ELECTRONICS

Amplifiers

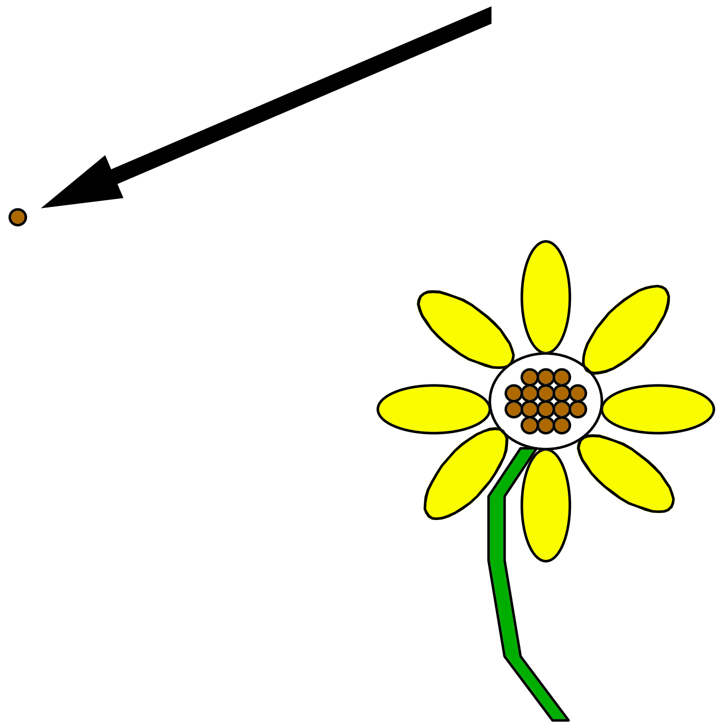
Amplifiers.

- What is covered ?
  - Some basic concepts.
- What is an Amplifier ?
- What do we mean by Gain ?
  - A , AOL and ACL.
- Effects of Input and Output Impedance.
- Gain/Bandwidth product.

Amplifiers.

Let us consider a Plant System

We start with the Seed



Amplifiers.

Let us consider a Plant System

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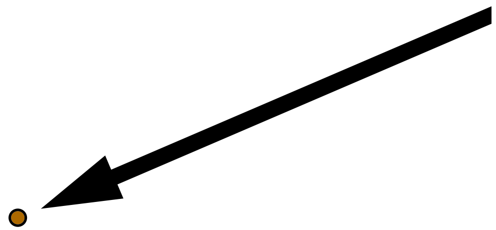
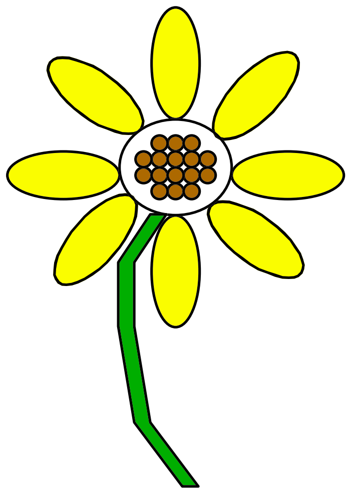


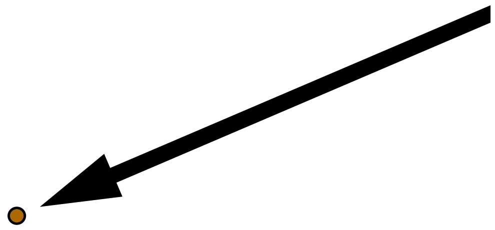
Add Soil, Sunlight and Water.



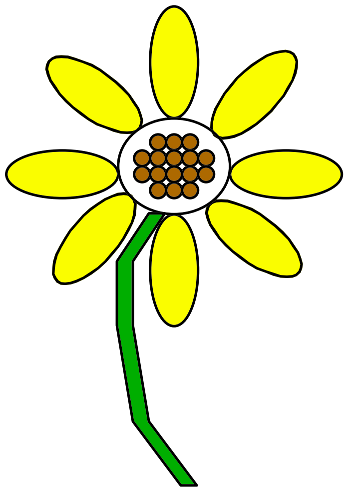
Amplifiers.

Let us consider a Plant System

We start with the Seed



Add Soil, Sunlight and Water.

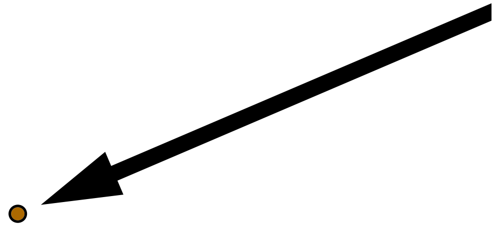


The Plant Grows.

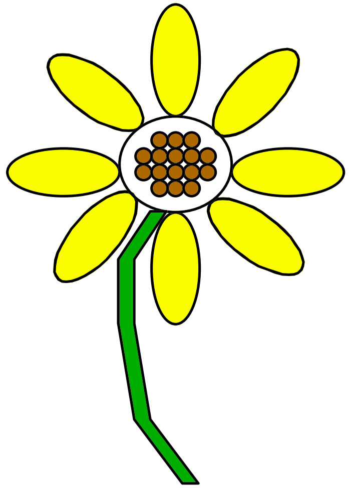
Amplifiers.

Let us consider a Plant System

We start with the Seed

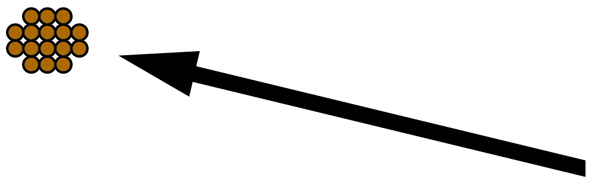


Add Soil, Sunlight and Water.



The Plant Grows.

We end up with more Seeds.



Amplifiers.

- What have we seen ?
- Overall we have increased the number of seeds (GAIN). { A = Output / Input }
- The plant needs power. (Sunlight, Water etc.)
- A time delay occurs from (seeds in) to (seeds out). (Propagation delay)
- We usually tend to ignore any side effects, waste products etc.

Amplifiers.

- How can we control the GAIN of our plant system ?
- Rather than plant all the seeds we just plant one or just some of them.
- This control when implemented in electronics is referred to as FEEDBACK because we feed back some of the output to the input of the system.

Amplifiers.

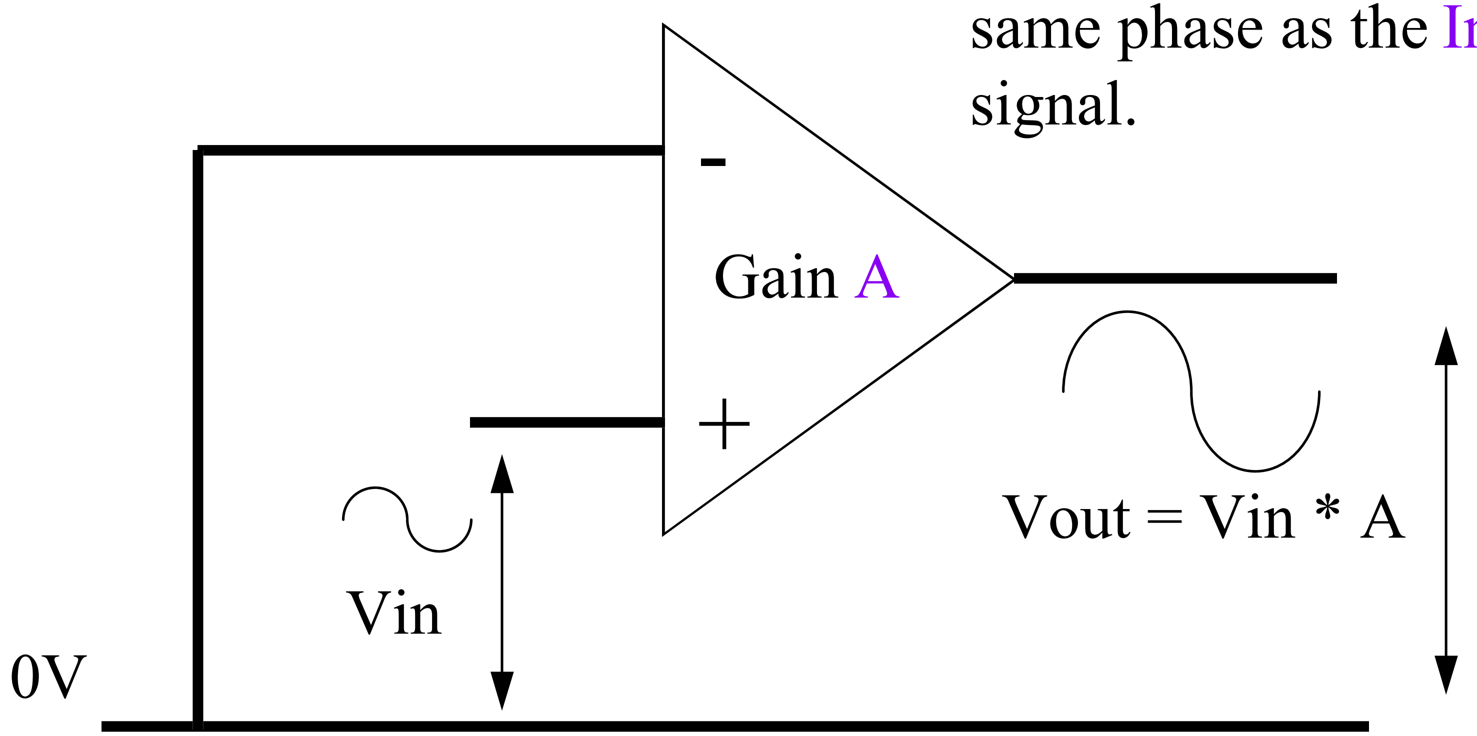
- With no control applied to the amplifier, then its natural GAIN is known as (AOL) the OPEN LOOP GAIN of the amplifier.
- With a controlled system where we ensure that the system has a specific gain less than the (AOL) then we say we have introduced NEGATIVE FEEDBACK.
- The letter “A” is used to define the gain of an amplifier. (ACL) closed loop gain i.e. gain with feedback.

Amplifiers.

Amplifier Configuration.

Single Ended

When a signal is applied to the Non Inverting input then the Output is the same phase as the Input signal.

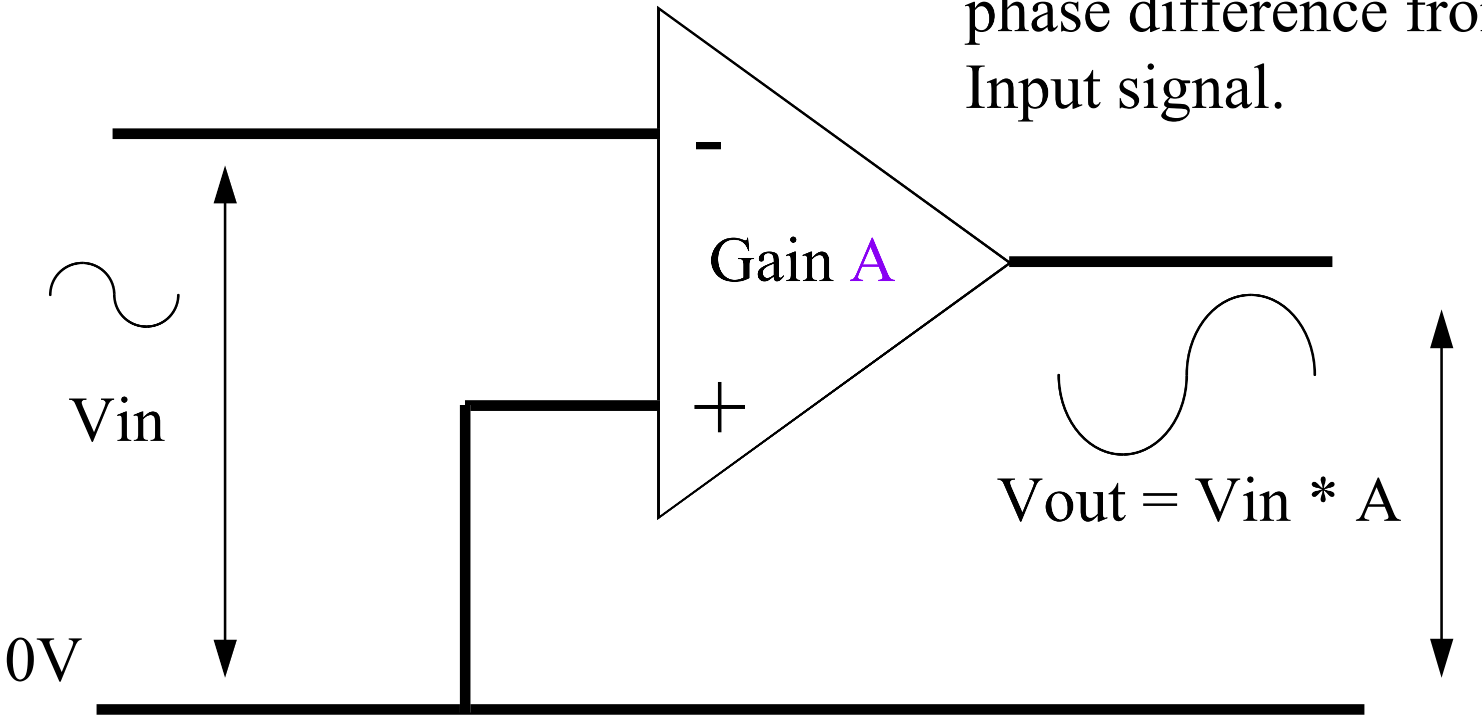


Amplifiers.

Amplifier Configuration.

Single Ended

When a signal is applied to the Inverting Input then the Output has a 180^o phase difference from the Input signal.



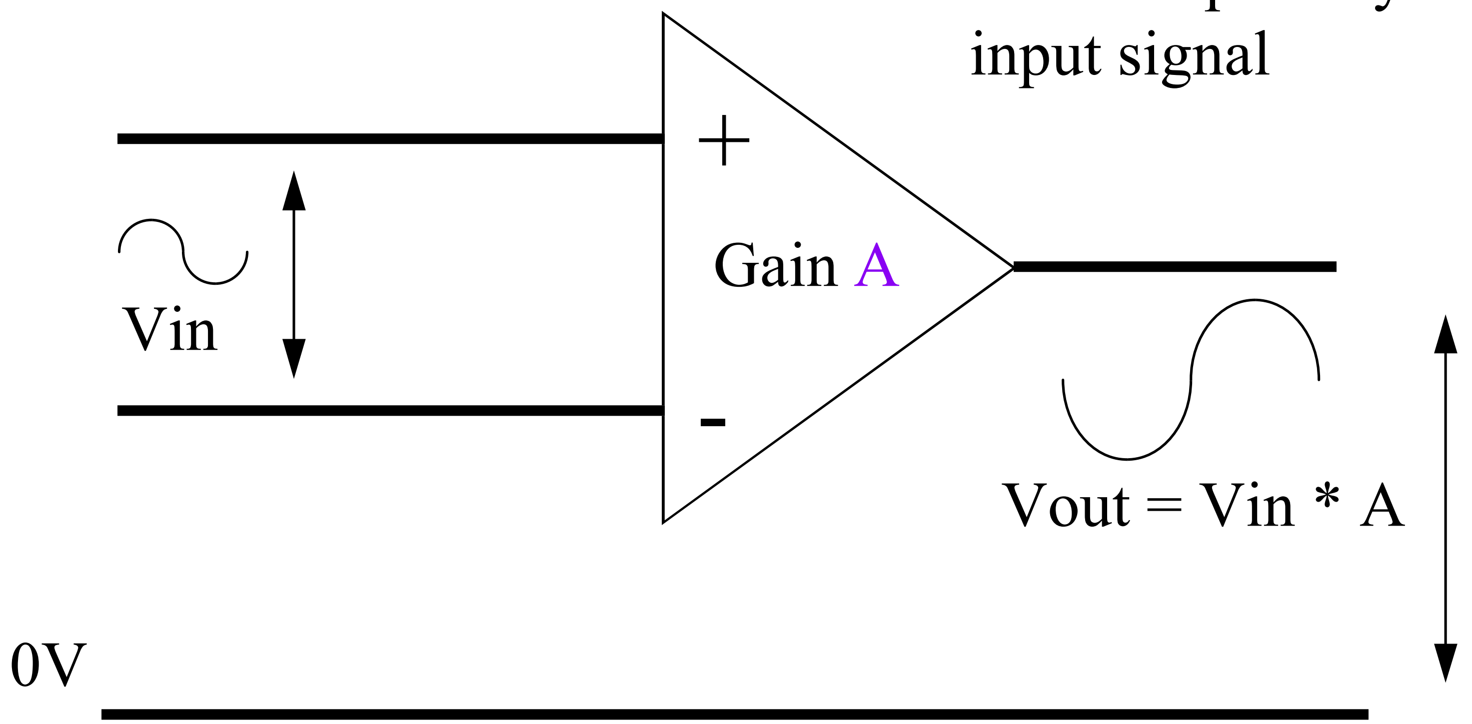
Amplifiers.

Amplifier Configuration.

The Amplifier in Differential mode.

