Feedback Amplifiers

UNIT IV

Why Feedback Amplifiers?

The gain of **a** **common source** amplifier = $g_m R_D$

The gain of **a common emitter** amplifier = $g_m R_C$

g_m= transconductance

(1) Ambient temperature changes
(2) Parameter variations

→ g_m, R_C and R_D changes → Gain changes

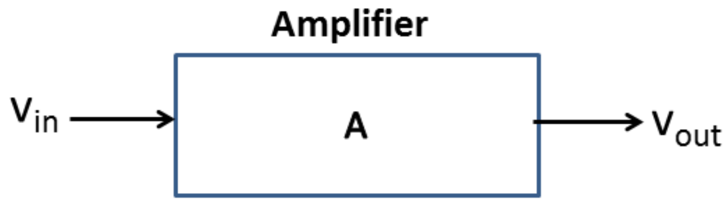
The aim is to make the **gain less sensitive** to temperature and other device parameter variation.

For this, feedback is used in amplifiers

Feedback Amplifiers - Introduction

What is an amplifier?

It is a circuit that amplifies (increases the strength of) the input signal.



$A = V_{out}/V_{in}$

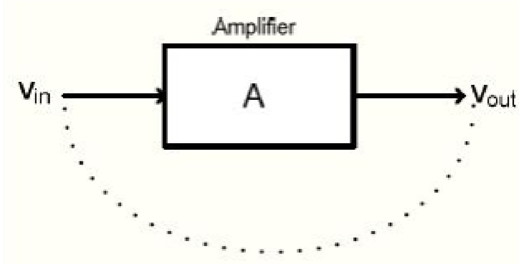
$V_{out} = A\ V_{in}$

What is feedback ? What is meant by feedback? Define feedback

- In the field of electronics, **feedback** is a process (method) in which a portion (fraction, part) of the output signal (which may be voltage or current) is returned (fed back) to the input.

- **Feedback** can be applied to amplifier circuits to **modify** their performance characteristics such as **gain**, **bandwidth**, input and output resistance etc

- Feedback is the fundamental concept in the design of a stable amplifier and an unstable oscillator circuit.



Feedback Amplifiers - Introduction

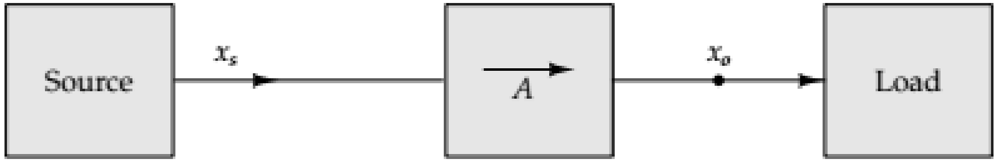
What is feedback amplifier?

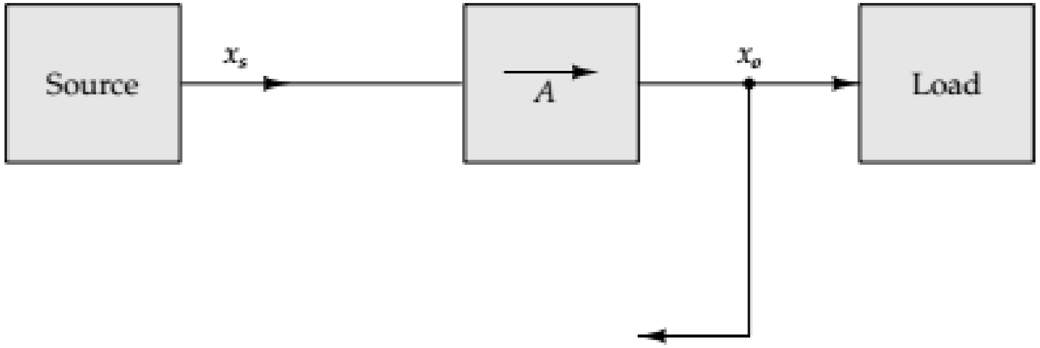
- ❖ Feedback amplifier is an amplifier in which a feedback path exists from output to input.
- ❖ A feedback amplifier consists of (contains) two parts: an amplifier and a feedback circuit.

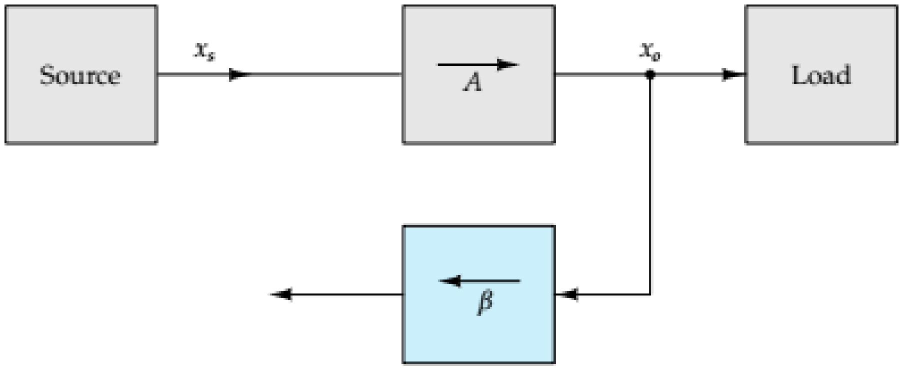
Feedback Amplifier $\Rightarrow$ **Amplifier** + **Feedback circuit**

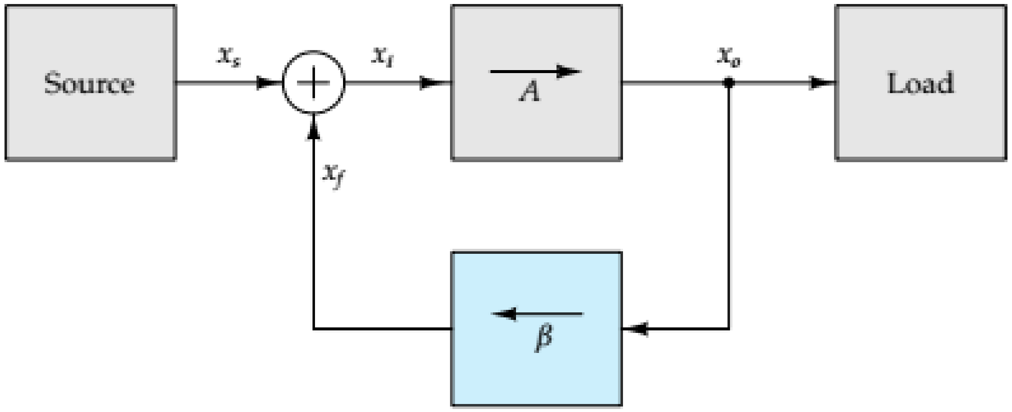
- ❖ The purpose of feedback circuit is to return a fraction of the output voltage to the input of the amplifier.
- ❖ In a feedback amplifier, a fraction (portion) of the output signal is fed back to the input.

