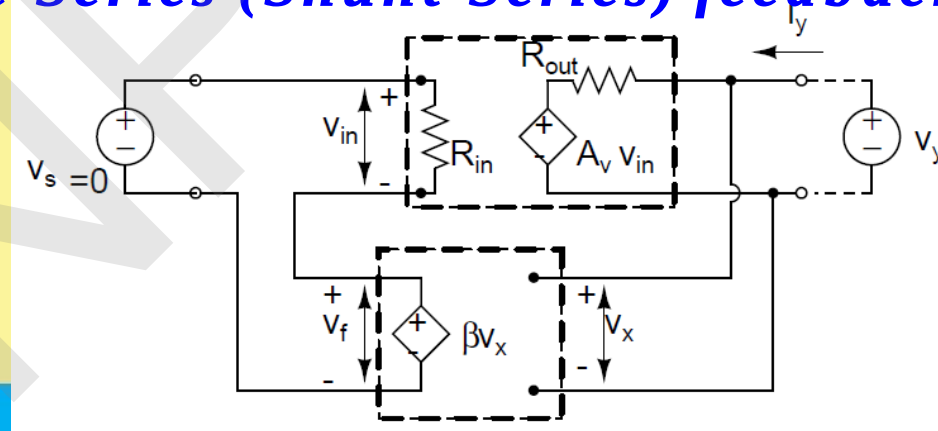
Output signal:

Forward amplifier gain:

T.F. of F.B. Network :

R_{in} :

R_{out} :



Application circuit-3 (contd.)

Feedback configuration: *Voltage-Series (Shunt-Series) feedback*

S_s :

S_o :

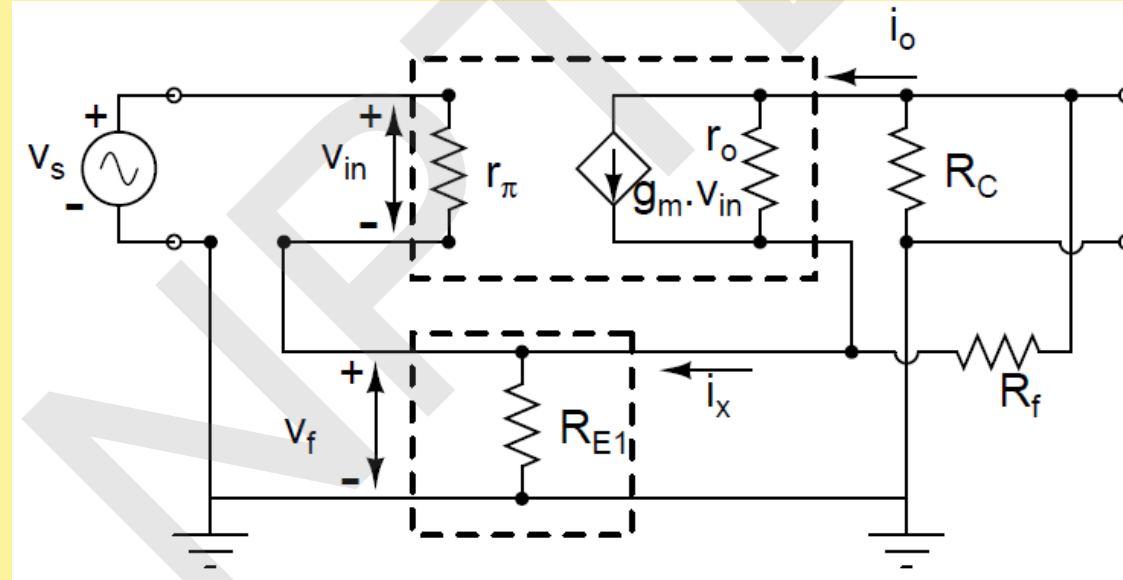
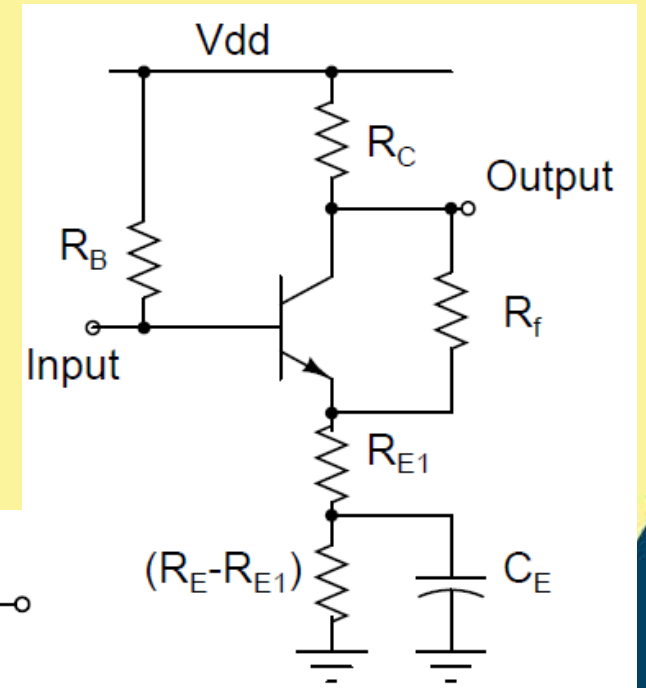
A :