Note the polarity of the input signal

Differential



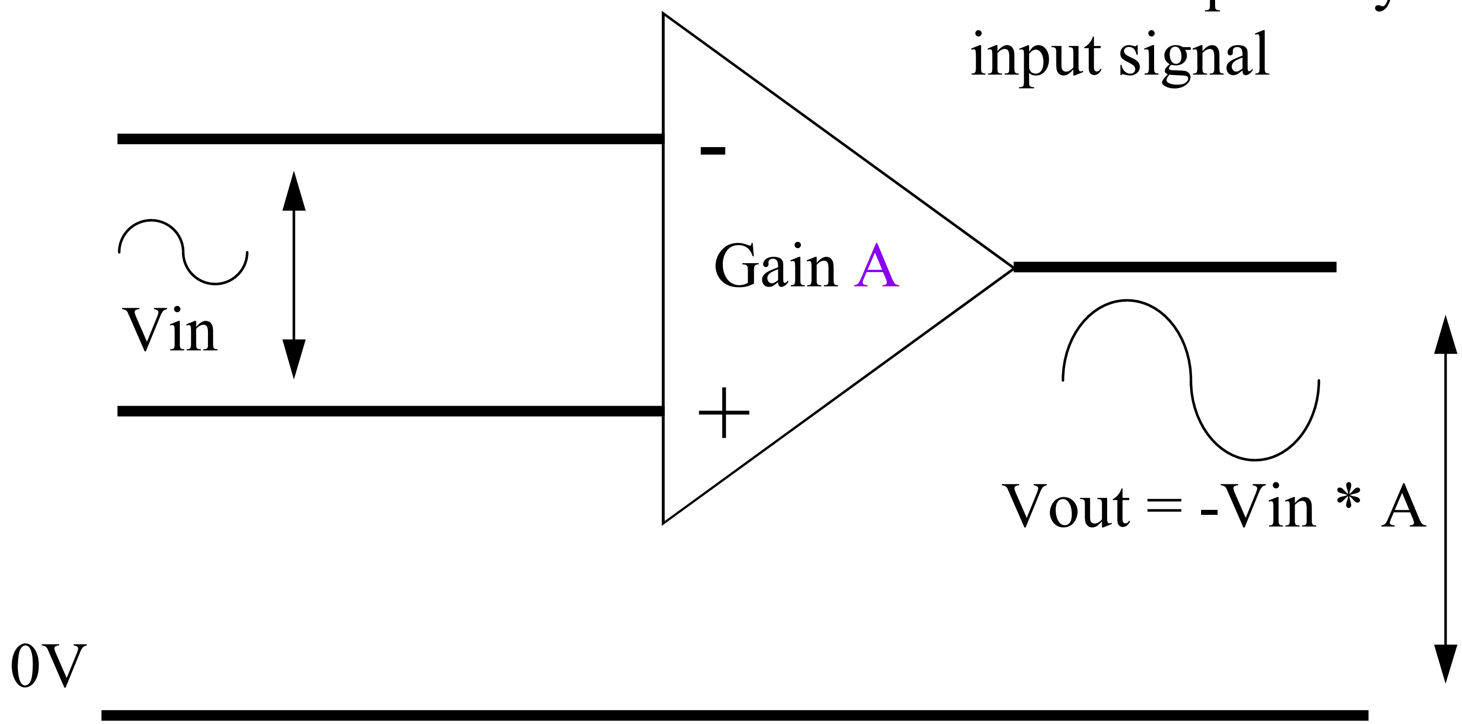
Amplifiers.

Amplifier Configuration.

The Amplifier in Inverter Differential mode.

Note the polarity of the input signal

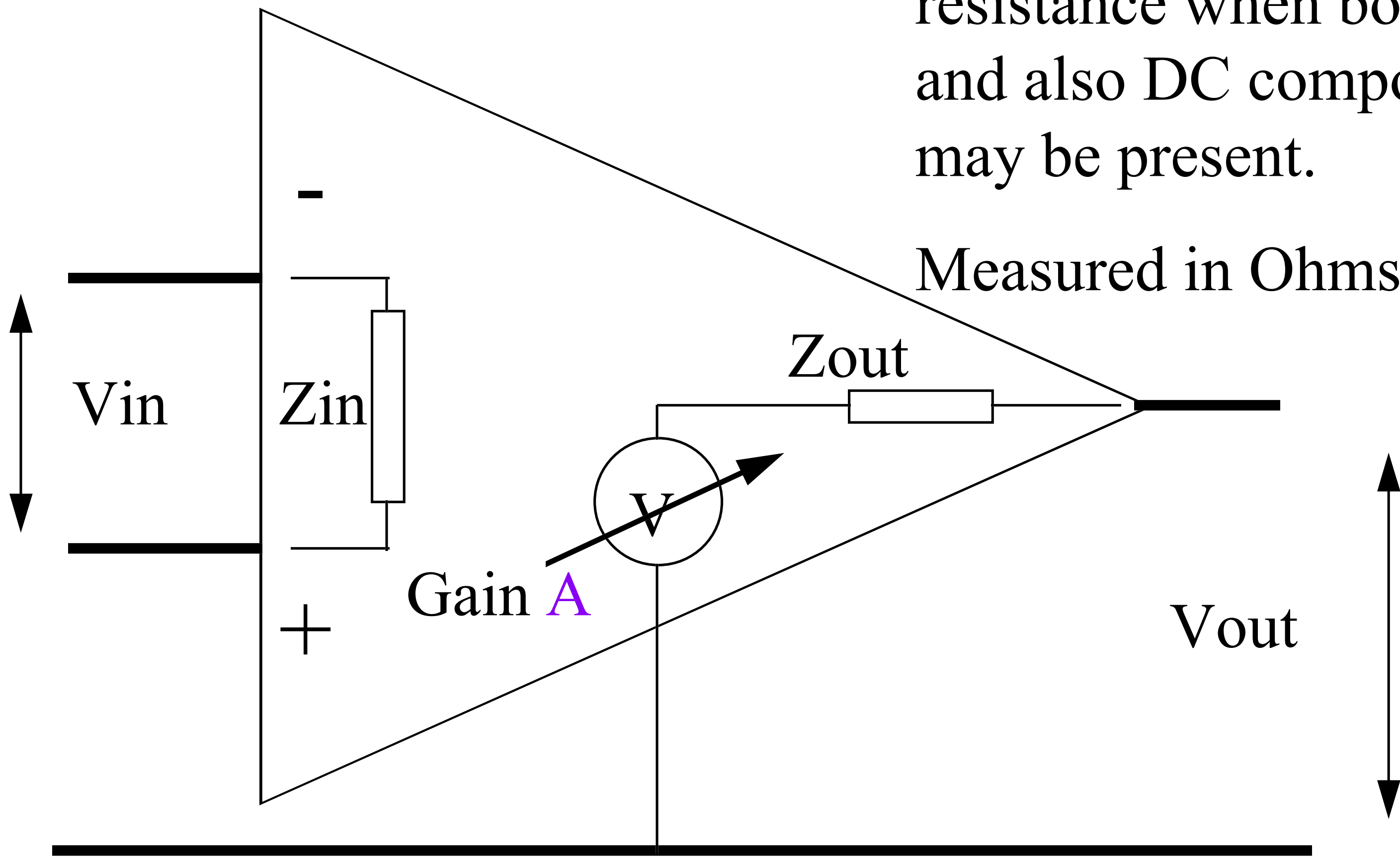
Differential



Amplifiers.

The Proof

The Ideal Amplifier Model.

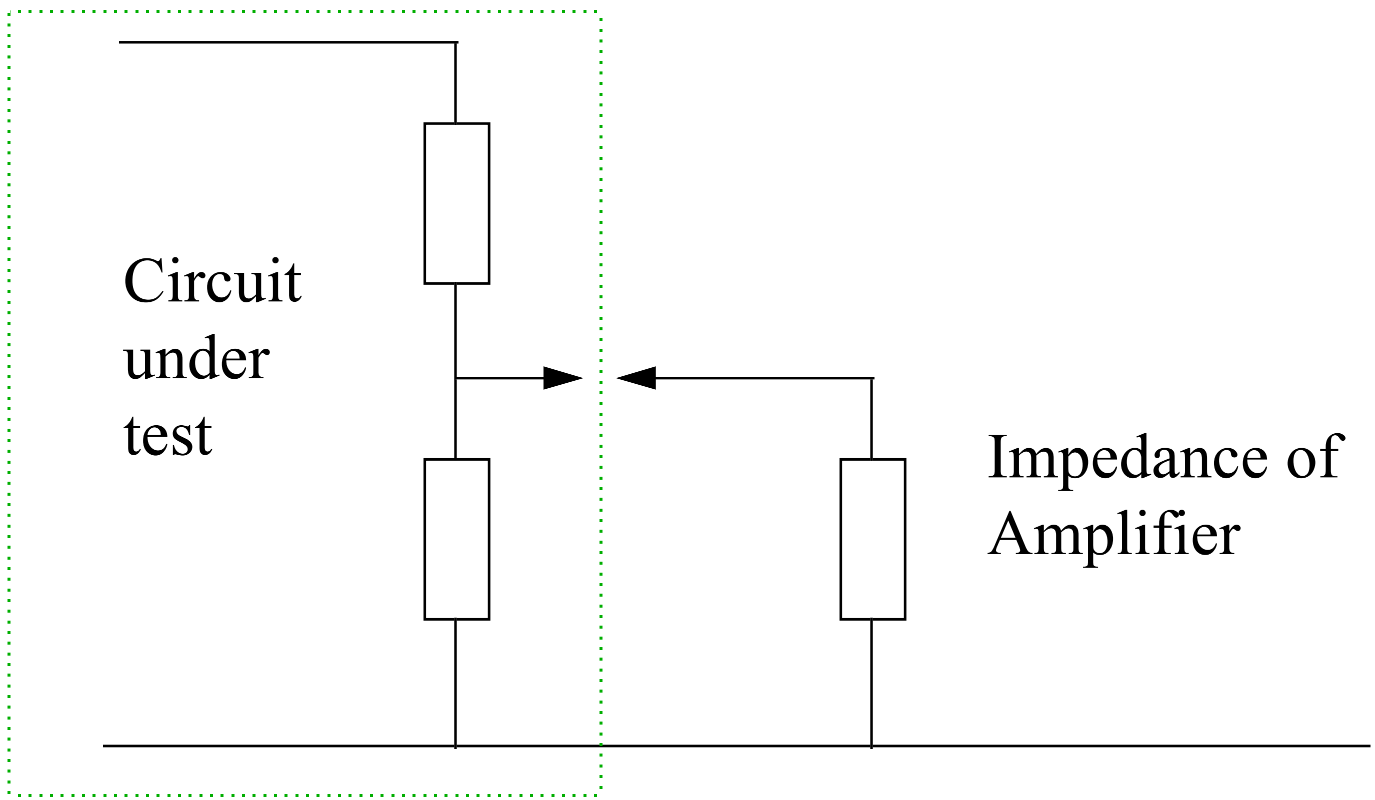


Z is used to define the resistance when both AC and also DC components may be present.

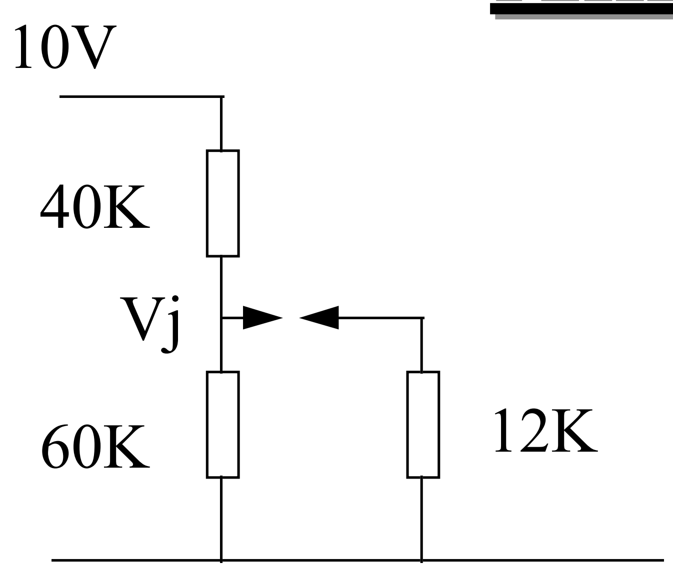
Measured in Ohms

Amplifiers.

- If the input of the Amplifier is to be connected to some other circuit then what should its Input Resistance/Impedance be ?

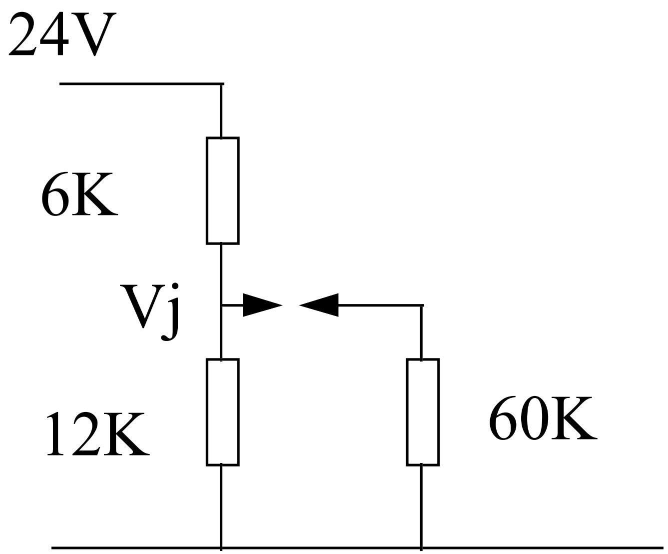


Amplifiers.



Vj before connection is ?V

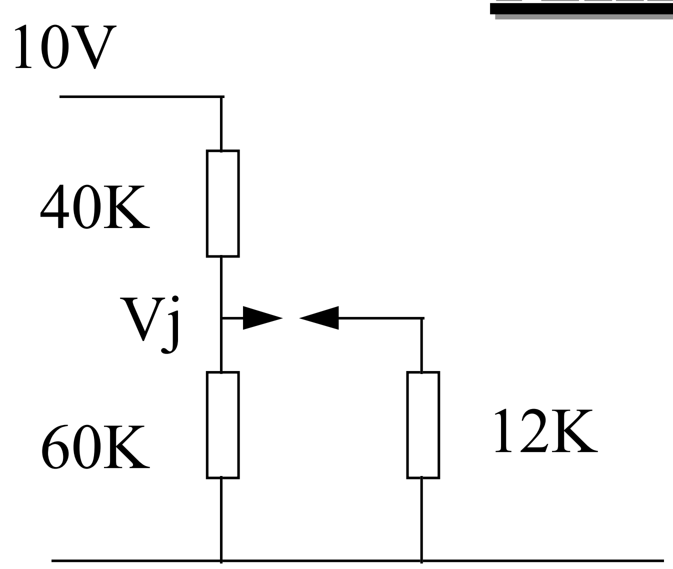
Vj after connection is ?V



Vj before connection is ?V

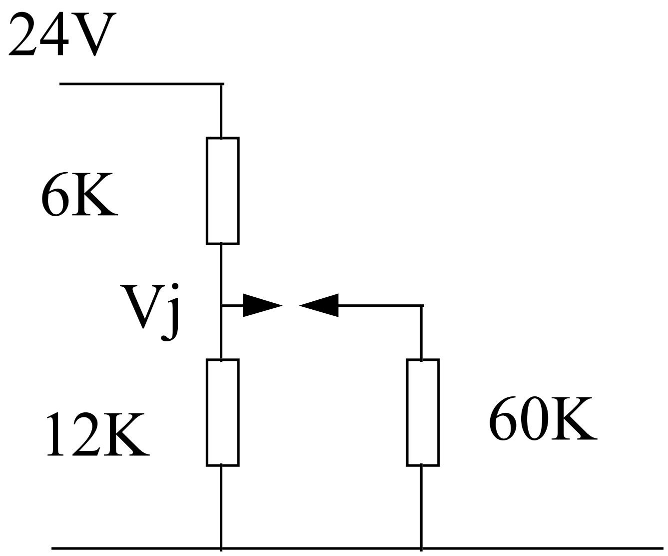
Vj after connection is ?V

Amplifiers.