Feedback Amplifiers - Introduction









Feedback Amplifier: Block diagram

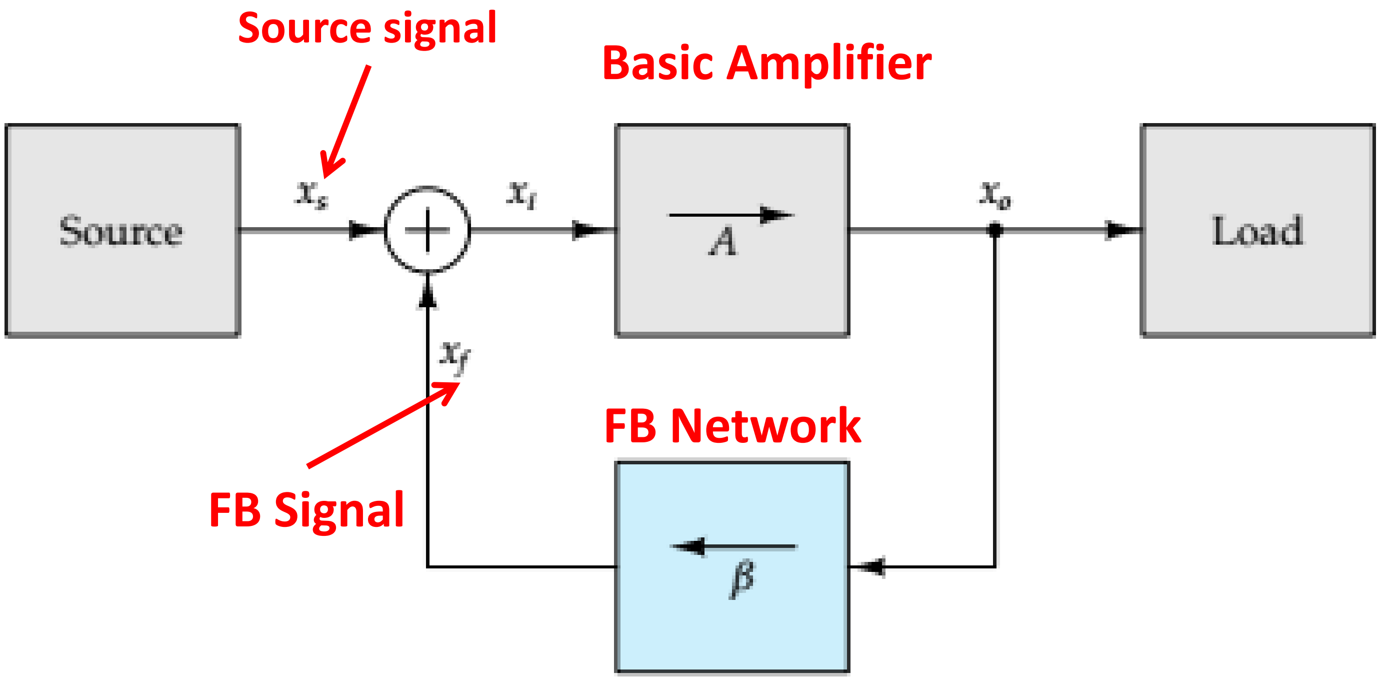
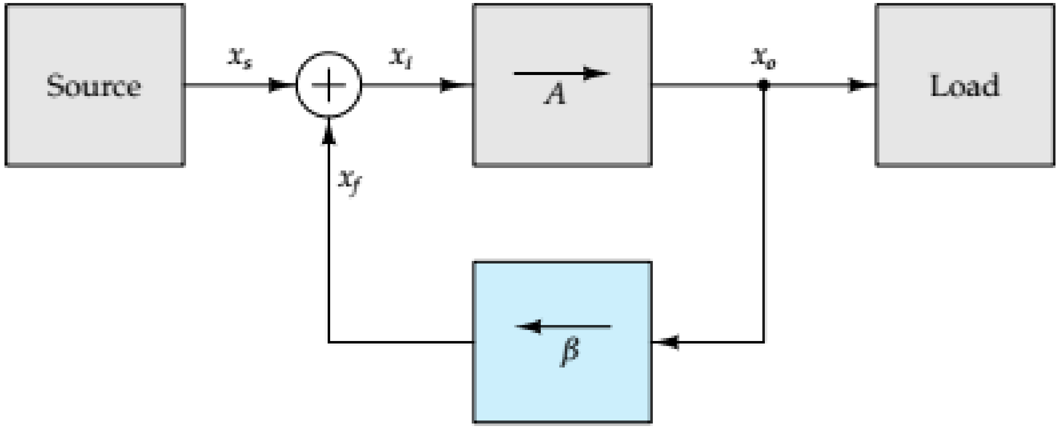


Figure: Block diagram of a feedback amplifier

Another name feedback amplifier

❖ A **feedback amplifier** is sometimes referred to as a **Closed-Loop amplifier** because the feedback forms a closed loop between the input and output.