β_{FB} :

R_{in} :

R_{out} :

It is a positive feedback !



Application circuit-3 (contd.)

Feedback configuration: *Voltage-Series (Shunt-Series) feedback*

S_s :

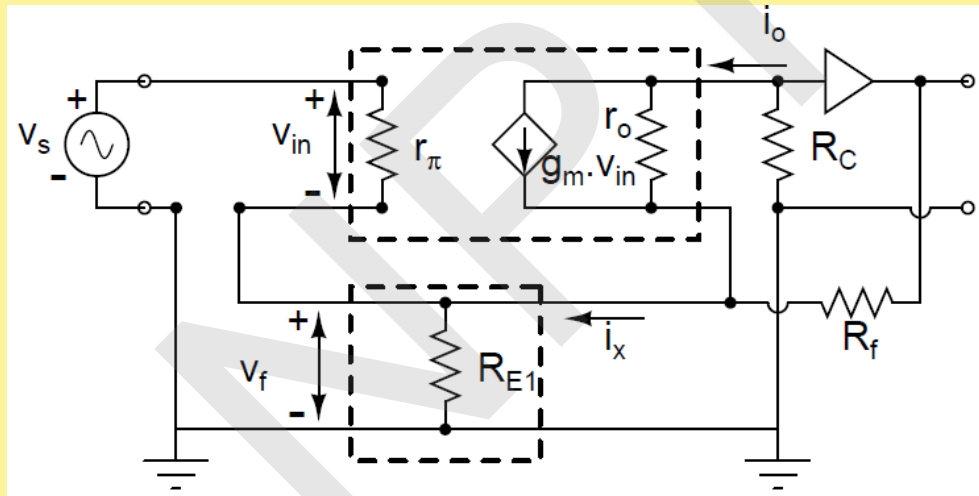
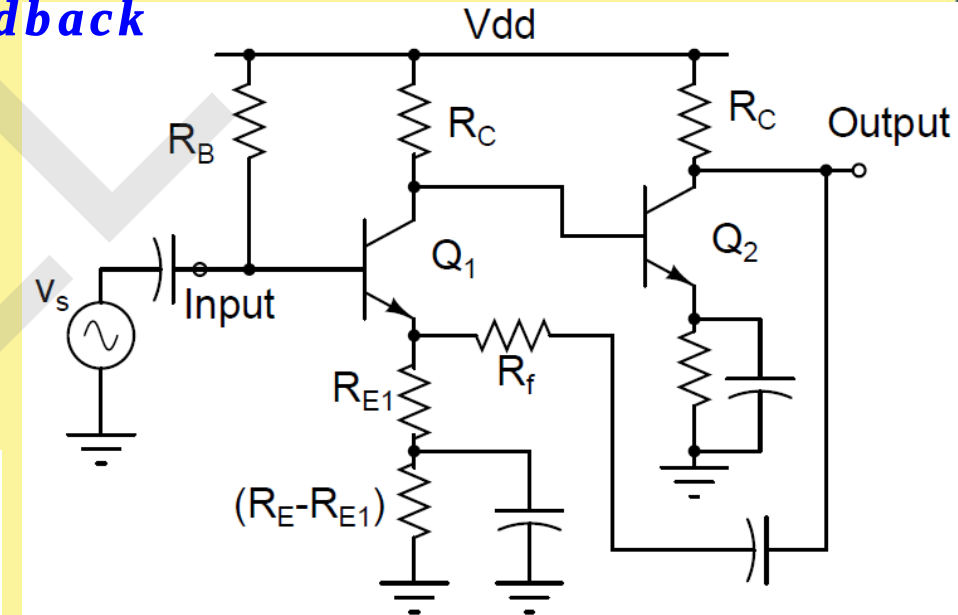
S_o :