Vj before connection is 6V

Vj after connection is 2V

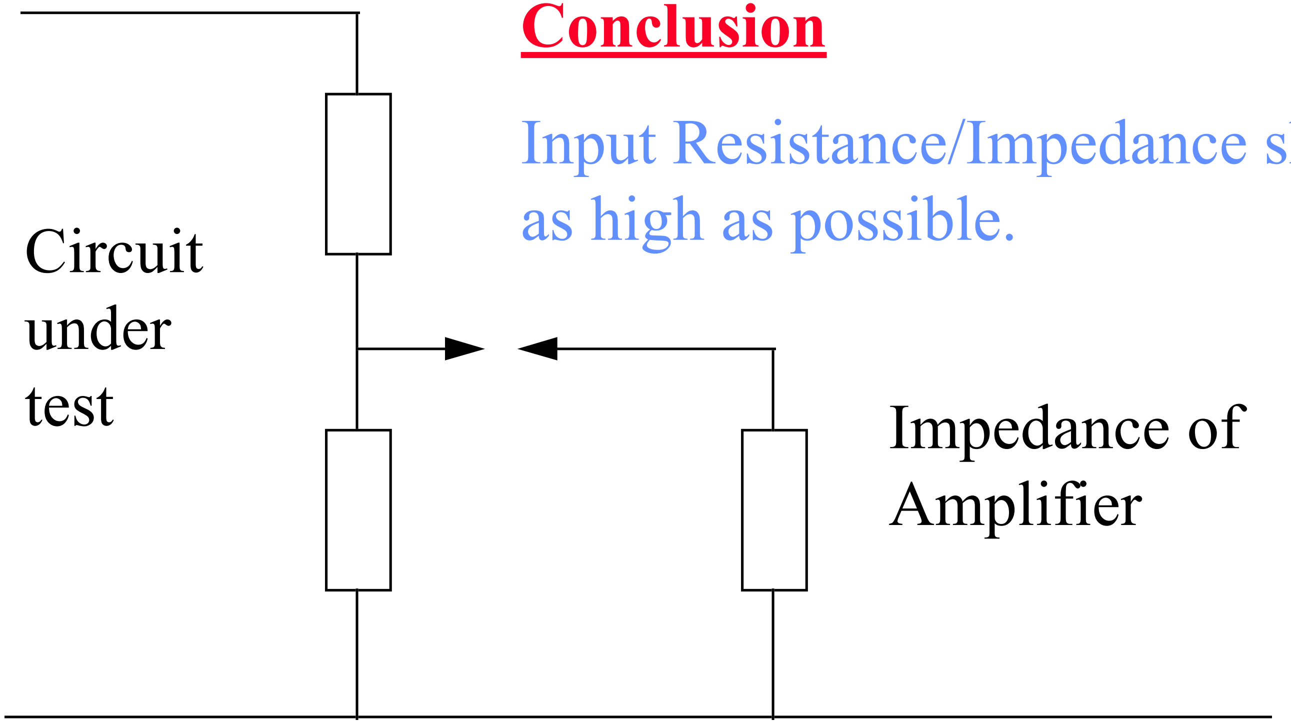


Vj before connection is 16V

Vj after connection is 15V

Amplifiers.

- If the input of the Amplifier is to be connected to some other circuit then what should its input resistance/impedance be ?

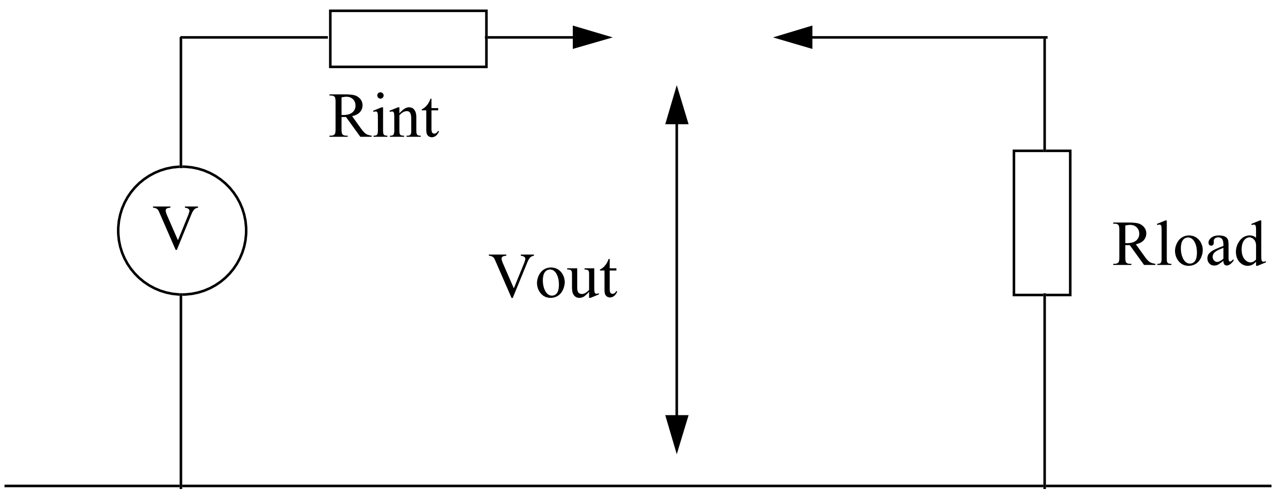


Conclusion

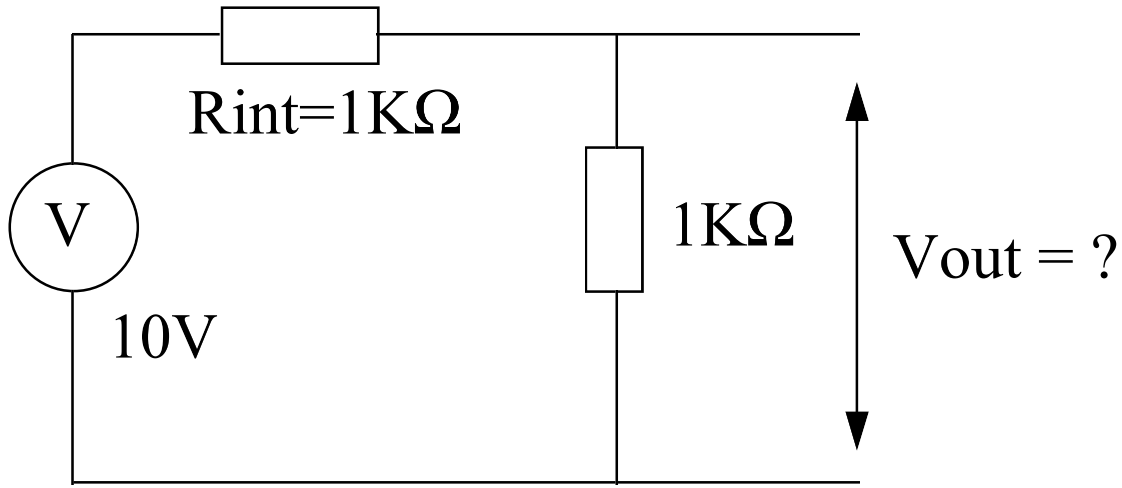
Input Resistance/Impedance should be as high as possible.

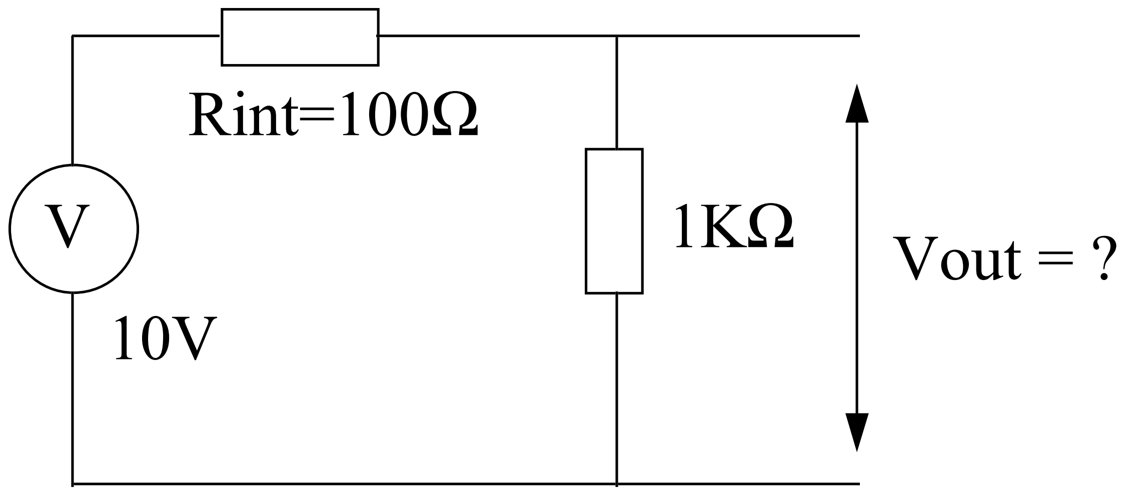
Amplifiers.

- If the Output of the Amplifier is to be connected to some other circuit then what should its Output Resistance/Impedance "Rint" be?

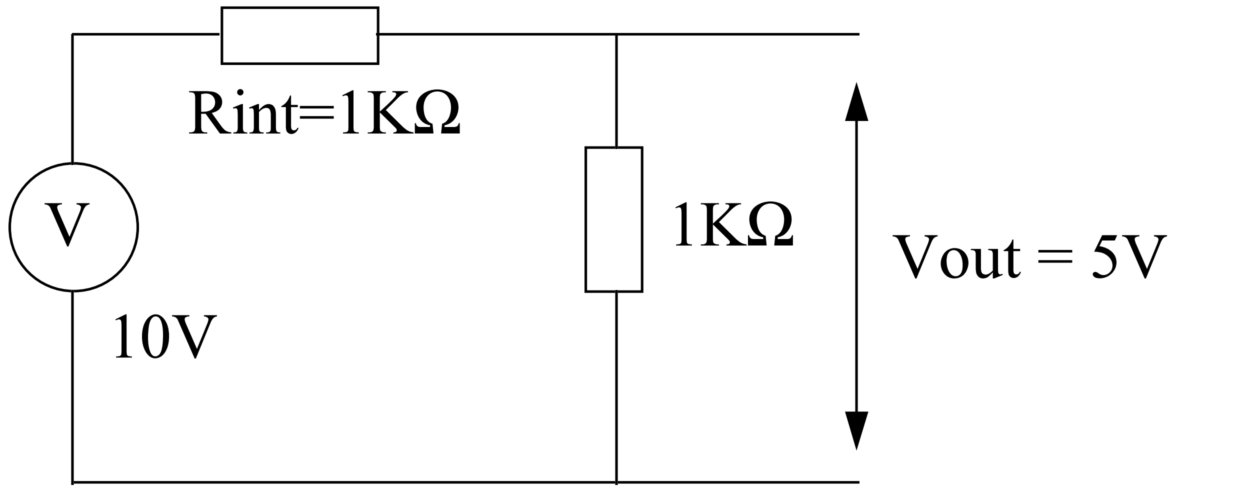


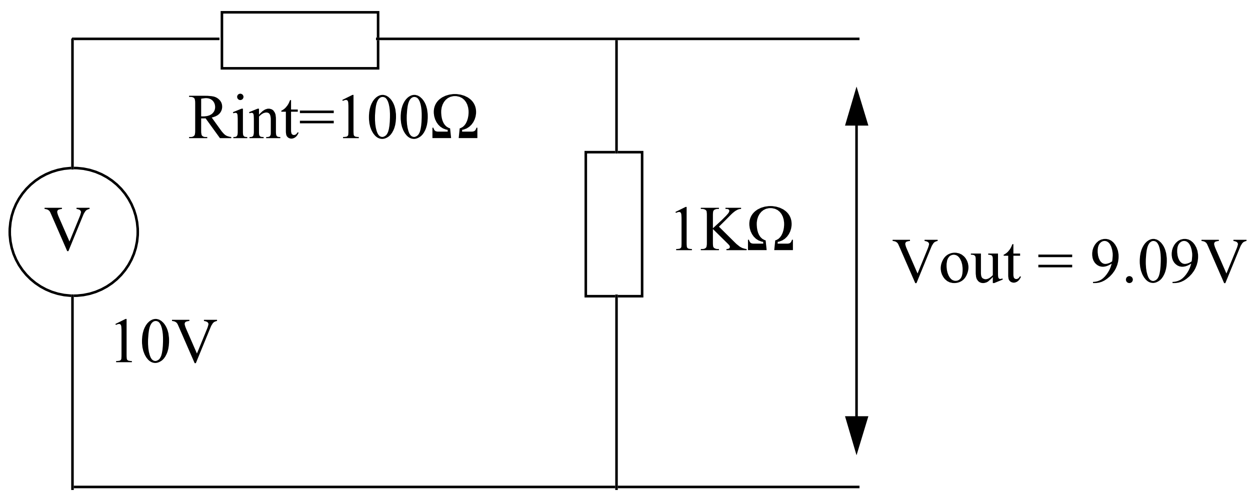
Amplifiers.





Amplifiers.



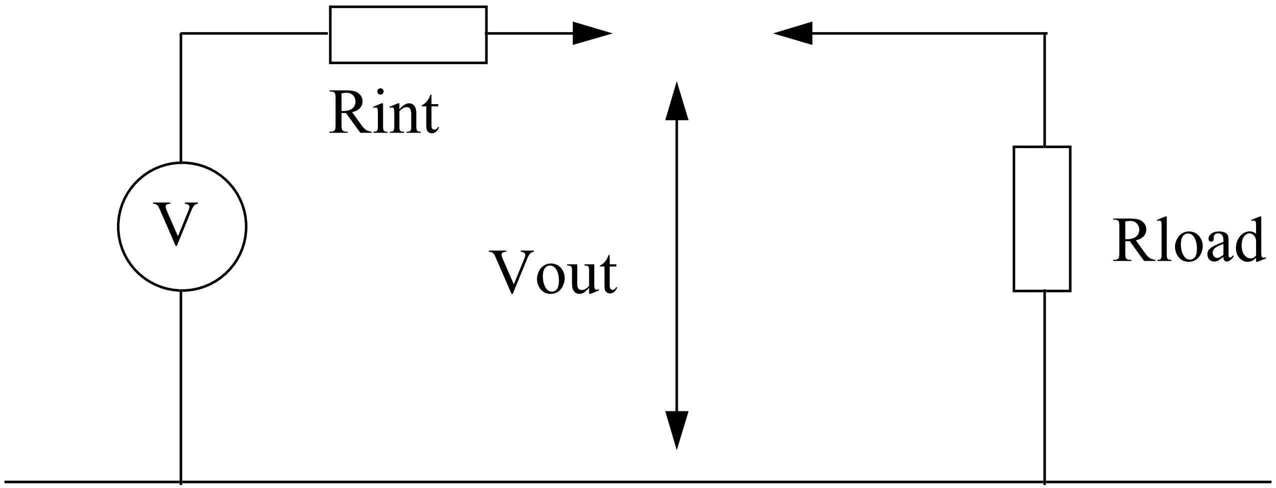


Amplifiers.

- If the Output of the Amplifier is to be connected to some other circuit then what should its Output Resistance/Impedance "Rint" be?

Conclusion

Output Resistance/Impedance should be as low as possible.



Amplifiers.

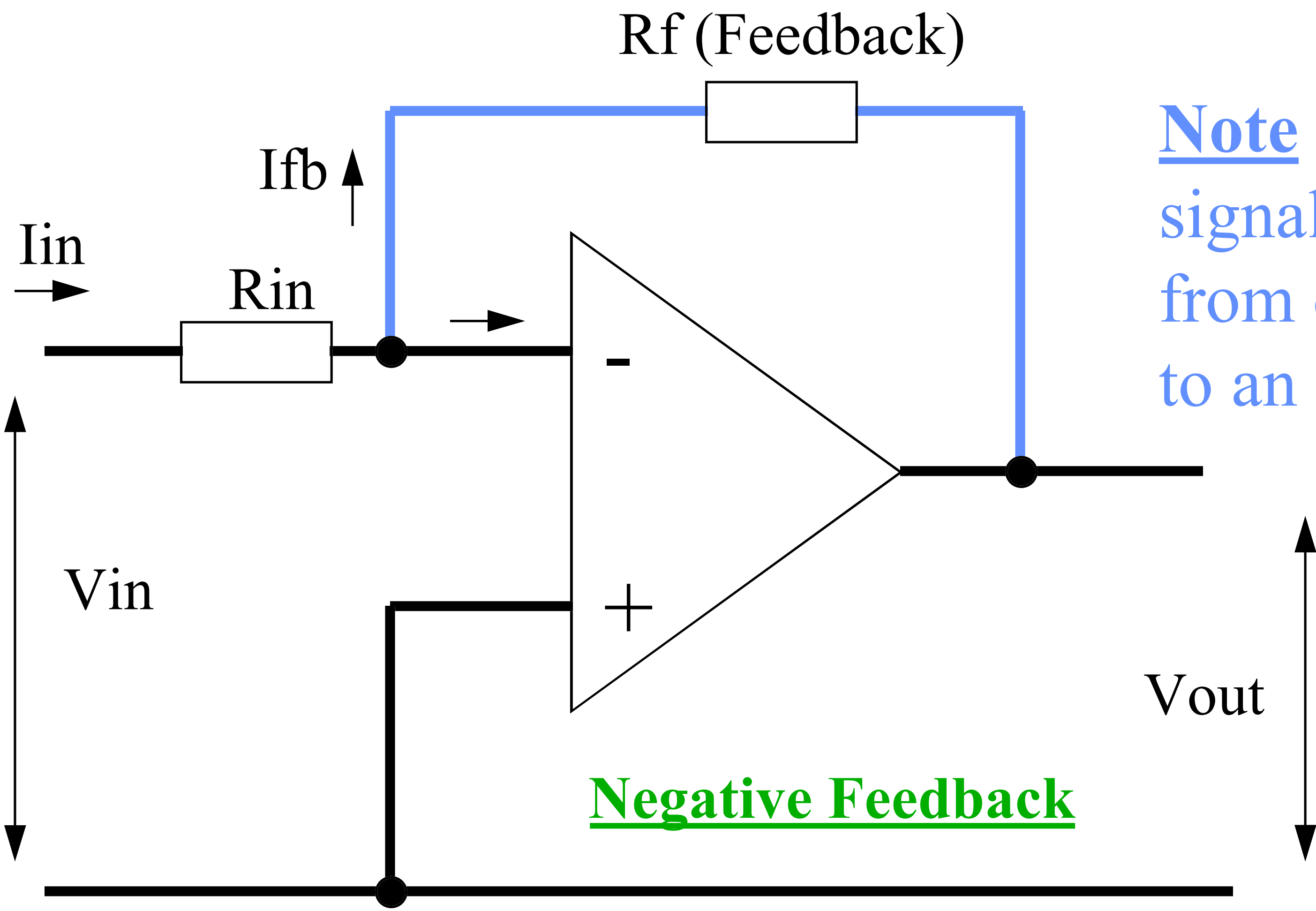
- Summary :-
- The Ideal Amplifier should have Infinite Input Impedance.
- The Ideal Amplifier should have Zero Output Impedance.
- The Ideal Amplifier should have an Infinite Gain.