Nomenclature



A: Gain without feedback (<u>Open-loop gain</u>)

A_f: Gain with feedback (<u>closed-loop gain</u>)

$\boldsymbol{\beta}$: Feedback factor

$\mathbf{A\beta}$: Loop gain

$1+\mathbf{A\beta}$: Amount of feedback

Types of Feedback

The feedback can be classified into two types:

(1) Negative feedback (2) **Positive feedback**

■ Negative feedback

- If the feedback signal applied to the input is out of phase with the input signal (i.e., feedback signal is 180 out of phase with the input signal), then the feedback is called negative Feedback.
- The polarity of the feedback signal is opposite that of the input signal.
- Negative feedback is also known as **degenerative feedback** because it degenerates (or reduces) the output signal
- **In the negative feedback,** the feedback signal is ***subtracted*** from the source signal. So, the feedback signal **reduces** the strength of the input signal that appears at the input of the basic amplifier. i.e. the feedback signal ***opposes*** the source signal.
- ***Negative feedback*** *concept is used in* ***amplifiers.***

Negative Feedback Amplifier: Block diagram

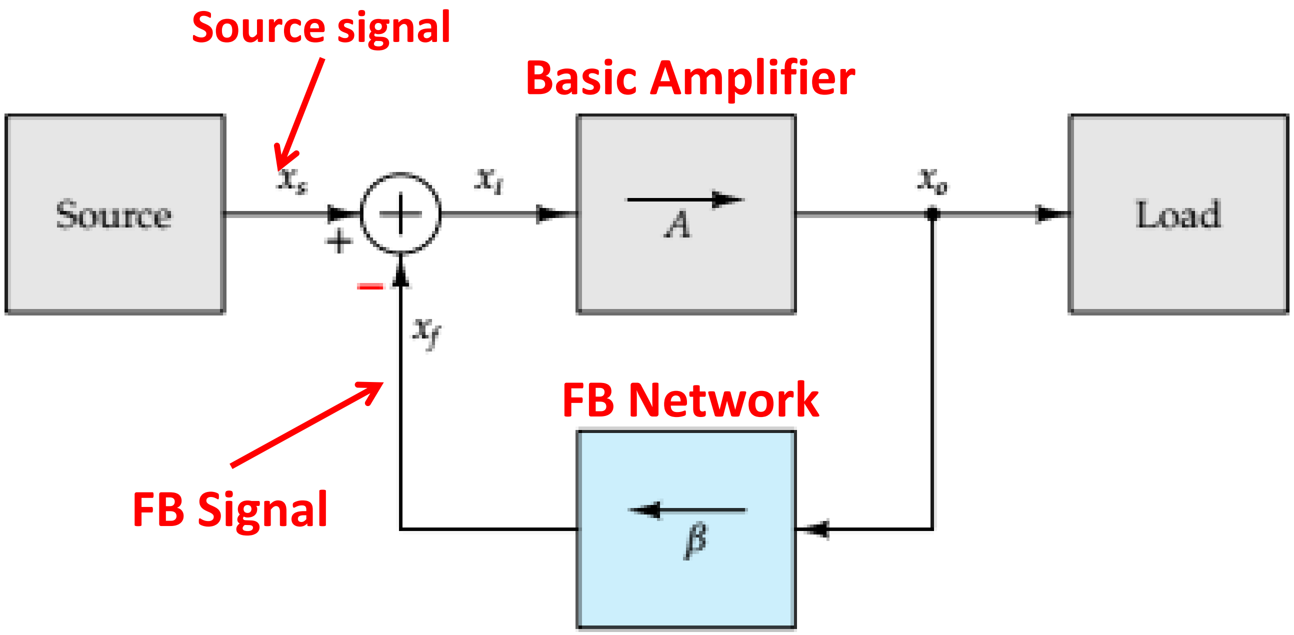


Figure: Block diagram of a **negative** feedback amplifier

Positive Feedback

- If the feedback signal applied to the input is in phase with the input signal, then the feedback is called **positive Feedback**.

- The polarity of the feedback signal is same as that of the input signal.

- Positive feedback is also known as **regenerative feedback** because it increases the output signal

- **In the positive feedback,** the feedback signal is **added *to*** the source signal. So, the feedback signal **increases** the strength of the input signal that appears at the input of the basic amplifier. i.e. the feed back signal ***aids*** the source signal.