A :

β_{FB} :

R_{in} :

R_{out} :



Application circuit-3 (contd.)

Feedback configuration: *Voltage-Series (Shunt-Series) feedback*

$$A : A_v =$$

$$R_{in} = \quad R_{out} =$$

$$\beta_{FB} = R_{E1} / (R_f + R_{E1})$$

Suitable range of R_{E1}

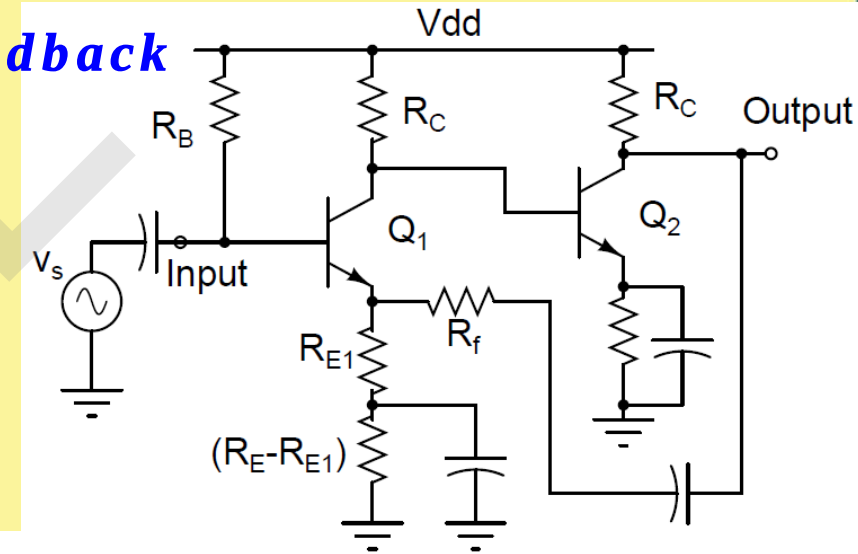
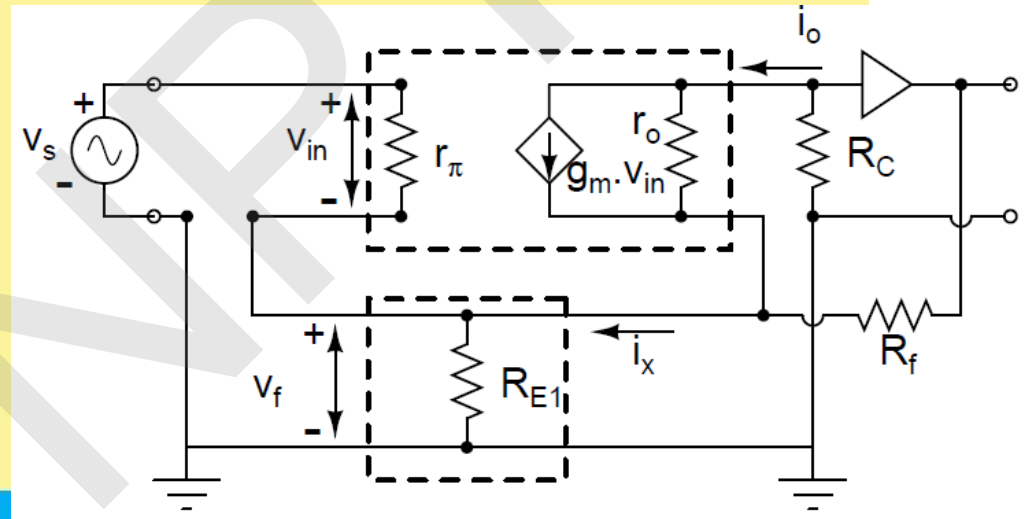
$$R_{out_\beta} \ll R_{in} \quad R_{in_\beta} \gg R_{out}$$