Amplifiers

Feedback.

Amplifiers.

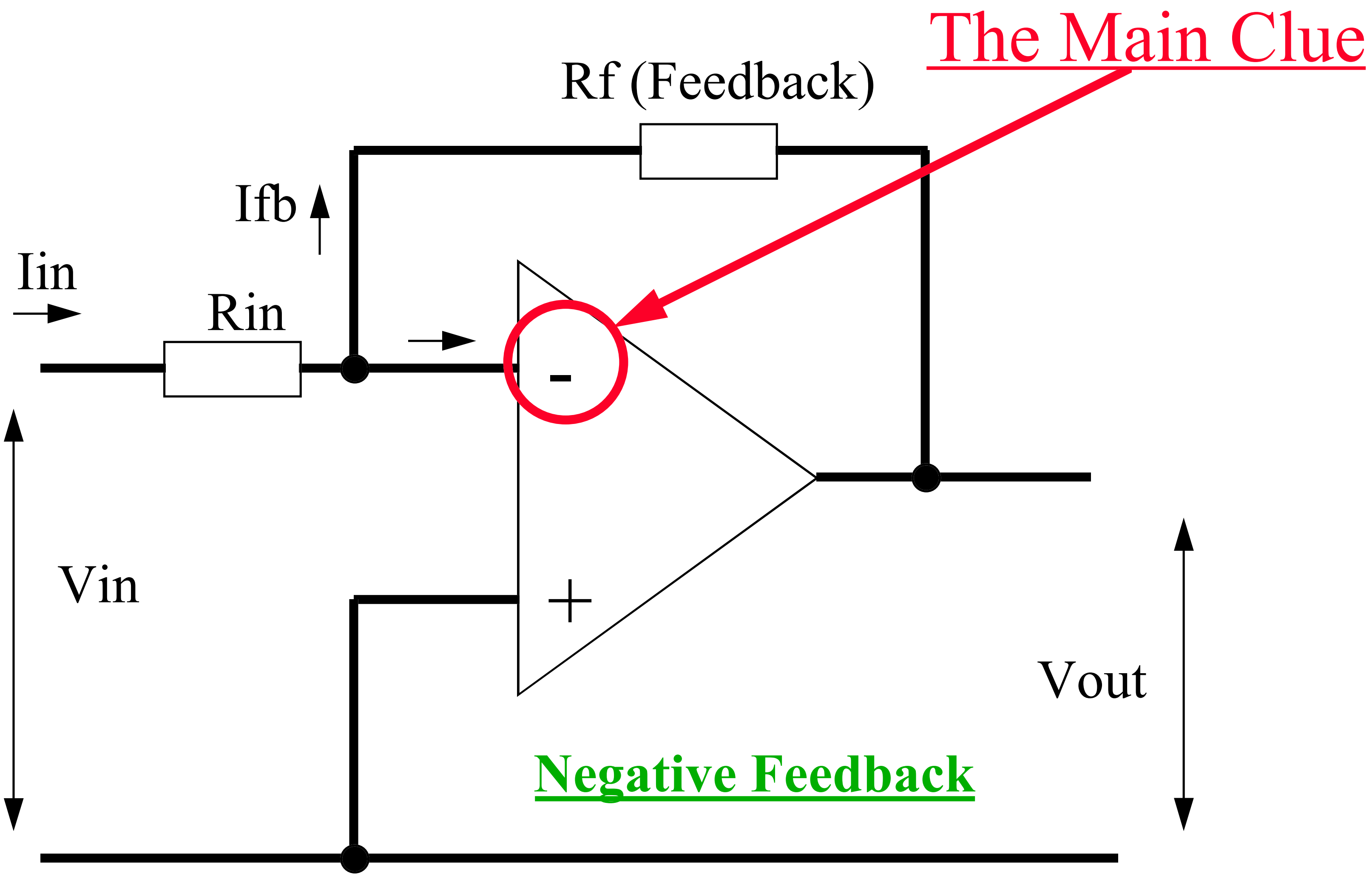
Feedback . . . . . How do we recognize it ?



Note Some signal goes from output to an input.

Negative Feedback

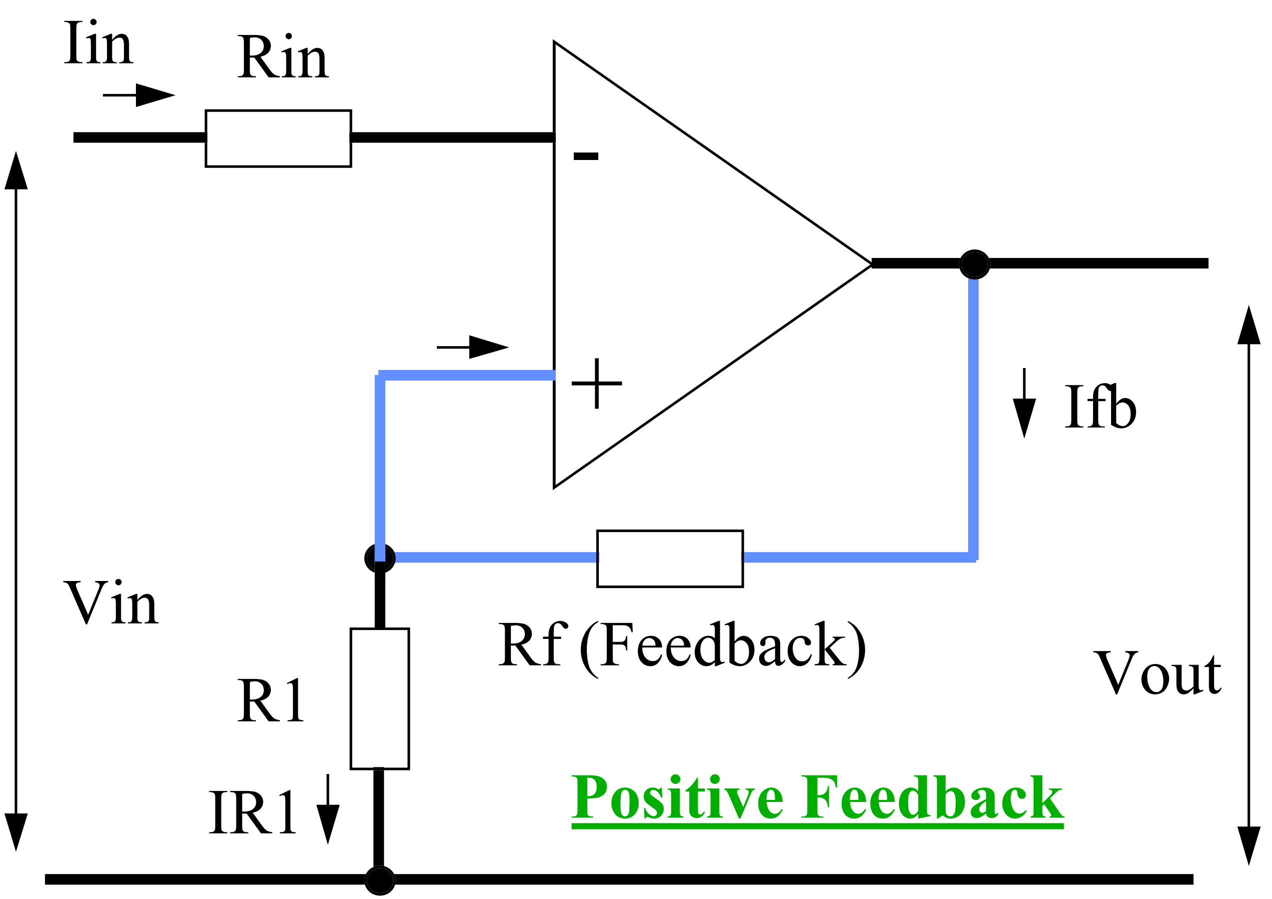
Amplifiers.



The Main Clue
Rf (Feedback)
Ifb
Iin
Rin
-
+
Vin
Vout
Negative Feedback

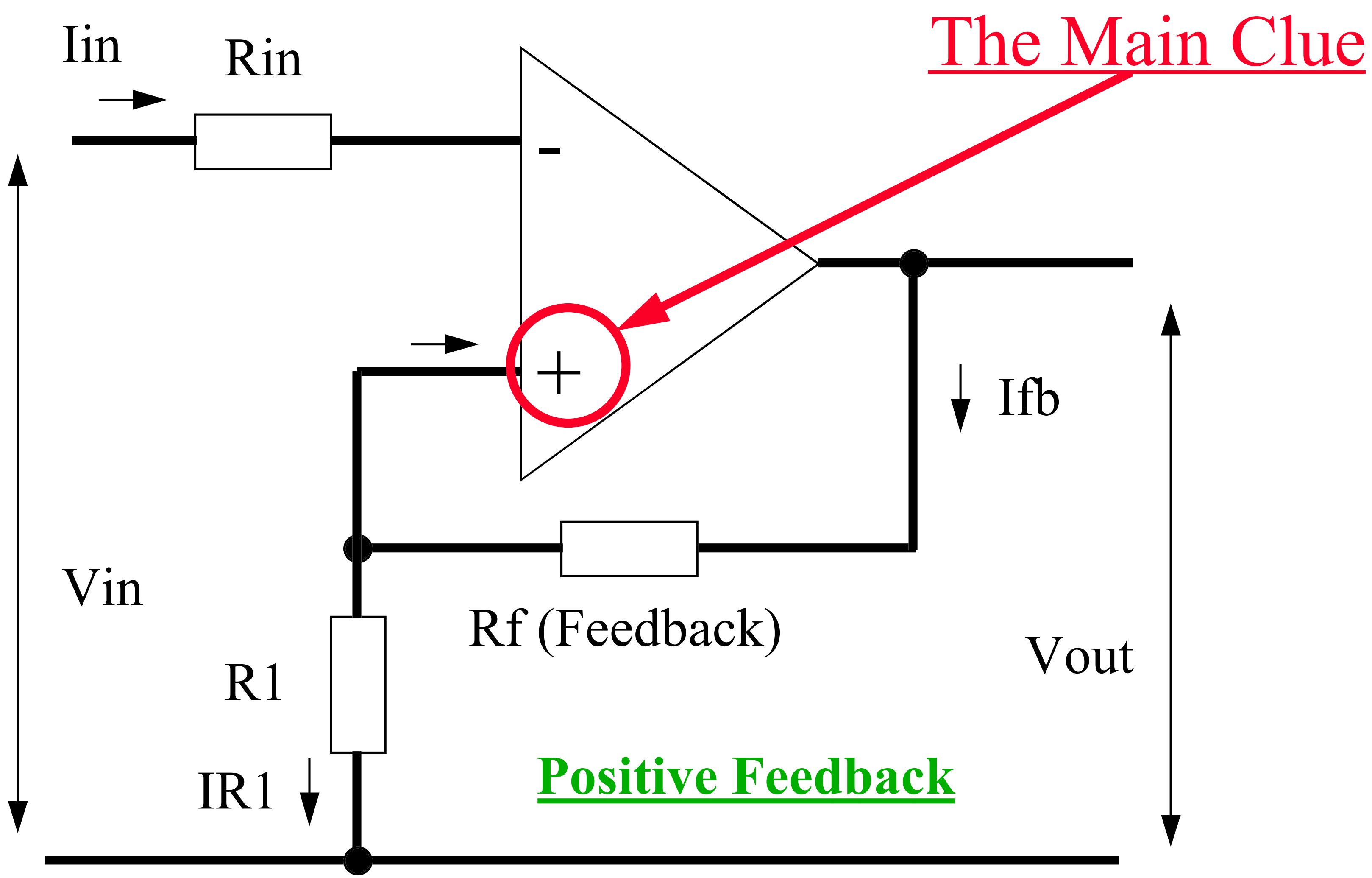
Amplifiers.

Feedback . . . . . How do we recognize it ?



Note Some signal goes from output to an input.

Amplifiers.


The Main Clue
Iin
Rin
-
+
Ifb
Vin
Rf (Feedback)
Vout
R1
IR1
Positive Feedback

Amplifiers.

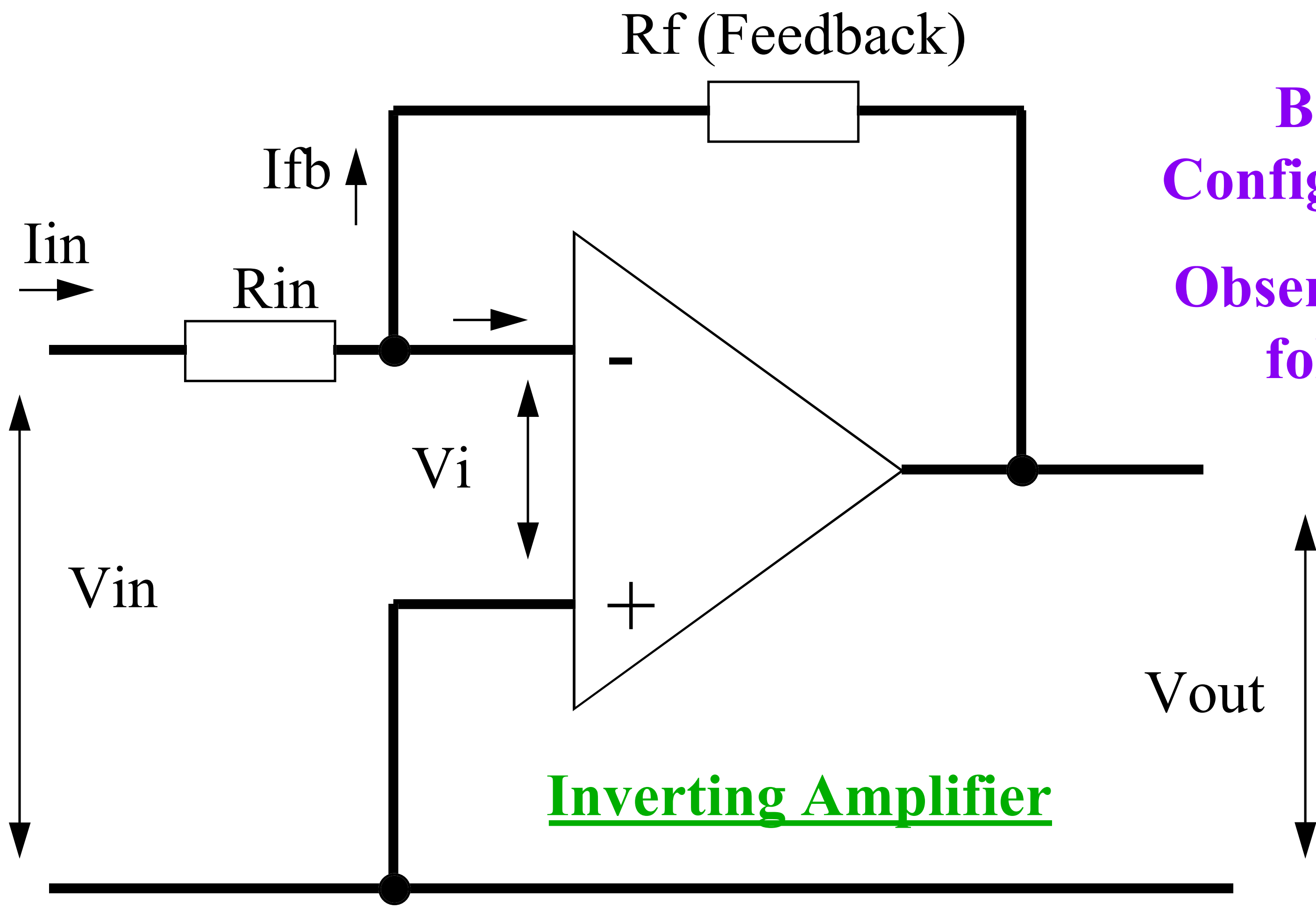
Effect of Gain

- Assume Gain of amplifier G is 10^7 and power rails of Amplifier are ±12Volts.
- If an Input voltage of One Volt is applied.
  - The amplifier would try to give an Output of 10^7Volts. (Input voltage * Gain)
  - However it is the power rails that would limit the Output to 12Volts.
- Therefore once the Input voltage exceeds the (power rails voltage) divided by the Gain no further effect will be noticed.

Amplifiers.