- ***Positive feedback*** *concept is used in* ***oscillators***

Positive Feedback Amplifier: Block diagram

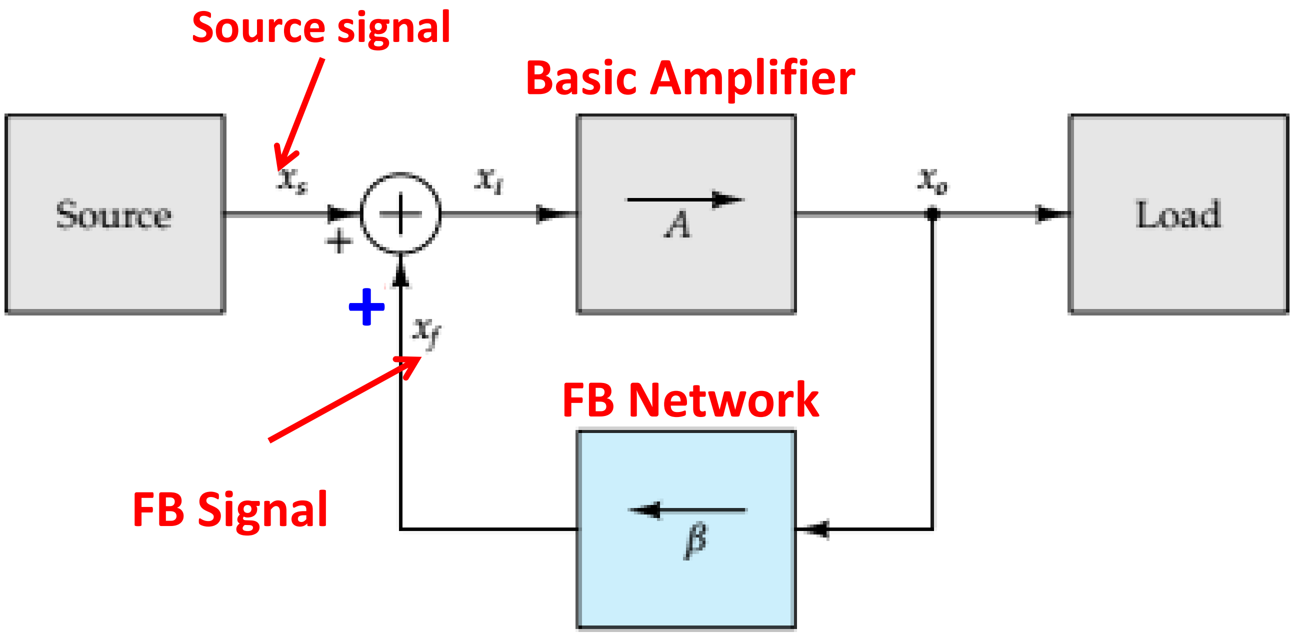


Figure: Block diagram of a **positive** feedback amplifier

Voltage gain with negative feedback

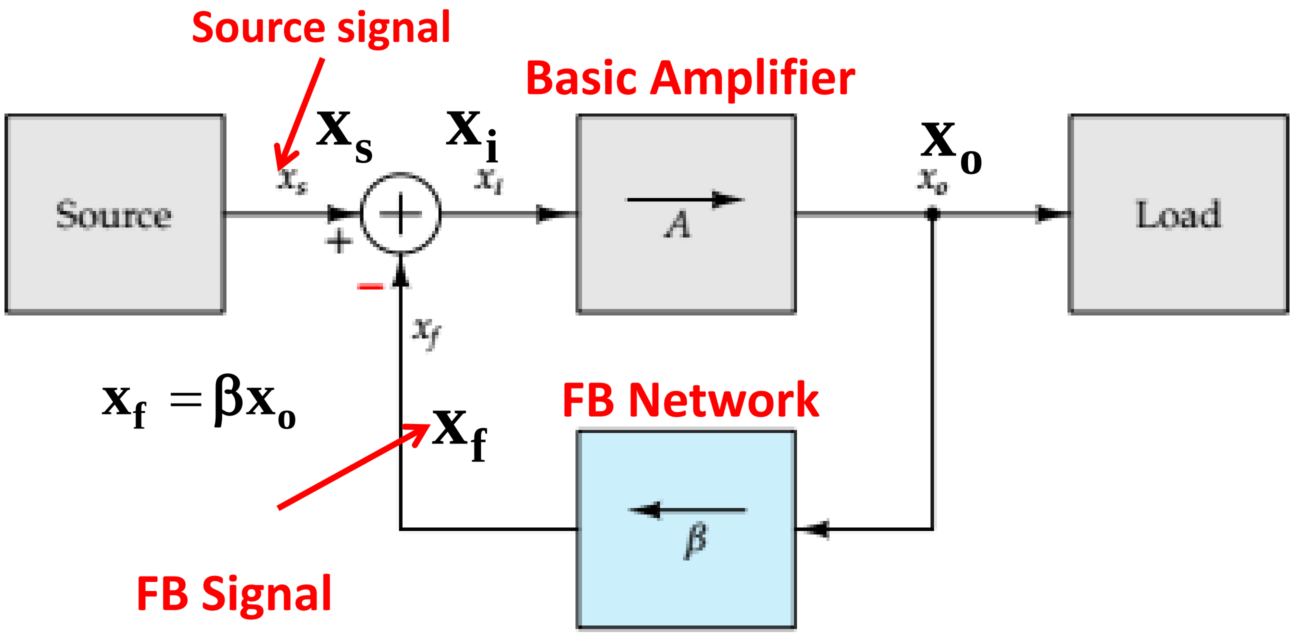


Figure: Block diagram of a **negative** feedback amplifier

❖ The x signals can be voltage or current

Without feedback

The gain of an amplifier (A) without feedback is given by

$$\boxed{A = \frac{x_o}{x_s} = \frac{x_o}{x_i}} \quad [1]$$

With feedback

For a negative feedback, the input to the amplifier is

$$x_i = x_s - x_f \quad \Rightarrow \quad x_s = x_i + x_f$$

The gain of the amplifier with feedback is

$$A_f = \frac{x_o}{x_s}$$

$$A_f = \frac{x_o}{x_i + x_f}$$

But the feedback signal is

$$x_f = \beta x_o$$

$$\boxed{A_f = \frac{x_o}{x_i + \beta x_o}} \quad [2]$$

From (1), we get

$$\boxed{x_o = A x_i} \quad [3]$$

Substituting (3) in (2), we get

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

This can be written as

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

❖ In the case of negative feedback, the gain of the feedback amplifier (A_f) is smaller than the open-loop gain (A) by a factor of ($1+A\beta$)

If $A\beta >> 1$, then the above equation becomes

$$\mathbf{A_f} \cong \frac{\mathbf{A}}{\mathbf{A\beta}} \cong \frac{1}{\boldsymbol{\beta}}$$

❖ It means that the **gain of the feedback amplifier** is almost entirely determined by the **feedback network**.

❖ In other words, the overall gain will have **very little dependence** on the gain of the basic amplifier.

❖ The gain *A* is usually a function of

(1) Ambient temperature changes
(2) Device parameter variations

❖ Thus closed-loop gain would be **more stable** and is nearly independent of changes of open-loop gain.

Some properties of Negative feedback

Advantages of Negative feedback

- It helps to **stabilize the gain**
- It **increases bandwidth** [Bandwidth of amplifier with feedback is greater than bandwidth of amplifier without feedback].
- It **reduces distortions**
- It improves the linearity of operation
- It improves the **signal to noise ratio (SNR).**
- It improves the **input resistance and output resistance**

Disadvantages of Negative feedback

- **It reduces the gain of the circuit.**

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

Some properties of positive feedback

Advantages of Positive feedback

- **It increases the gain of the amplifier** (It is used to increase the gain of the signal.

  When the input signal strength is very weak and if we want to increase its strength, we go for a carefully designed positive feedback amplifier.