$$A' \cdot \beta_{FB} \gg 1$$

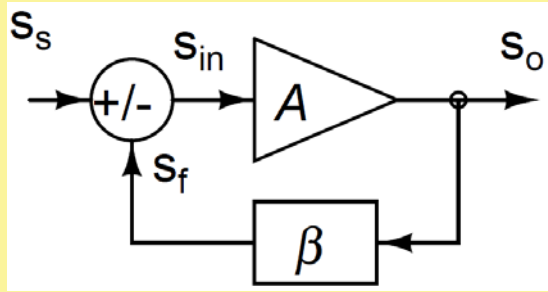
A_f :

R_{in_f} :

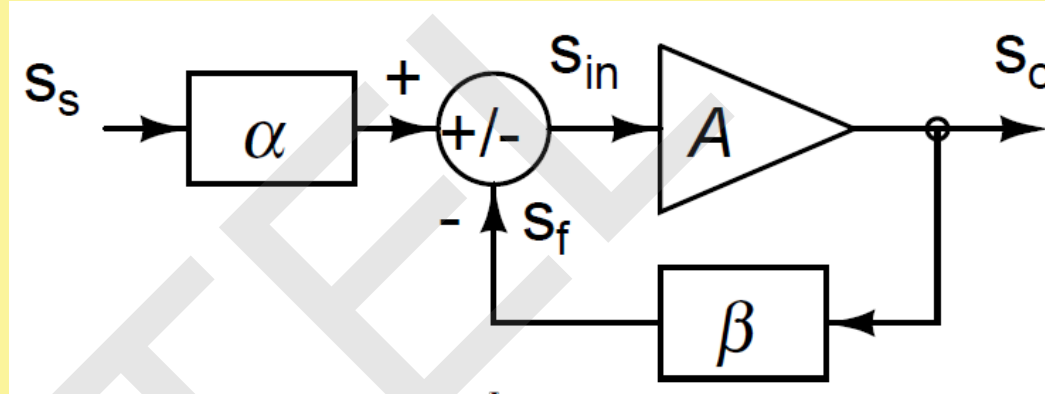
R_{out_f} :