The Proof

The effects of Feedback on an Amplifier.



Basic Configuration

Observations follow

Inverting Amplifier

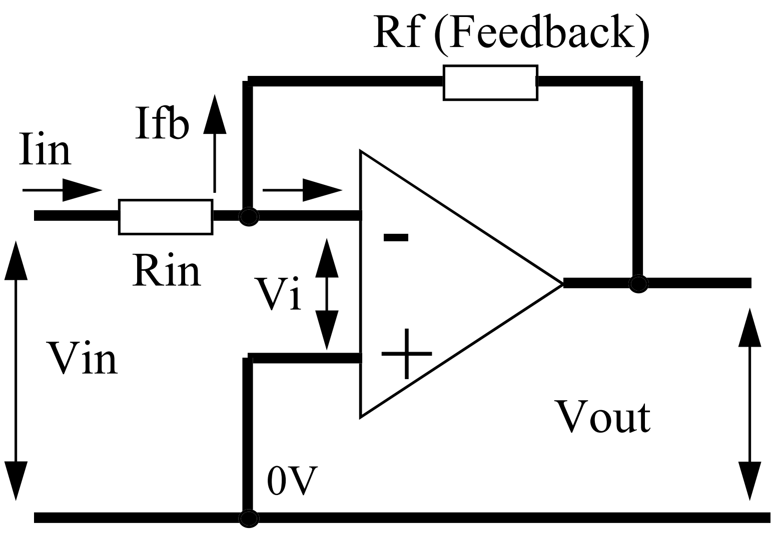
Amplifiers.

The Proof

Observation 1. Vout = Vi * Gain. As Gain is very large then even when Vout reaches Power rail voltage then Vi will still be insignificant. Therefore when the +ve input is tied to ground then the -ve input will be virtually at the same potential. In this configuration the -ve input is said to be a Virtual Earth.

Observation 2. As the input impedance of the amplifier is very high it can be assumed by default that Iin = Ifb .

Observation 3. If Vin goes Positive then Vout will go negative. It is an Inverting Amplifier.



Amplifiers.

The Proof

Using Ohms law $Iin = \frac{(Vin - 0V)}{Rin} = \frac{Vin}{Rin}$

Voltage across Rin

and $Ifb = \frac{(0V - Vout)}{Rf} = \frac{-Vout}{Rf}$

Voltage across Rf

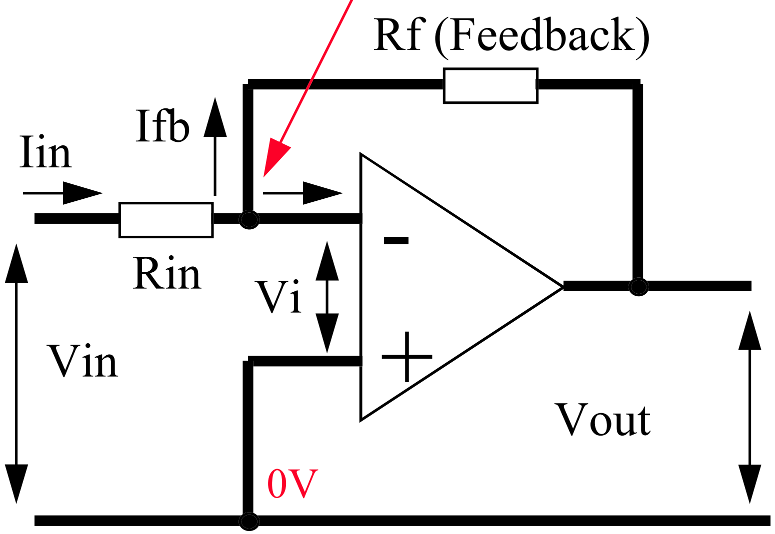
However as $Iin = Ifb$

Therefore $\frac{Vin}{Rin} = \frac{-Vout}{Rf}$

By default this point is also 0V because it is a virtual earth point

and we Remember that

$$\text{Gain } A = \frac{Vout}{Vin}$$



Amplifiers.

The Proof

$$\frac{Vin}{Rin} = \frac{-Vout}{Rf}$$

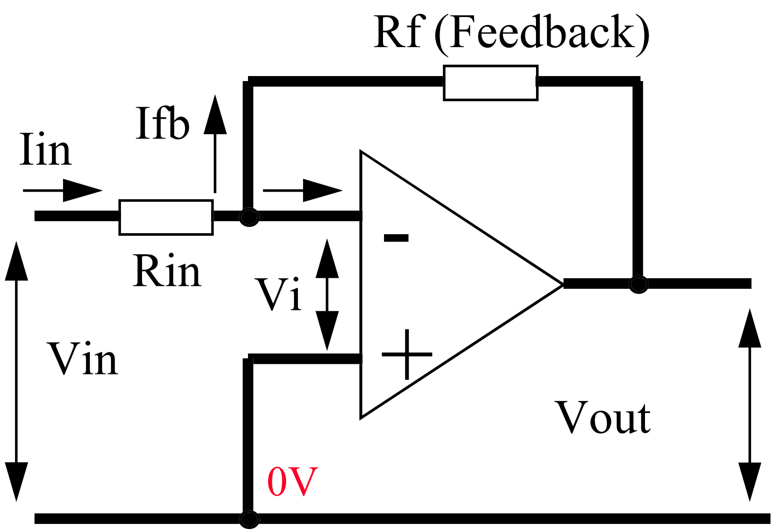
$$\frac{(-1) * Rf * Vin}{Vin * Rin} = \frac{-Vout * Rf * (-1)}{Rf * Vin}$$

$$\frac{(-1) * Rf * \cancel{Vin}}{\cancel{Vin} * Rin} = \frac{-\cancel{Vout} * \cancel{Rf} * (-1)}{\cancel{Rf} * Vin}$$

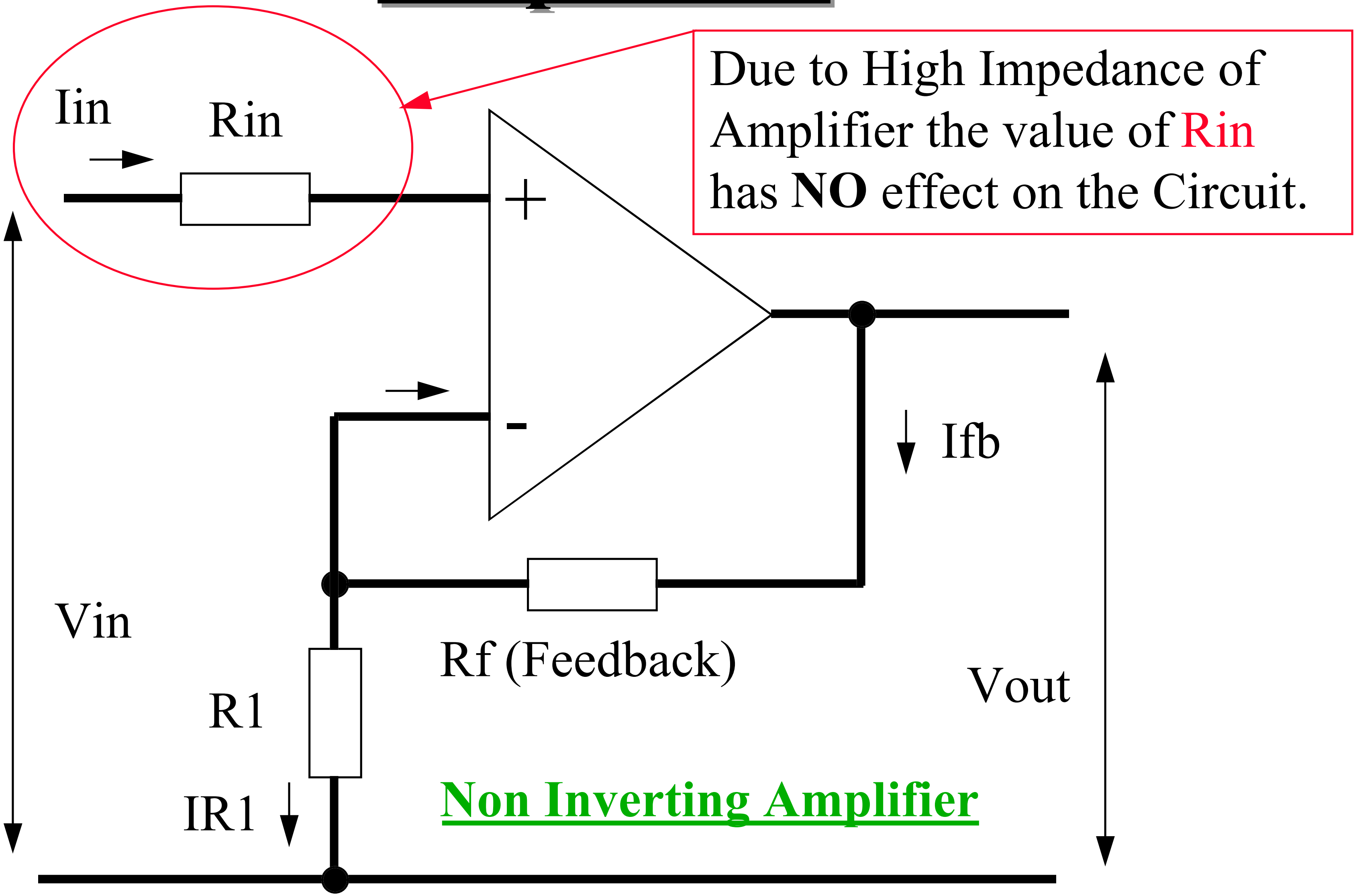
This gives us :-

Gain A $= \dfrac{Vout}{Vin} = \dfrac{\mathbf{-Rf}}{\mathbf{Rin}}$

Note The minus only indicates an Inverting Amplifier.



Amplifiers.


Iin
Rin
+
-
Ifb
Vin
R1
IR1
Rf (Feedback)
Vout
Due to High Impedance of Amplifier the value of Rin has NO effect on the Circuit.
Non Inverting Amplifier

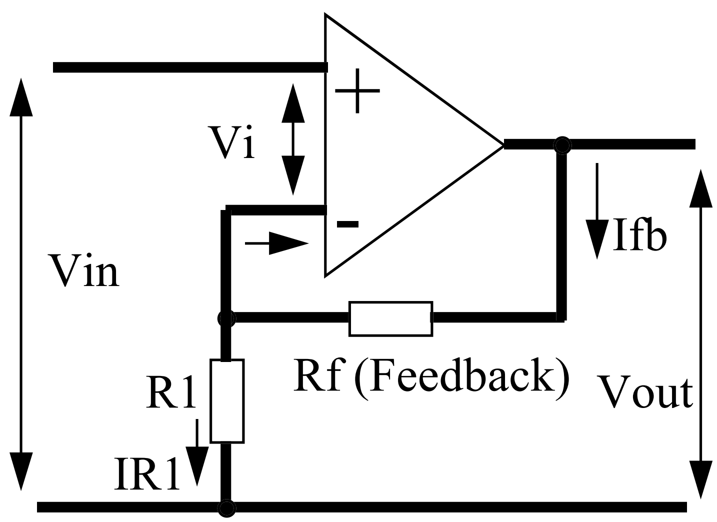
Amplifiers.

The Proof

Observation 1. Vout = Vi * Gain. As Gain is very large then even when Vout reaches Power rail voltage then Vi will still be insignificant. Therefore Vin effectively appears across R1 or Vin = VR1 .

Observation 2. As the input impedance of the amplifier is very high it can be assumed by default that No current will flow into either the Positive (+) or Negative (-) inputs .

Observation 3. If Vin goes Positive then Vout will also go positive. It this is an Non-Inverting Amplifier.



Amplifiers.

The Proof

Using Ohms law $IR1 = \frac{Vin}{R1}$

and $Ifb = \frac{(Vout - Vin)}{Rf}$

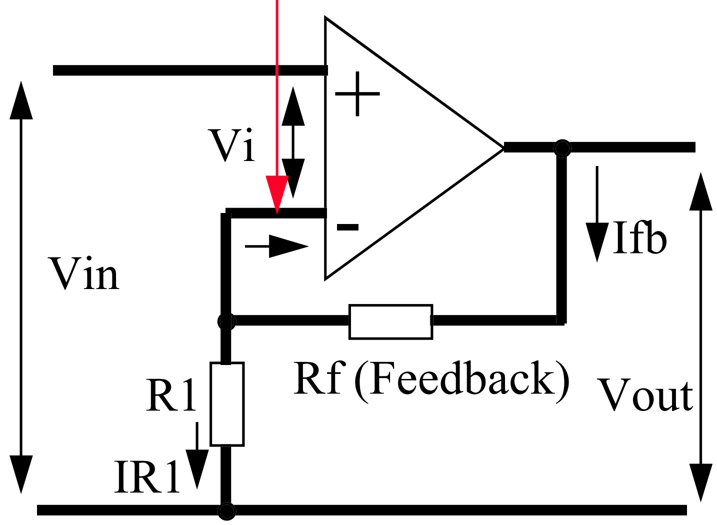
However as $IR1 = Ifb$

Therefore $\frac{Vin}{R1} = \frac{Vout - Vin}{Rf}$

and we Remember that

Gain $A = \frac{Vout}{Vin}$

By default this point is also Vin because Vi is insignificantly small.



Amplifiers.

The Proof

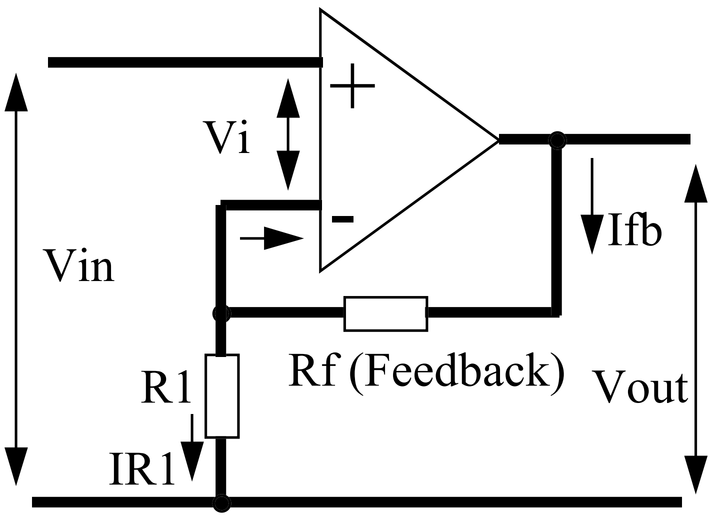
$$\frac{Vin}{R1} = \frac{(Vout - Vin)}{Rf}$$

$$\frac{Rf * Vin}{Vin * R1} = \frac{(Vout - Vin) * Rf}{Rf * Vin}$$

$$\frac{Rf * \cancel{Vin}}{\cancel{Vin} * R1} = \frac{(Vout - Vin) * \cancel{Rf}}{\cancel{Rf} * Vin}$$

This gives us :-

$$\frac{Vout - Vin}{Vin} = \frac{Rf}{R1}$$



Amplifiers.

The Proof

$$\frac{Vout - Vin}{Vin} = \frac{Rf}{R1}$$

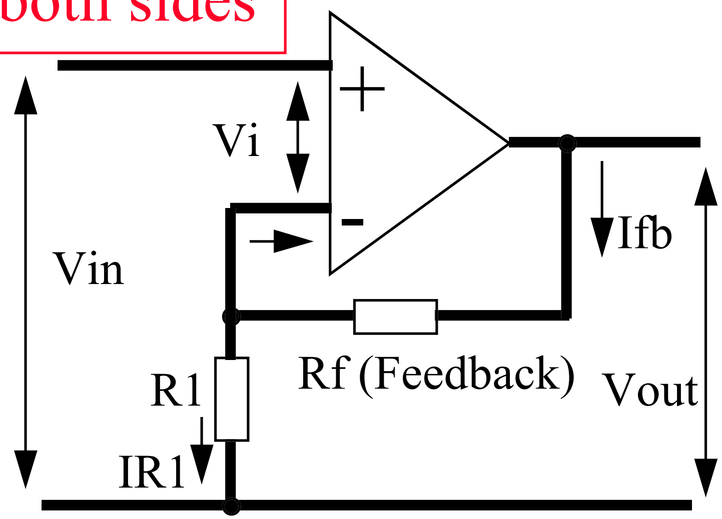
$$\frac{Vout}{Vin} - \frac{Vin}{Vin} = \frac{Rf}{R1}$$

$$\frac{Vout}{Vin} - \frac{1}{1} = \frac{Rf}{R1}$$

This gives us :-

Adding one to both sides

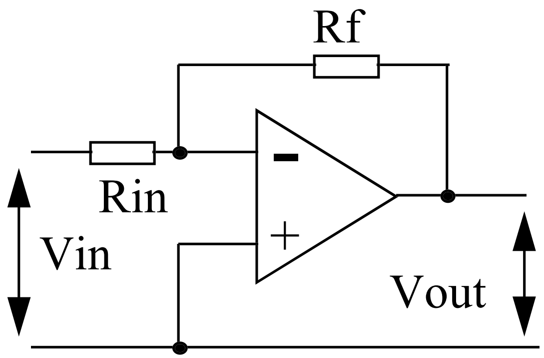
$$\left(\frac{Vout}{Vin}\right) - 1 + 1 = \frac{Rf}{R1} + 1$$



Gain A $= \frac{Vout}{Vin} = \mathbf{\frac{Rf}{R1} + 1}$

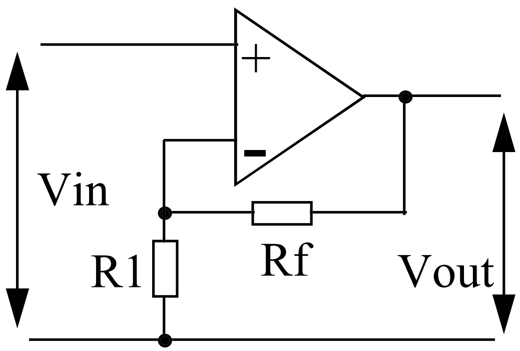
Amplifiers.