- **It is used to produce oscillation.**

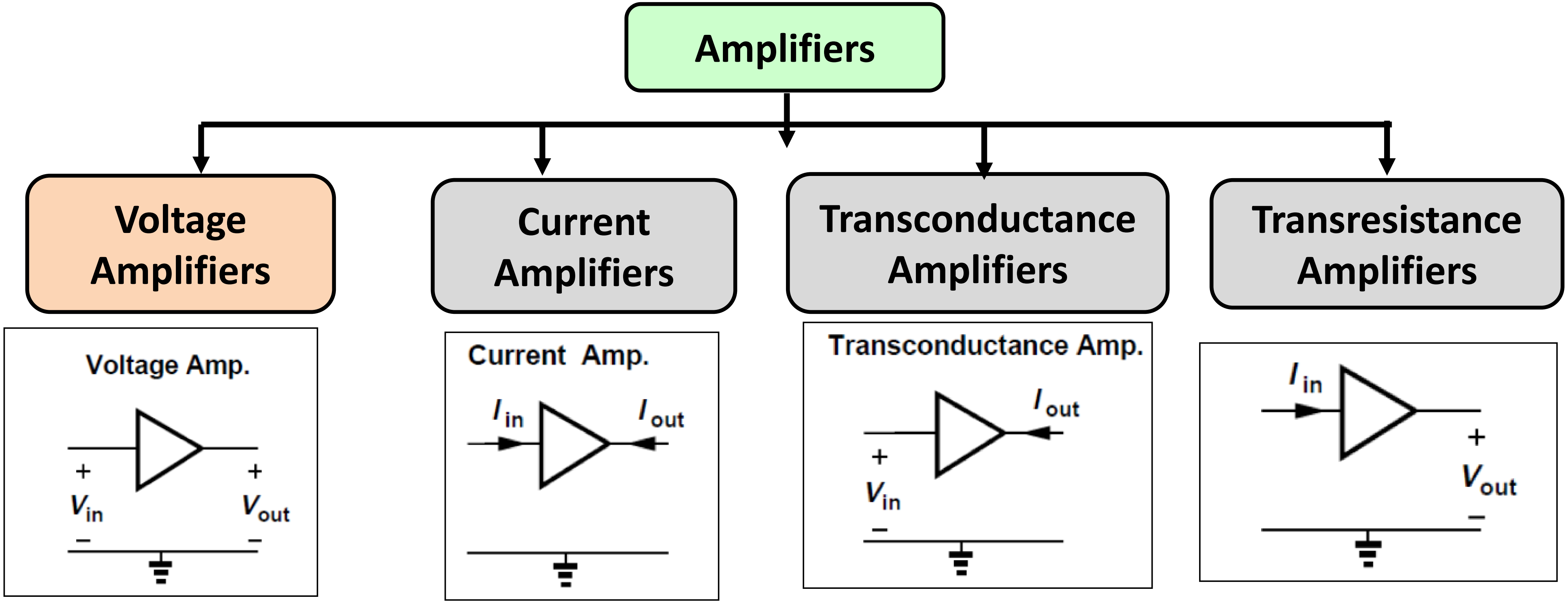
Disadvantages of Negative feedback

- It **reduces the bandwidth**
- It **reduces the stability of the gain**.

Feedback Topologies (Feedback Configurations)

Based on the **input signal** (voltage or current) and on the **output signal** (voltage or current), amplifiers can be classified into four categories.

1. **Voltage** amplifiers
2. **Current** amplifiers
3. **Transconductance** amplifiers
4. **Transresistance** amplifiers



Feedback in electronics

NOTE

How to measure voltage and current?

Voltage is measured with ***voltmeters***

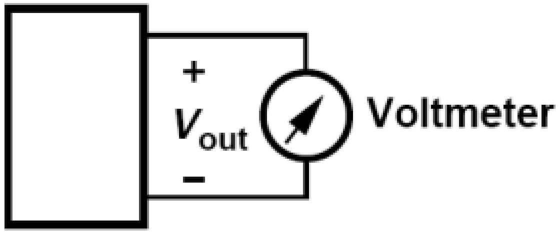
- Voltmeters are **connected in parallel** to the circuit

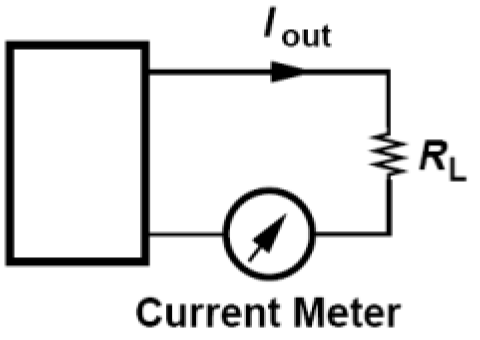
Current is measured with **ammeters**

- Ammeters are **connected in series** to the circuit

NOTE

- **How do we sense a voltage or a current?**





To sense a **voltage**, we place a voltmeter in **parallel.**

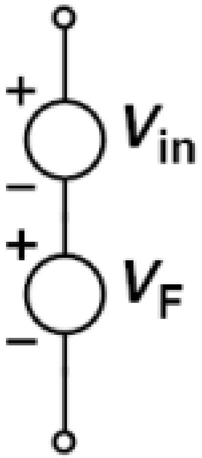
To sense a **current**, current meter is inserted in **series** with the signal

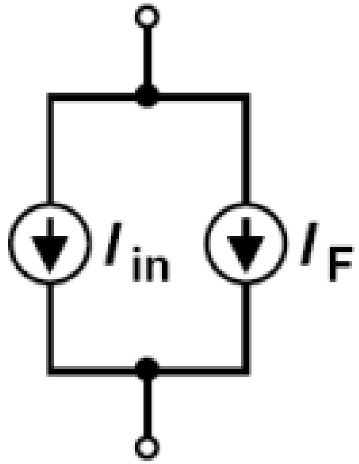
How to ADD voltage and current?

- Voltages are added by connecting voltage sources in series
- Currents are added by connecting current sources in parallel (“shunt”)

NOTE

How do we add two voltages or two currents?