Feedback system with pre-stage: *Basic concepts*



$$A_f = \frac{A}{(1 + \beta \cdot A)}$$

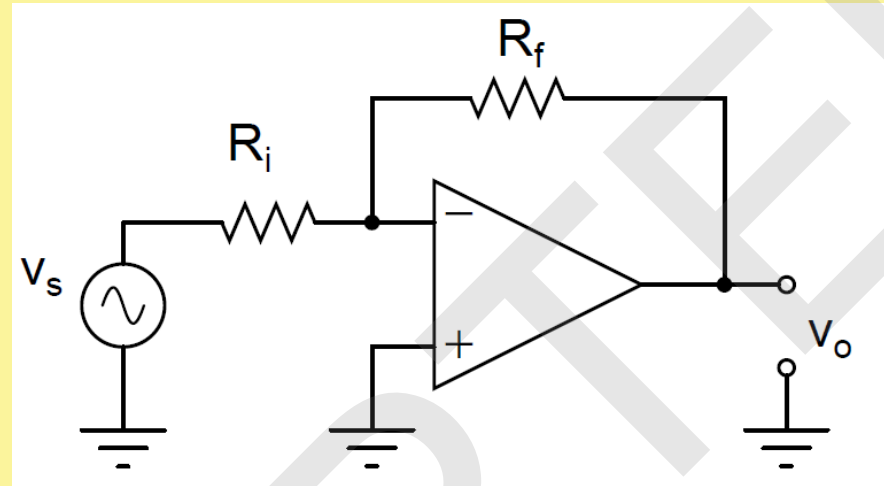
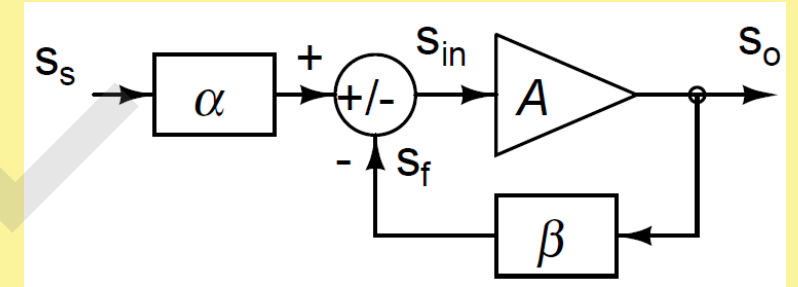


$$A_f = \frac{\alpha \cdot A}{(1 + \beta \cdot A)}$$

- **Basic model of feedback system consists of**
 - **Forward amplifier**
 - **Feedback path/network**
 - **Signal sampler**
 - **Signal mixer**
 - **Pre-stage (Alpha block)**

Feedback system using operational amplifier (Op-Amp)

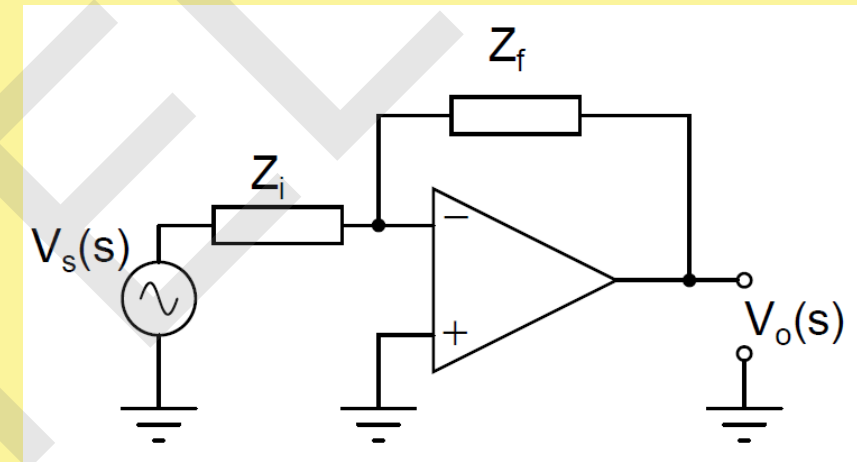
Inverting amplifier:



$$A_f = \frac{\alpha \cdot A}{(1 + \beta \cdot A)}$$

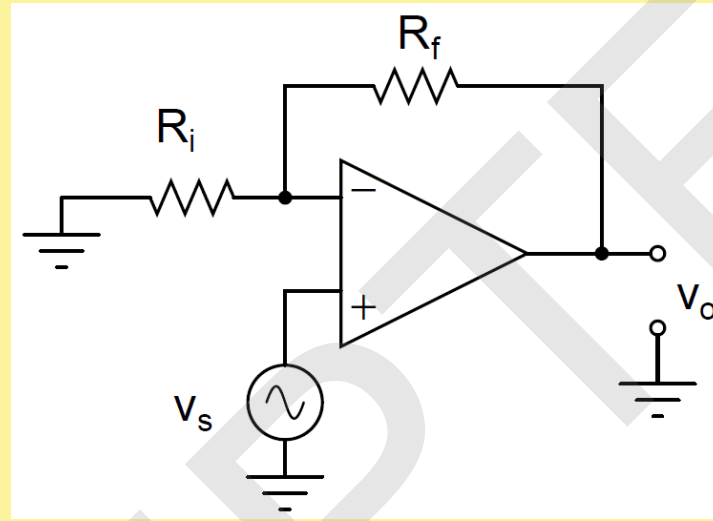
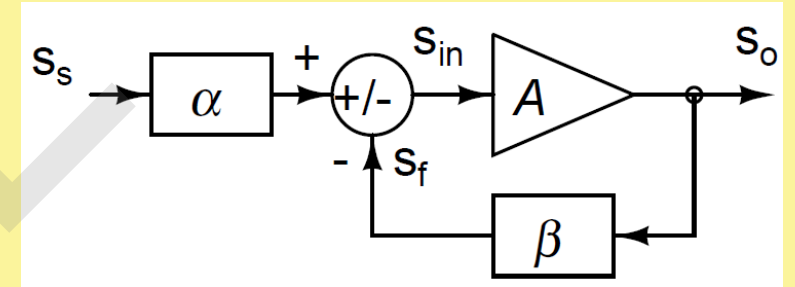
Feedback system using Op-Amp (contd.)

Integrator and Differentiator:



Feedback system using Op-Amp (contd.)

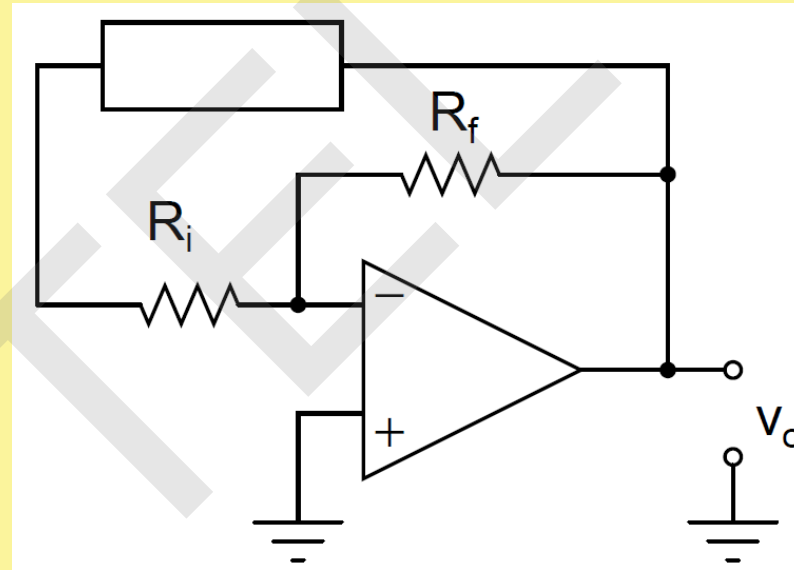
Non-inverting amplifier:



$$A_f = \frac{\alpha \cdot A}{(1 + \beta \cdot A)}$$

Feedback system using Op-Amp (contd.)

Two loop system :



Conclusion:

- ❑ **Application of feedback in BJT amplifiers**
 - ❑ Voltage-shunt (shunt-shunt) F.B.
 - ❑ Current-series (series-series) F.B.
 - ❑ Voltage-series (shunt-series) F.B.
- ❑ **Simple extension of basic FB model**
- ❑ **Application of feedback in op-amp circuits**
 - ❑ Inverting amplifier
 - ❑ Integrator and Differentiator
 - ❑ Non-inverting amplifier
 - ❑ A circuit with two feedback loops

Conclusion





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*Thank
you*