- Summary
- Gain for Inverting amplifier is :-



$$\text{Gain A} = \frac{V_{out}}{V_{in}} = \frac{-R_f}{R_{in}}$$

- Gain for Non-Inverting amplifier is :-

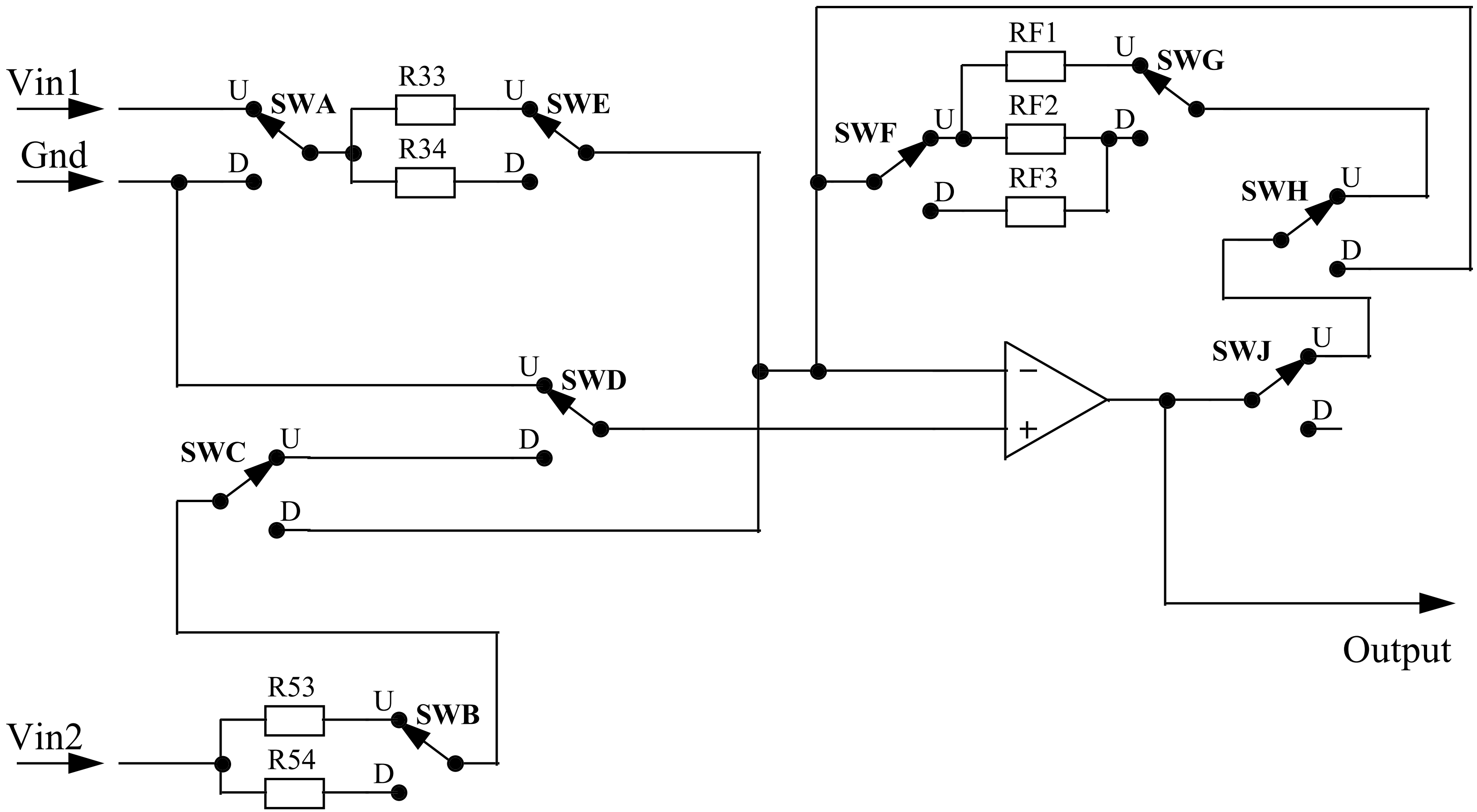


$$\text{Gain A} = \frac{V_{out}}{V_{in}} = \frac{R_f}{R_1} + 1$$

Amplifiers

Configurations.

Amplifiers.



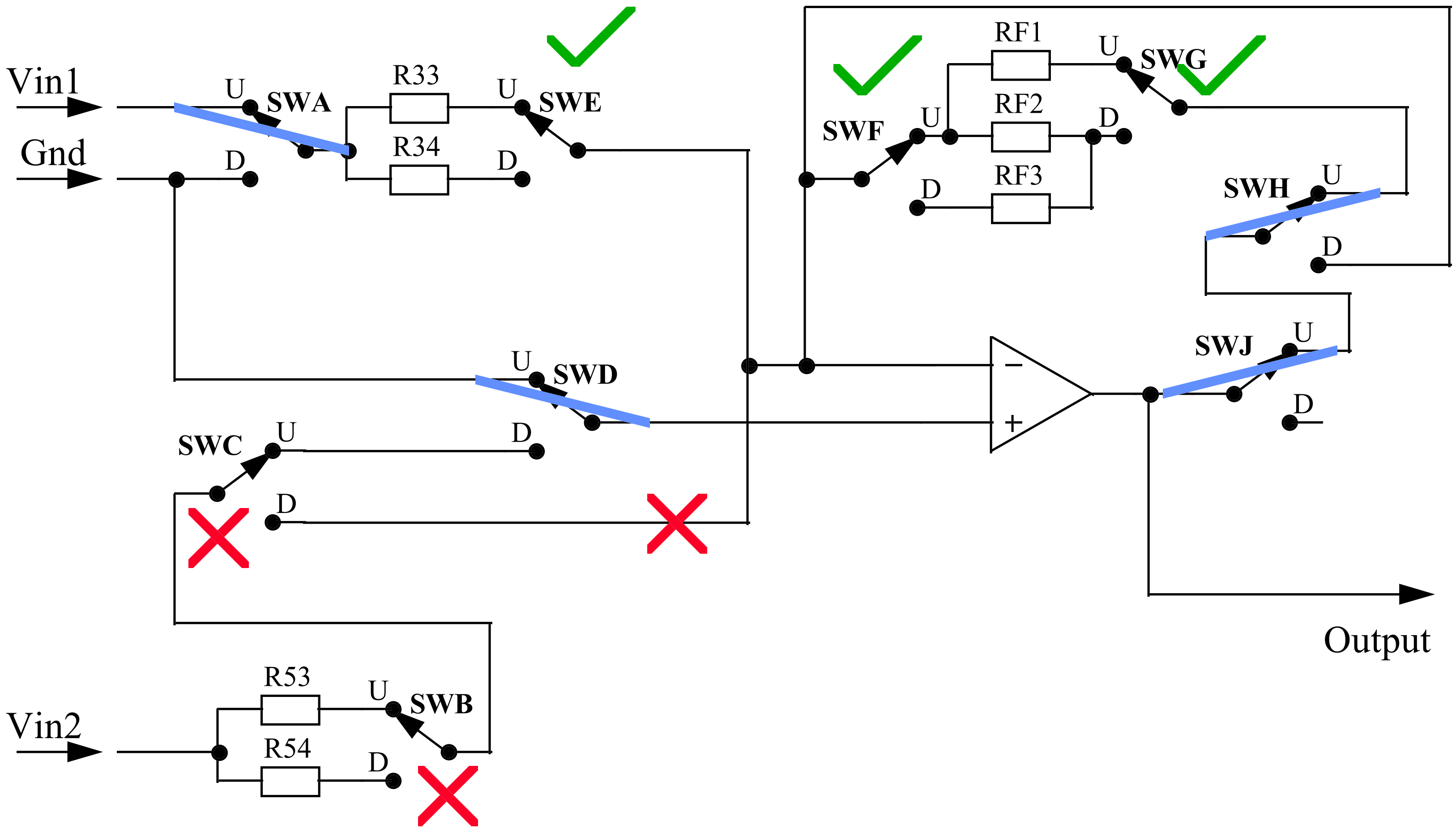
Generic Circuit Diagram.

Remove

Choice

Link

Amplifiers.



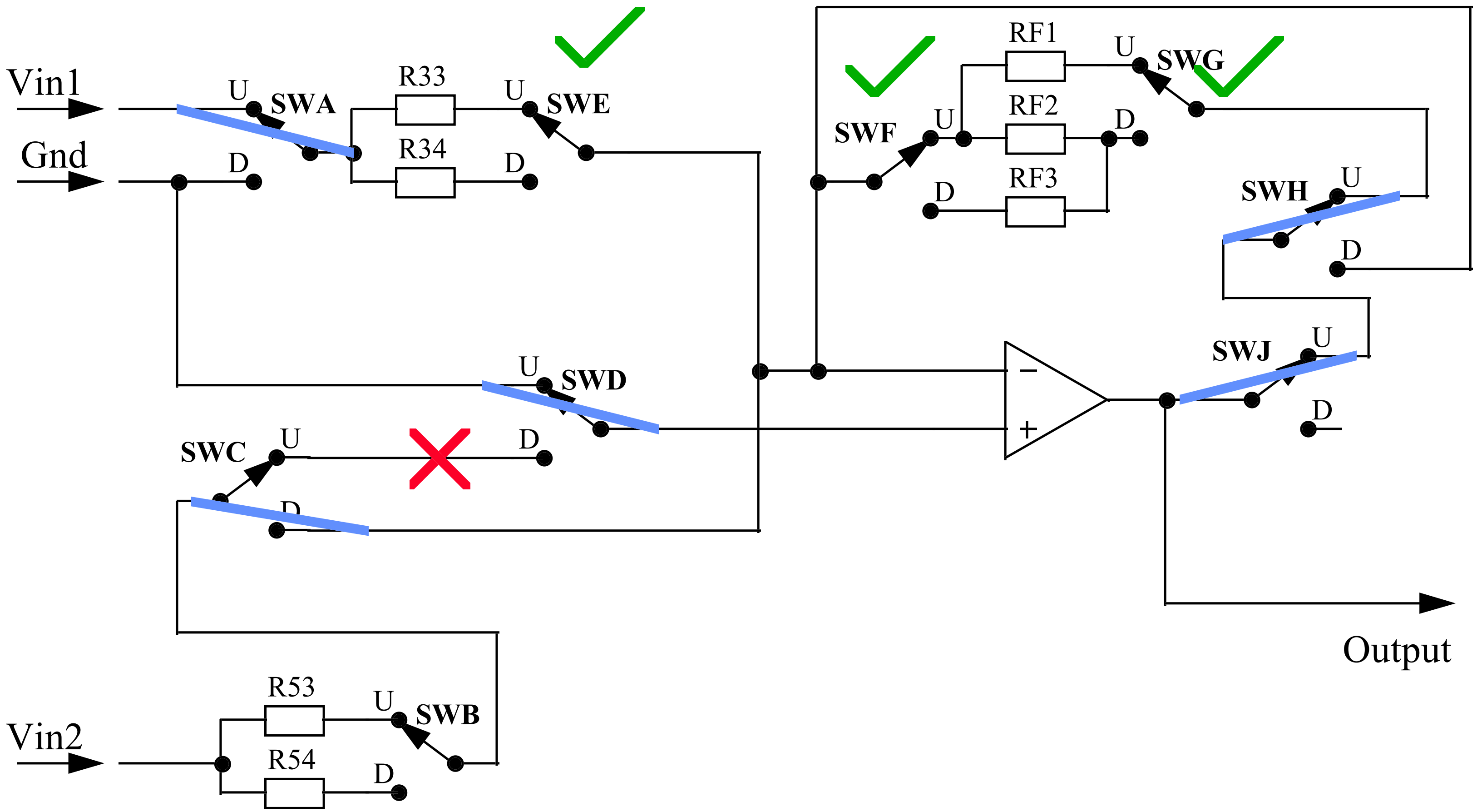
Inverting Amplifier Circuit Diagram.

Amplifiers.

Remove

Choice

Link



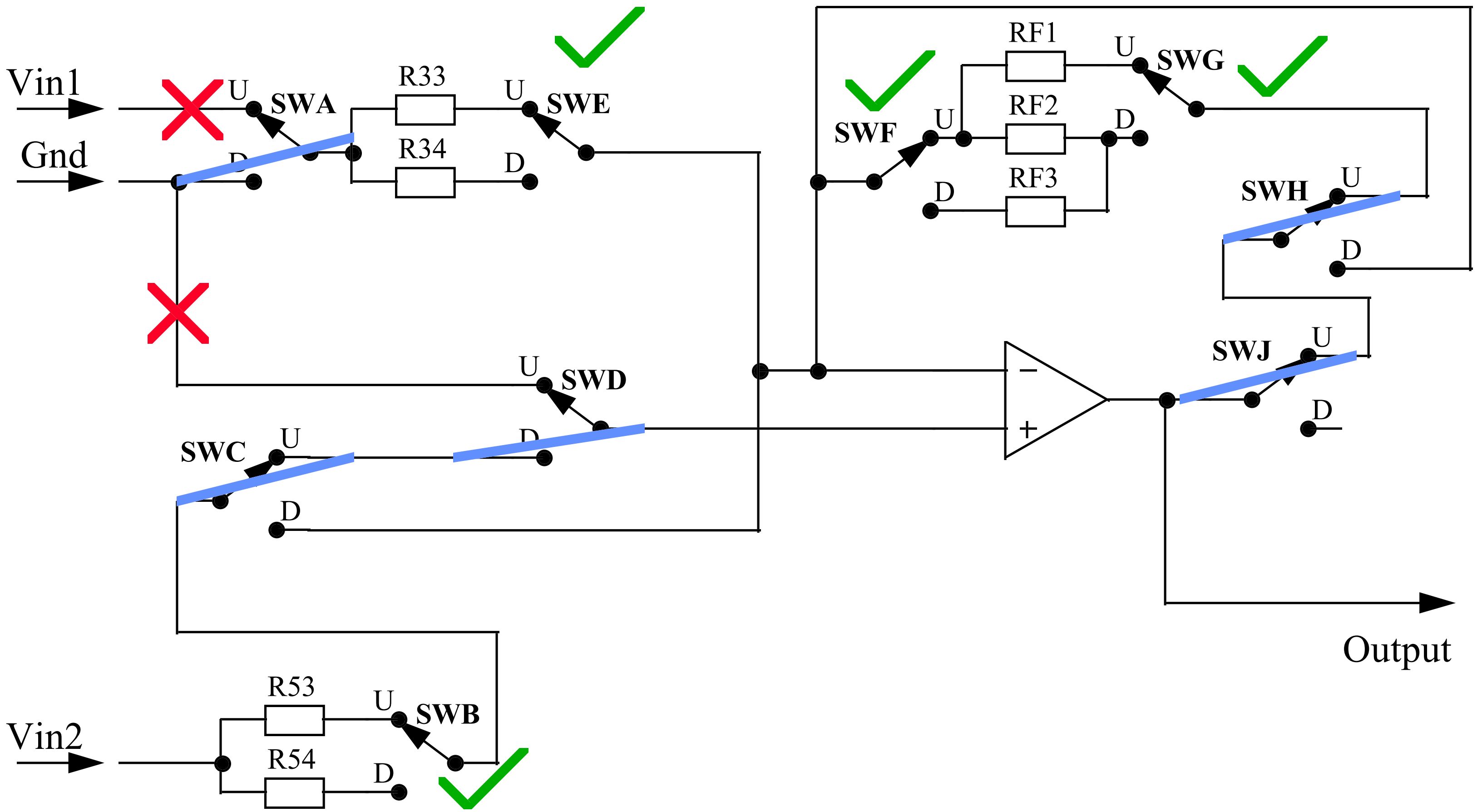
Inverting Summing Amplifier Circuit Diagram.

Remove

Choice

Link

Amplifiers.



Non-Inverting Amplifier Circuit Diagram.