- Voltages are added in series

- Currents are added in parallel

Feedback in electronics

NOTE

- **measure** the output:

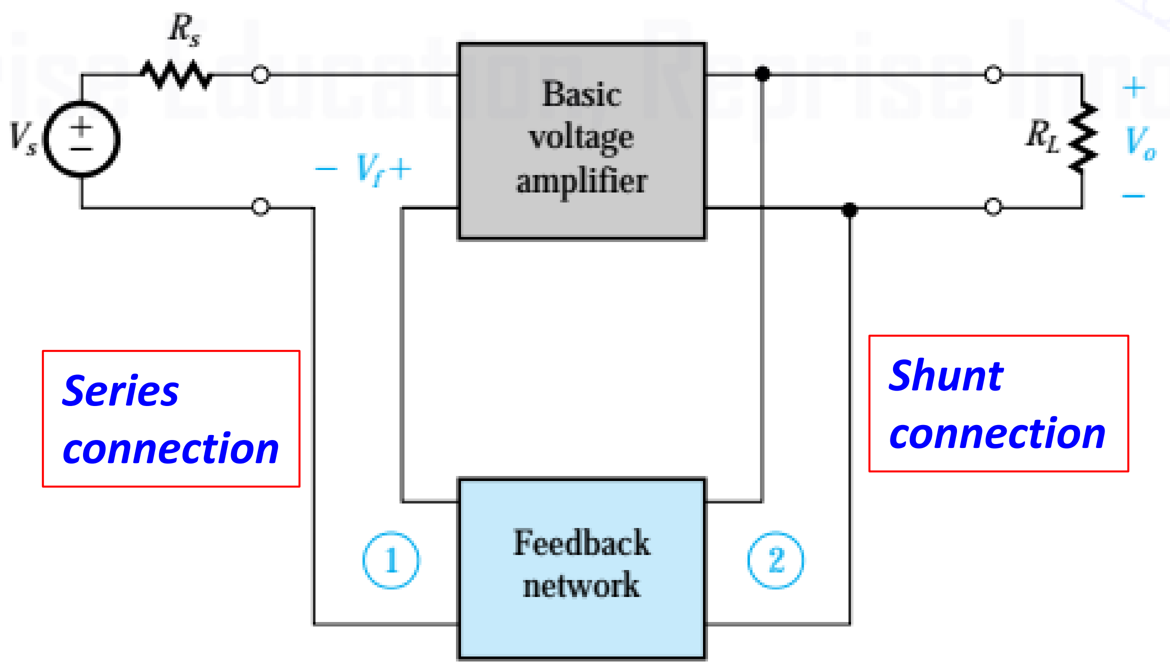
  Voltage or Current

- "**mix**" (feed back) the signal to the input as:

  Voltage or Current

Feedback Voltage Amplifier

Input signal: Voltage
Output Signal: Voltage



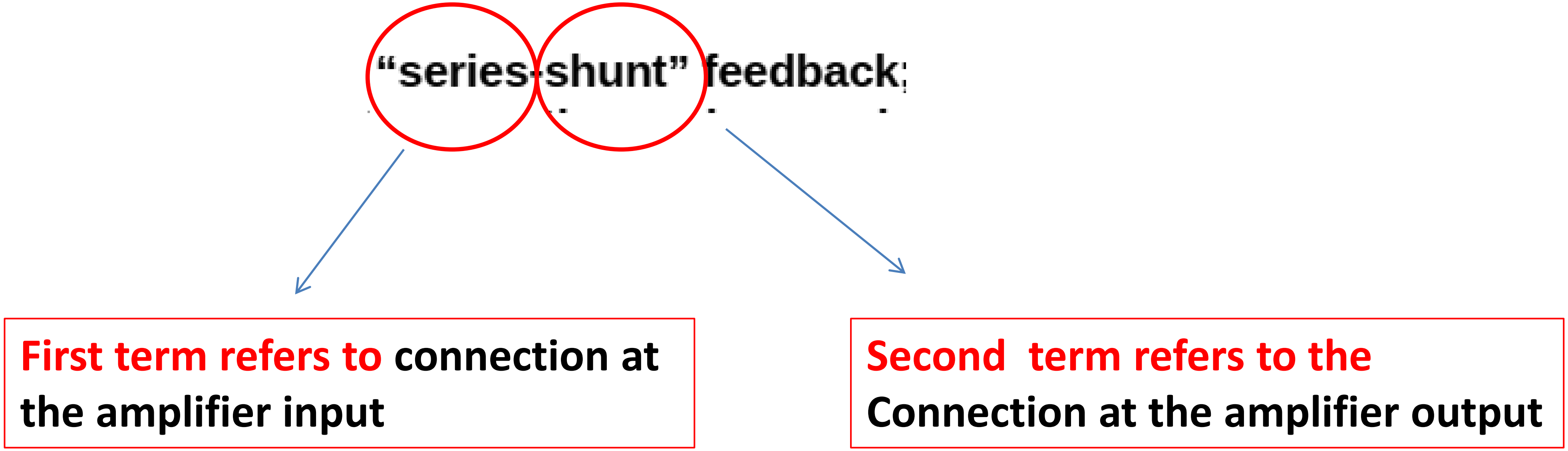
Block diagram of a **feedback** voltage amplifier.

Here, the output voltage is sensed (**sampled**). The feedback signal (voltage) is **mixed** with the source voltage.

The suitable feedback topology for the voltage amplifier is the **voltage-mixing, voltage-sampling**

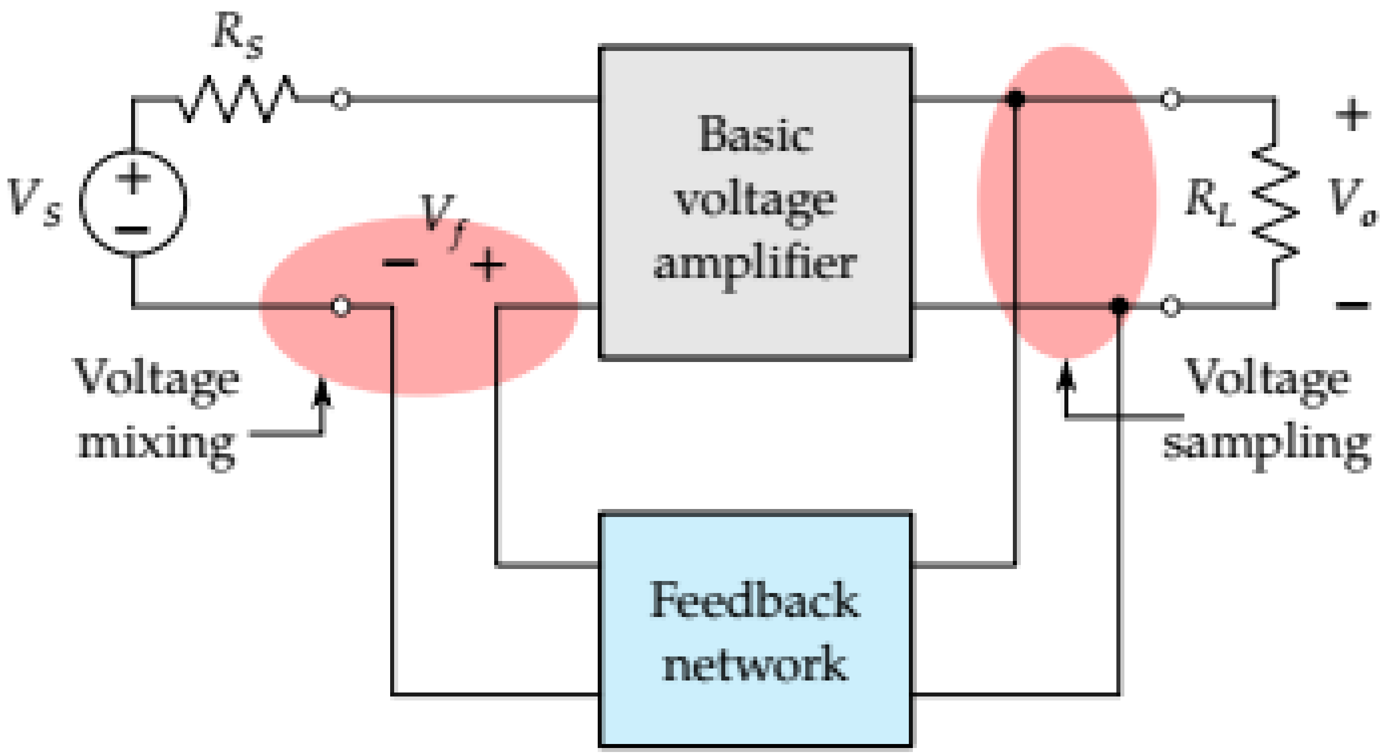
Because of the **series connection at the input** and the **parallel or shunt connection at the output**, this feedback topology is also known as **series–shunt feedback** topology.

“series-shunt” feedback



- Feedback topologies are named according to the connections: eg “series-shunt feedback” means series connection at the input and shunt connection at the output

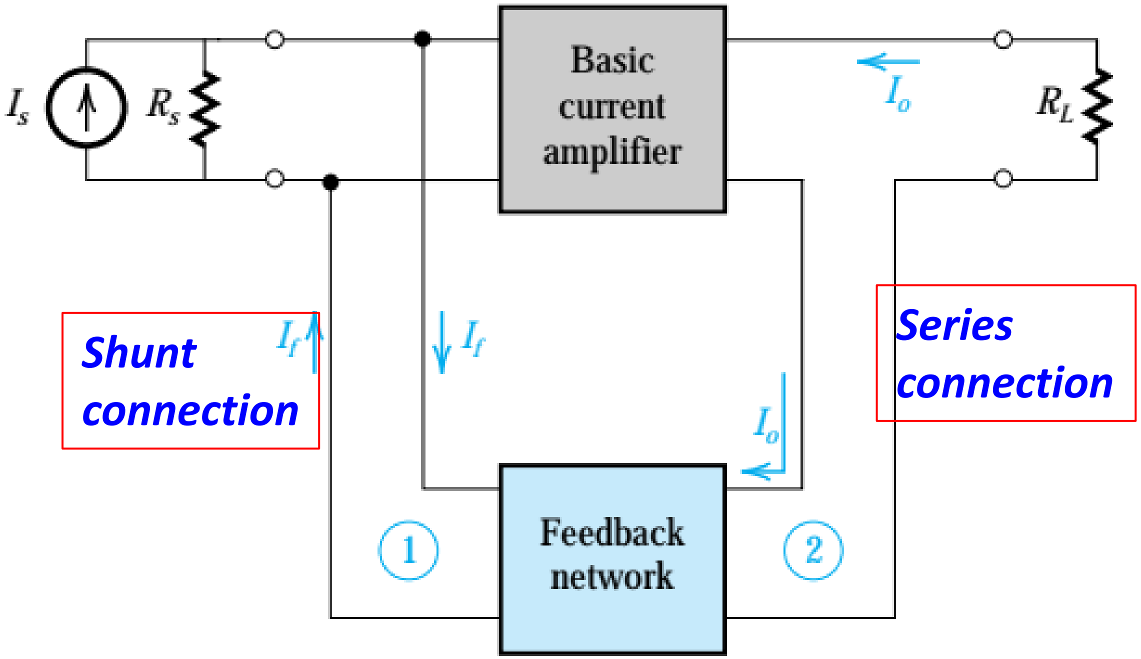
Feedback Voltage Amplifier



- Here, **voltage mixing** and **voltage sampl**ing are highlighted by the pink color shaded regions.

Feedback Current Amplifier

Input signal: **Current**
Output Signal: **Current**



Block diagram of a **feedback current** amplifier.

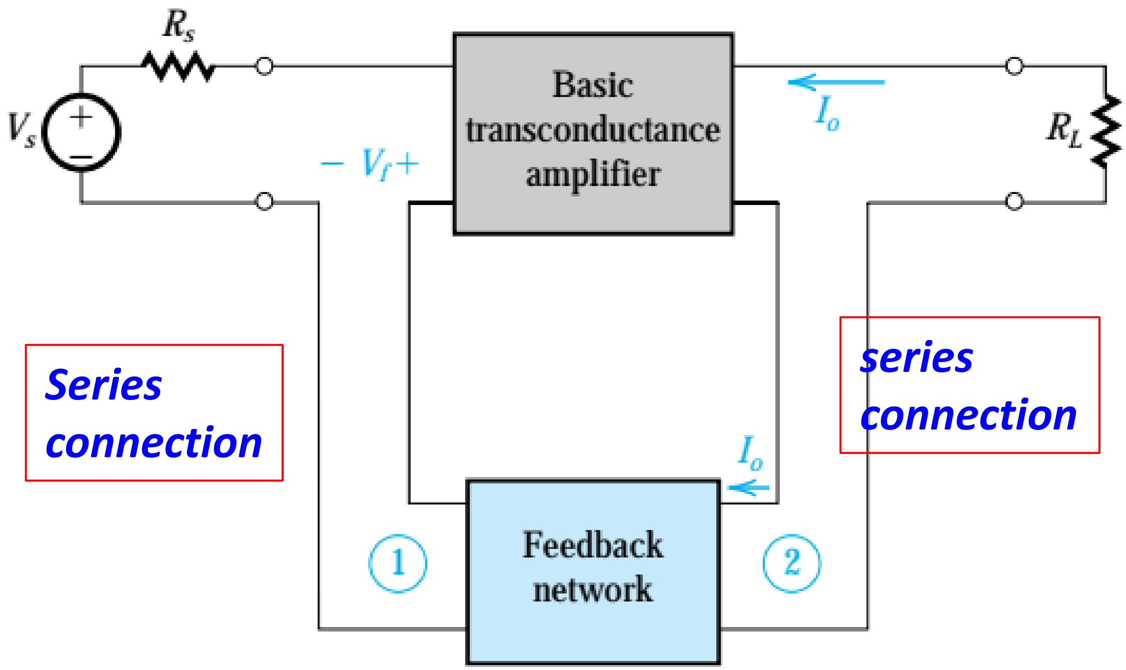
Here, the output current is sensed (**sampled**). The feedback signal (current) is **mixed** with the source current