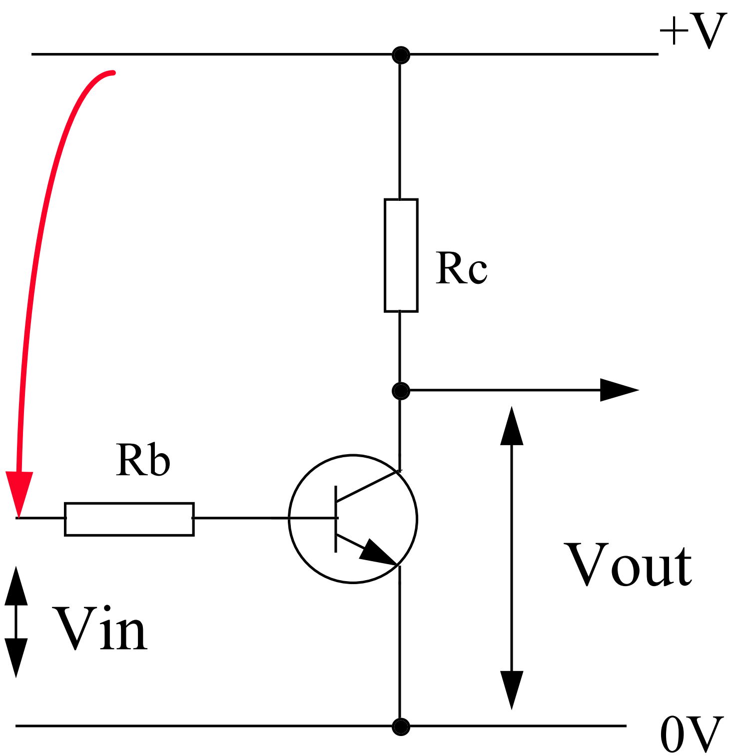
Transistor.

Amplifiers

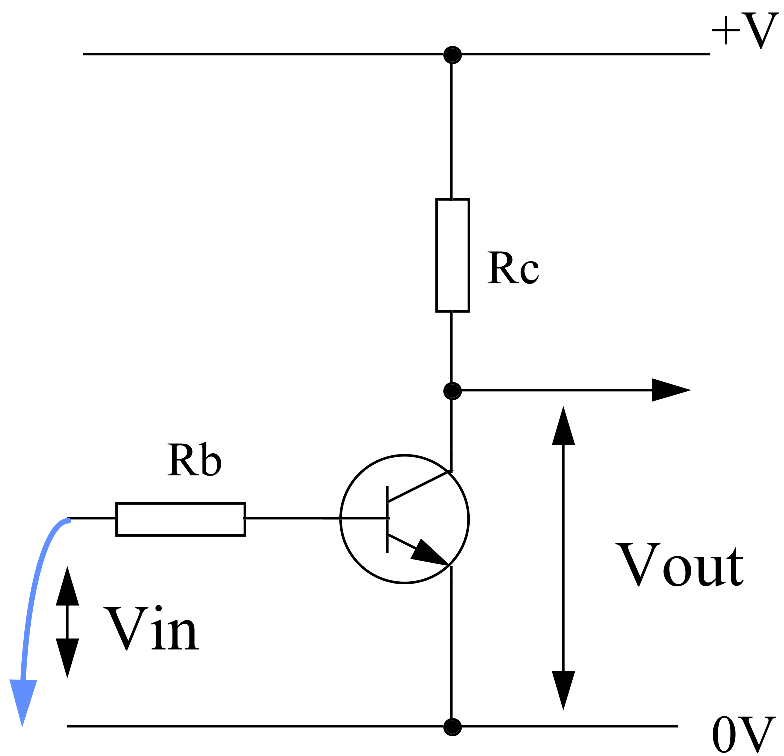
Used as a Switch.

Amplifiers.

- Using a Transistor as a Switch.
- V_{CE} virtually 0Volts



Saturated (Fully Conducting)



Cutoff (Not Conducting)

Amplifiers.

- Information to collect from the data sheets.
- Using Transistor type locate :-
  - Transistor Gain (Hfe)
  - Maximum Ic (Collector Current)
  - Maximum Voltage Collector/Emitter
  - Maximum Voltage Base/Emitter
- Circuit specification Information :-
  - Supply voltage
  - Input and Output Voltages and Current.

Amplifiers.

- Assume Gain of Transistor Hfe = 150 and +V = 9V , Rc = 1KΩ : Calculate minimum value of Rb to saturate the transistor.
- Voltage across Rc = 9V-Vsat ≅ 9V
- Current through Rc $= I_C = V/R$
  $= 9/1000 = 9mA$
- Gain $= I_C/I_B = 150 \;\therefore\; I_B = I_C/150 = 60\mu A$
- Voltage across Rb = 9V-0.7V = 8.3V
- Rb = V/I = 8.3/ 60μ= 138KΩ ≅ 120KΩ

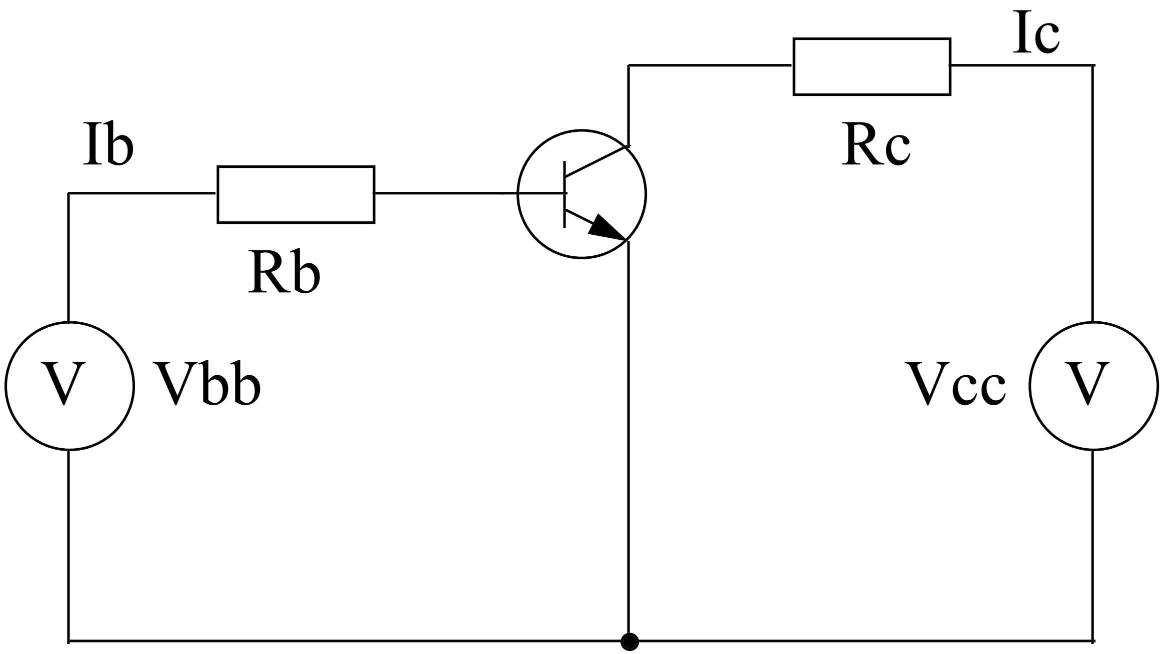
Transistor.

Amplifiers

Characteristics.

Amplifiers.

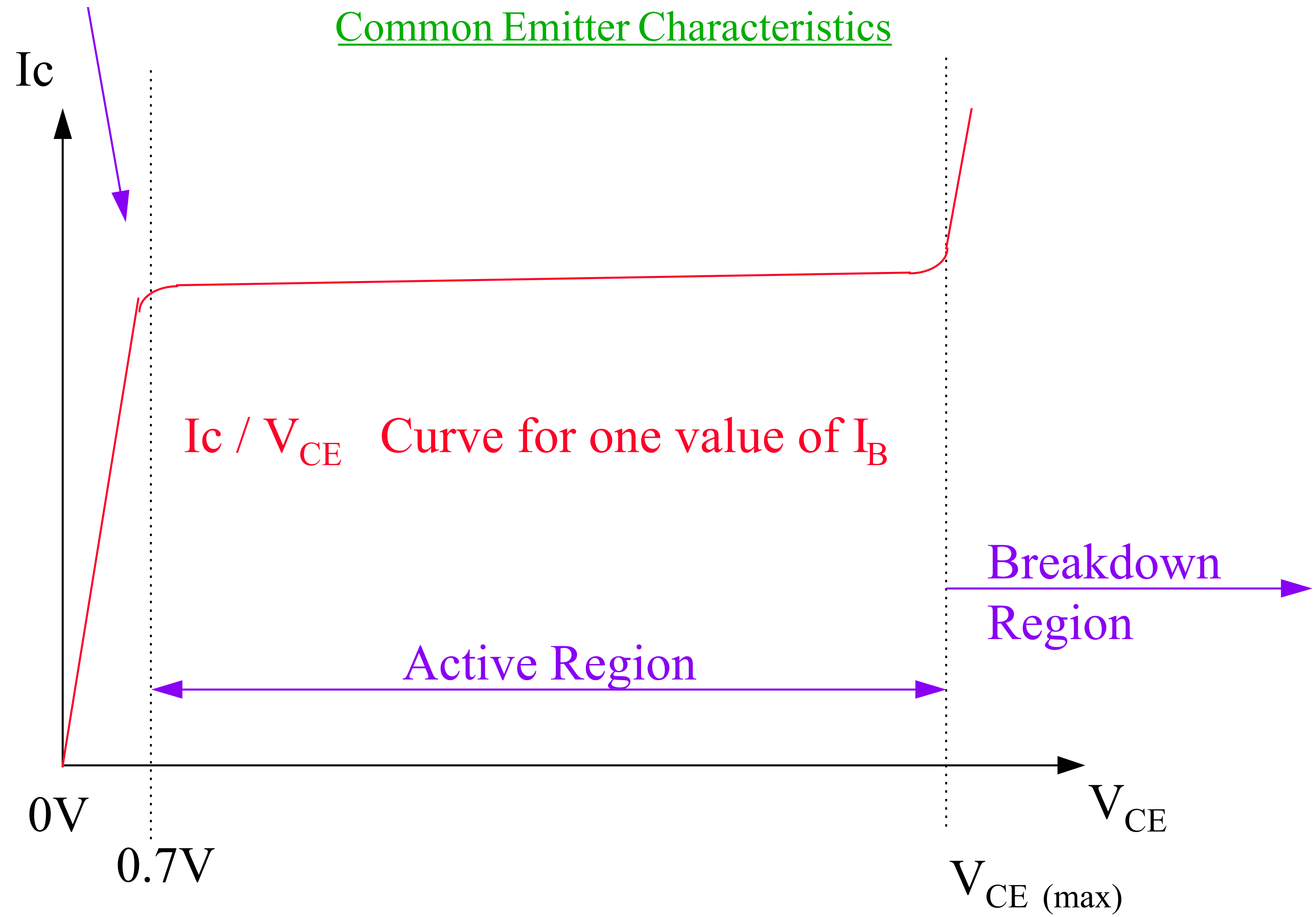
- Circuit to identify the characteristics of a transistor.
- Set Vbb and adjust Vcc (Record Ib, Ic, V_{ce}).



Amplifiers.

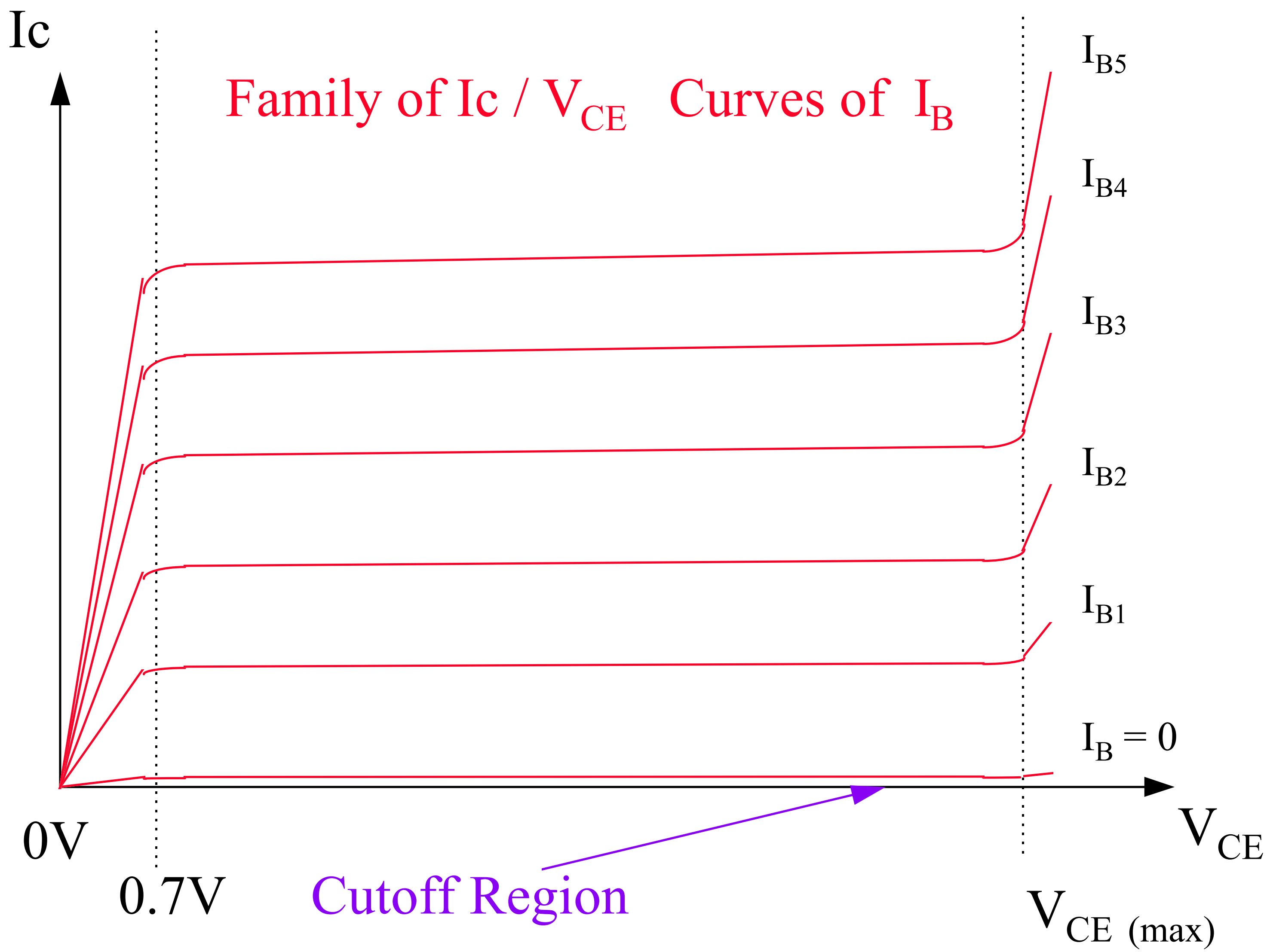
Saturation Region

Common Emitter Characteristics



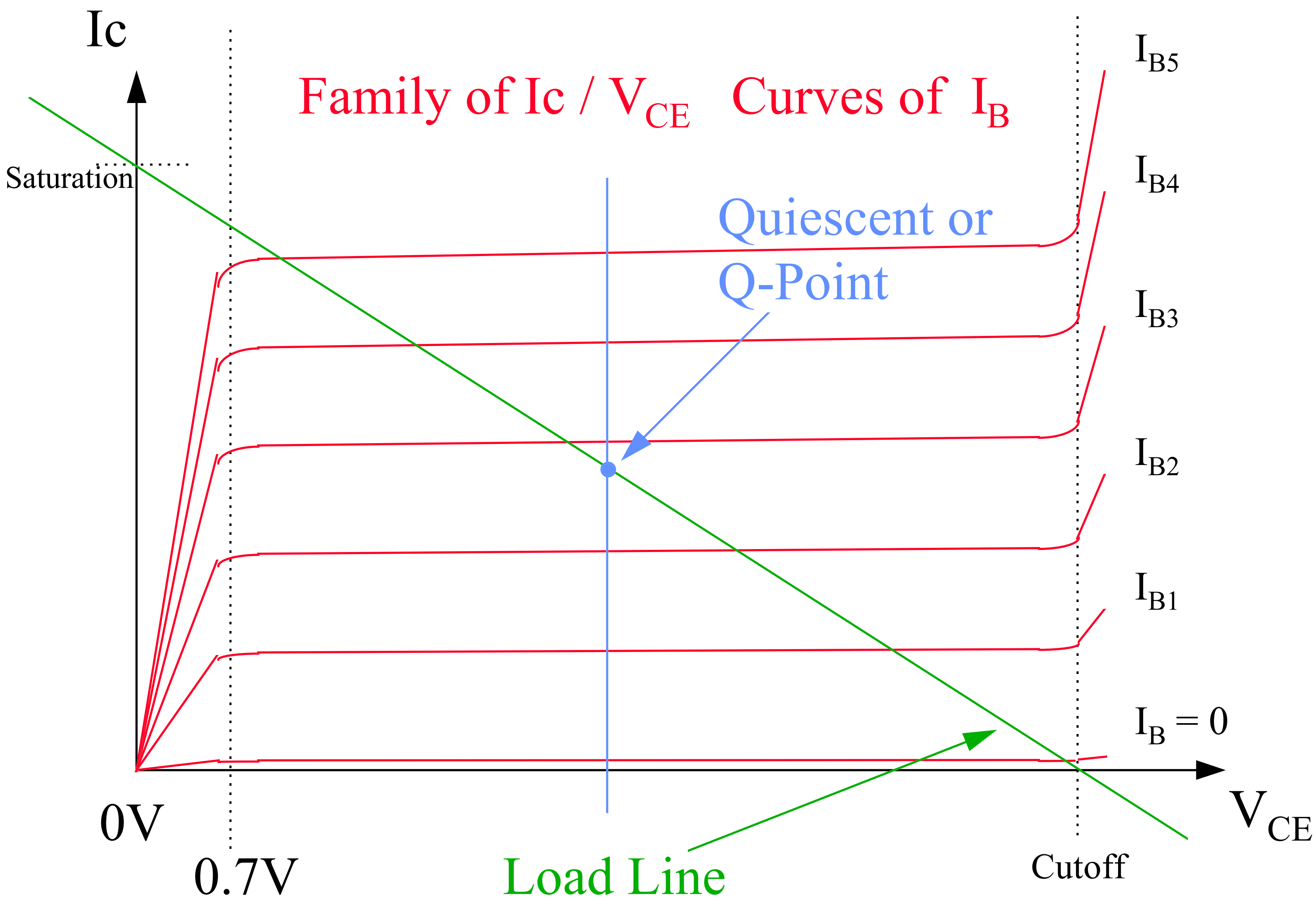
Amplifiers.