The suitable feedback topology for the current amplifier is the **current-mixing, current-sampling**

Because of the **parallel (or shunt) connection at the input** and the **series connection at the output**, this feedback topology is also known as **shunt-series feedback** topology.

Feedback Transconductance Amplifier

Input signal: **Voltage**
Output Signal: **Current**



Series connection

series connection

Block diagram of a **feedback** transconductance amplifier.

Here, the circuit senses (**samples**) the **output current** and returns a voltage as the feedback signal. This voltage **mixes** with the signal voltage.

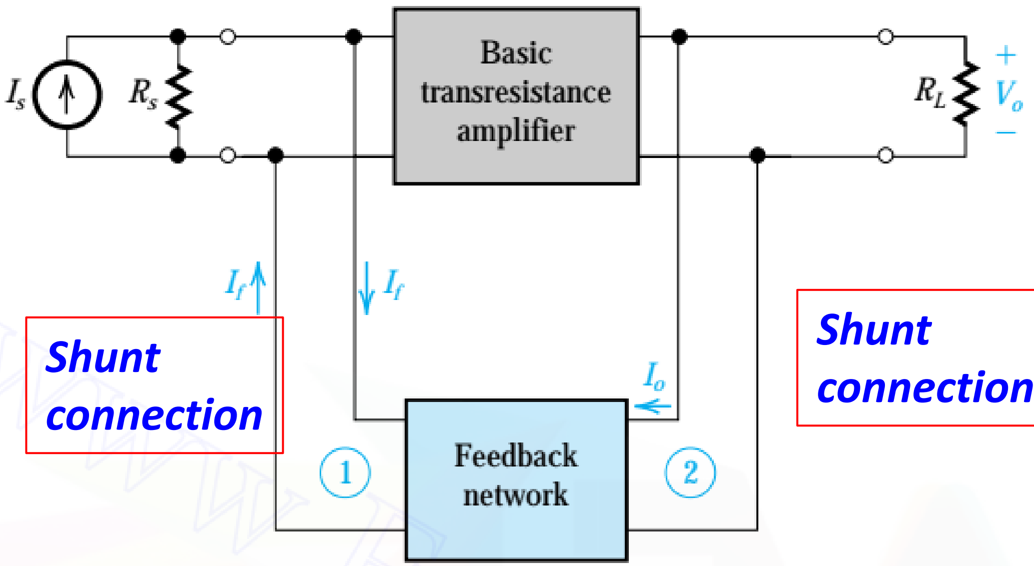
The suitable feedback topology for the transconductance amplifier is the **voltage-mixing, current-sampling**

Because of the **series connection at both the input and the output**, this feedback topology is also known as **series-series feedback** topology.

Feedback Transresistance Amplifiers

Input signal: **Current**
Output Signal: **Voltage**

Here, the output voltage is sensed (**sampled**) and a proportional current is returned to the input. This current **mixes** with the source current.



Shunt connection

Shunt connection

The suitable feedback topology for the transresistance amplifier is the **current-mixing**, **voltage-sampling**

Because of the **parallel (or shunt) connection at both the input and the output**, this feedback topology is also known as **shunt-shunt feedback** topology.

Block diagram of a **feedback** transresistance amplifier.

The four basic feedback topologies

- Series-shunt feedback [***voltage mixing and voltage sampling]***
- Shunt-series feedback [***Current mixing and current sampling]***
- Series-series feedback [***Voltage mixing and current sampling]***
- Shunt-shunt feedback [***Current mixing and voltage sampling]***

- A feedback amplifier is denoted either by its **input–output type** (e.g. voltage-to-voltage) or its **mixing–sampling** type (e.g. series–shunt).

- The two descriptions are equivalent.

Typical amplifier type	Gain	Reference topology name	Alternate topology name
Voltage Amplifier	V_O/V_{IN}	voltage-mixing voltage-sampling	series–shunt
Current Amplifier	I_O/I_{IN}	current-mixing current-sampling	shunt–series
Transconductance Amp	I_O/V_{IN}	voltage-mixing current-sampling	series–series
Transimpedance Amp	V_O/I_{IN}	current-mixing voltage-sampling	shunt–shunt

Feedback relationship

	Gain	**Input resistance**	**Output resistance**
Without feedback	A	R_i	R_o
Series-shunt	$A_f = \frac{A}{1+\beta A}$	$R_{if} = R_i(1+\beta A)$	$R_{of} = \frac{R_o}{1+\beta A}$
Series-series	$A_f = \frac{A}{1+\beta A}$	$R_{if} = R_i(1+\beta A)$	$R_{of} = R_o(1+\beta A)$
Shunt-shunt	$A_f = \frac{A}{1+\beta A}$	$R_{if} = \frac{R_i}{1+\beta A}$	$R_{of} = \frac{R_o}{1+\beta A}$
Shunt-series	$A_f = \frac{A}{1+\beta A}$	$R_{if} = \frac{R_i}{1+\beta A}$	$R_{of} = R_o(1+\beta A)$

END