Transistors



Amplifiers.

Transistors



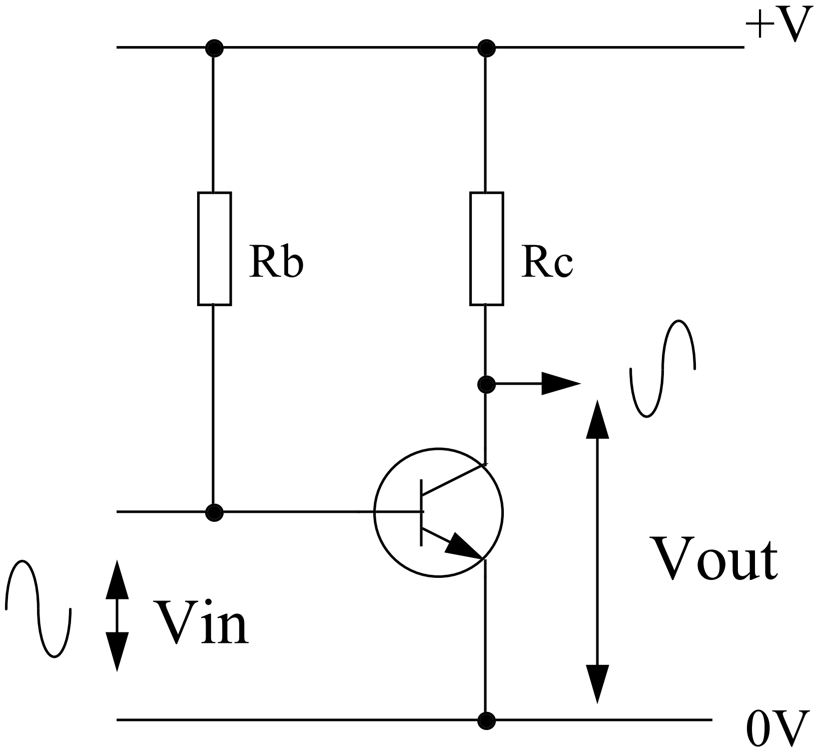
Transistor.

Amplifiers

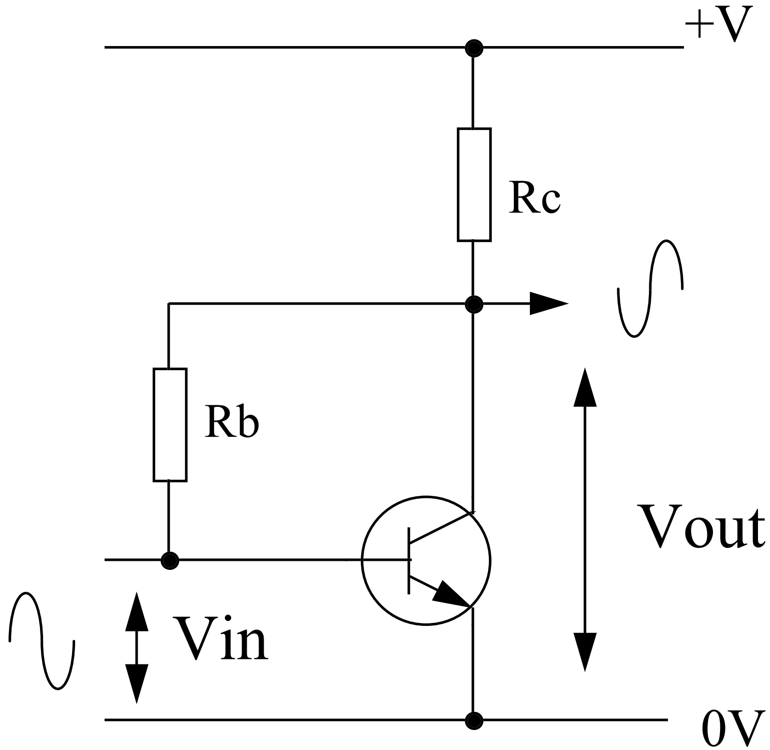
Unregulated.

Amplifiers.

- Transistor Unregulated Bias methods
- Disadvantage Rb dependent on Hfe



Circuit 1



Circuit 2

Using Worksheet & Circuit 1

Amplifiers.

- Transistor Hfe = 100 : +V = 12V : Ic = 10mA
- Calculate values of Rb and Rc.
- If Ic = 10mA then Vout biased @ 8.5 Volts.
- Voltage across Rc = 12V-8.5V = 3.5V
- Current through Rc = I_C = 10mA
- then Rc = 3.5/10mA = 350Ω
- Gain = I_C/I_B = 100 ∴ $I_B = I_C/100$ = 100µA
- Voltage across Rb = 12V-0.7V = 11.3V
- Rb = V/I = 11.3/ 100µA= 113KΩ

Using Circuit 1
Example 2

Amplifiers.

- Assume Hfe = 200 and +V = 15V , Rc = 560Ω and Vout biased @ 8.5 Volts
- Calculate value of Rb and Ic.
- Voltage across Rc = 15V-8.5V = 6.5V
- Current through Rc = V/R = 6.5/560 = 11.6mA = I_C
- Gain = I_C/I_B = 200 ∴ $I_B = I_C/200$ = 58μA
- Voltage across Rb = 15V-0.7V = 14.3V
- Rb = V/I = 14.3V / 58μA = 246.55KΩ

Transistor.

Amplifiers

Regulated.

Amplifiers.

- Transistor Regulated Bias method

Guidelines:-

Get Ic from Characteristics

Design to required Gain

VR_E = Vsupply/Gain

$V_{BE} = 0.7V$

Ib = Ic / Hfe

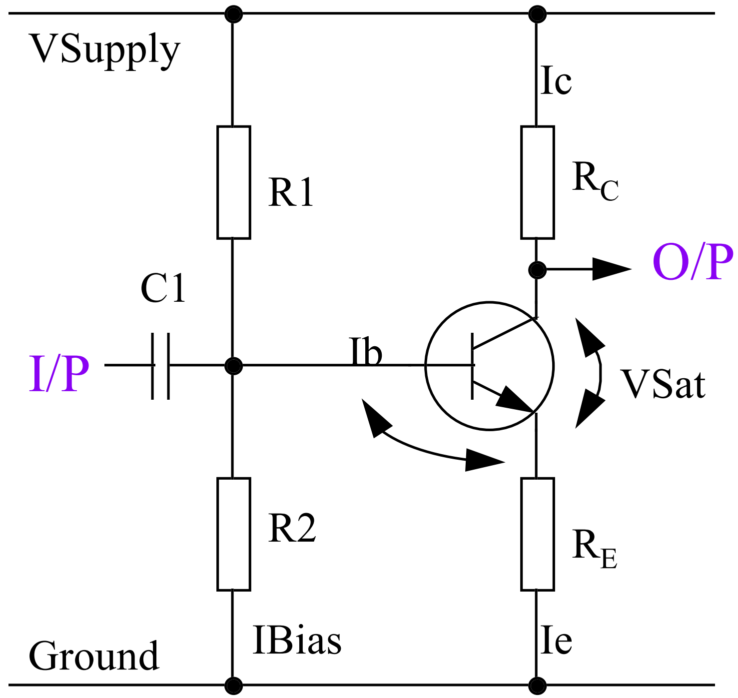
I Bias = Ib * 10

VSat = 0 to 0.2V

Ie = Ic + Ib

Check that the

Gain = R_C / R_E



Regulated
Using Worksheet **Amplifiers.**

- Transistor Hfe = 100 : +V = 12V :
  Target Gain = 18 : Vout Bias = 6 Volts
- If Bias = 6 Volts then I_C = 17.5mA
- Calculate Emitter Resistance Voltage
- VR_E = Vsupply / Gain = 12/18 = 0.66 V
- Calculate Collector Resistance
- Voltage across R_C = 12V - (VSat + VR_E)
  = 12 - (0 + 0.66) = 11.34V
- $R_C = V/I = 11.34/17.5*10^{-3} = 648\Omega \cong 680\Omega$
- Gain $\cong R_C/R_E = 18 \therefore R_E = 648/18 = 36\Omega$
- Preferred values $R_E = 33\Omega$ and $R_C = 680\Omega$

Regulated Using Worksheet Amplifiers.

- Calculate base Current and Voltage
- $Ib = Ic / Hfe = 17.5*10^{-3} / 100 = 175\mu A$
- $Vb = Ve + 0.7V = 0.66 + 0.7 = 1.36V$
- Use times ten rule for bias chain Current.
- $IBias = Ib * 10 = 1.75mA$
- Calculate Resistance of Bias Resistors
- $R2 = Vb / IBias = 1.36 / 1.75*10^{-3} = 777\Omega$
- $R1 = (Vsupply-Vb) / IBias$

  $(12 - 1.36) / (1.75*10^{-3}) =$

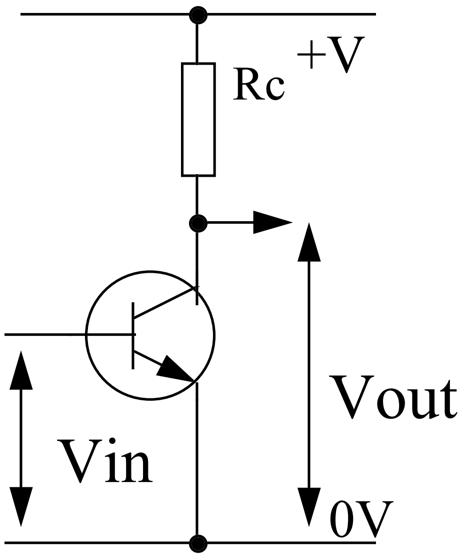
  $10.64 / (1.75*10^{-3}) = 6080\Omega$
- Preferred values R1 = 5K6Ω and R2 = 680Ω

Transistor.

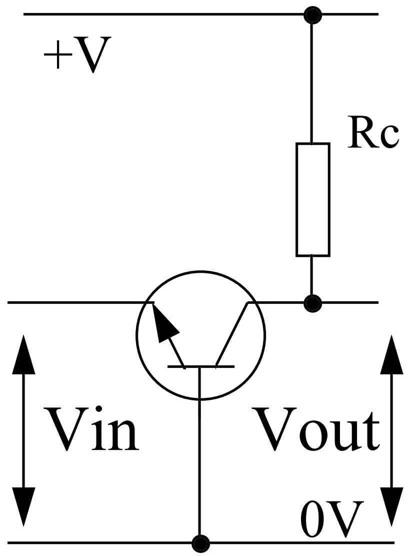
Amplifiers

Configurations.

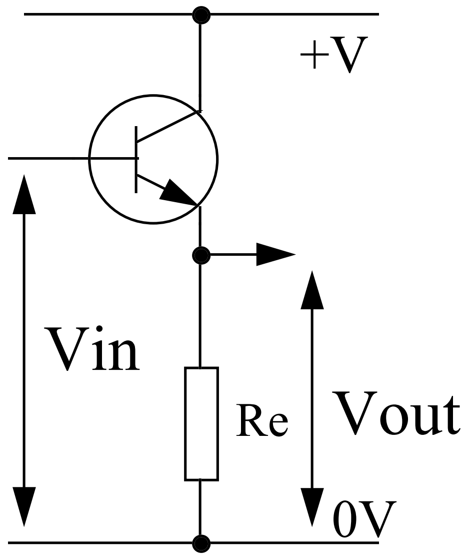
Amplifiers.



Common Emitter



Common Base



Common Collector

	Gain		Impedance	
Mode	Voltage	Current	Input	Output
Common Emitter	High	High	Medium	Medium
Common Base	High	Less than 1	Low	High
Common Collector	Less than 1	High	High	Low

Transistor.

Amplifiers

Operation Classes.

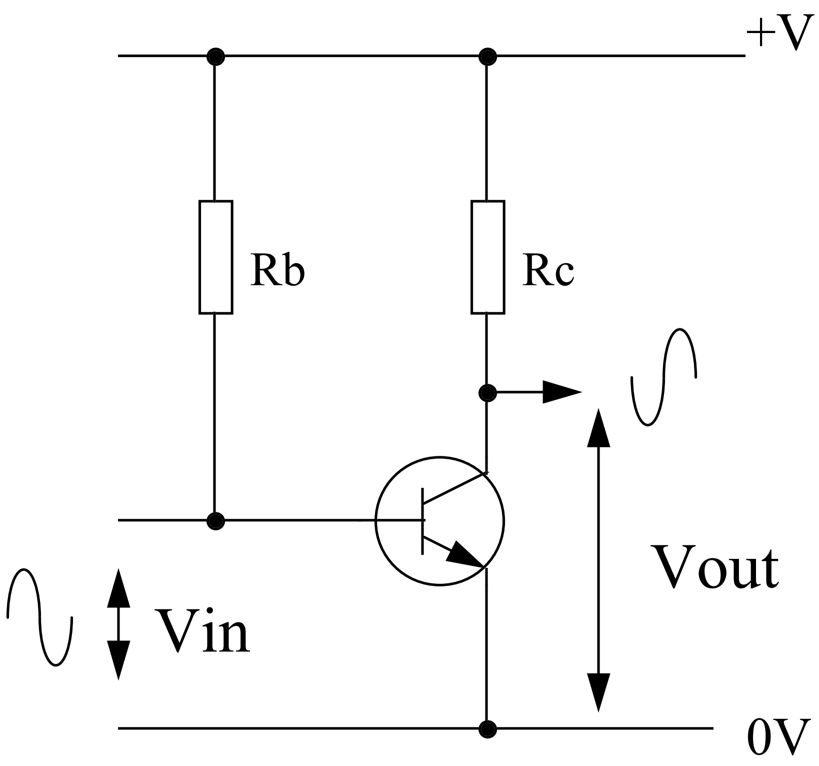
Classes

Amplifiers.

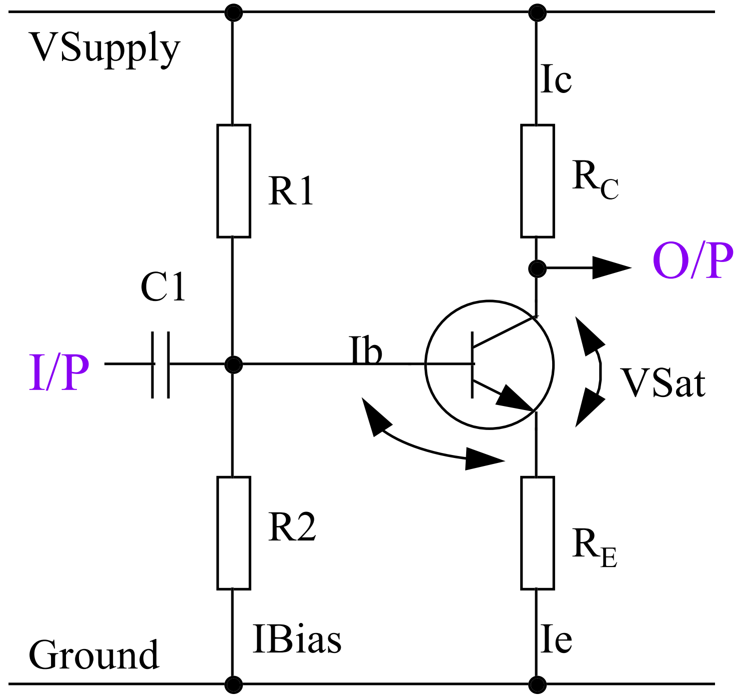
- Class "A"
- Main Characteristics.
- The amplifier biased so that all 360^o of input signal is amplified.
- Advantages.
- Little or low distortion in output signal.
- Linear output.
- Disadvantages.
- Efficiency max 25%.

Amplifiers.

- Class “A” Amplifiers.



Class “A” Amplifier
Un-Regulated



Class “A” Amplifier
Regulated

<u>Classes</u>

<u>Amplifiers.</u>

- Class “B”
- <u>Main Characteristics.</u>
- The amplifier biased so that only 180^{o} of input signal is amplified.
- <u>Advantages.</u>
- Efficiency max 78.5%
- <u>Disadvantages.</u>
- Subject to Cross over distortion in output signal.

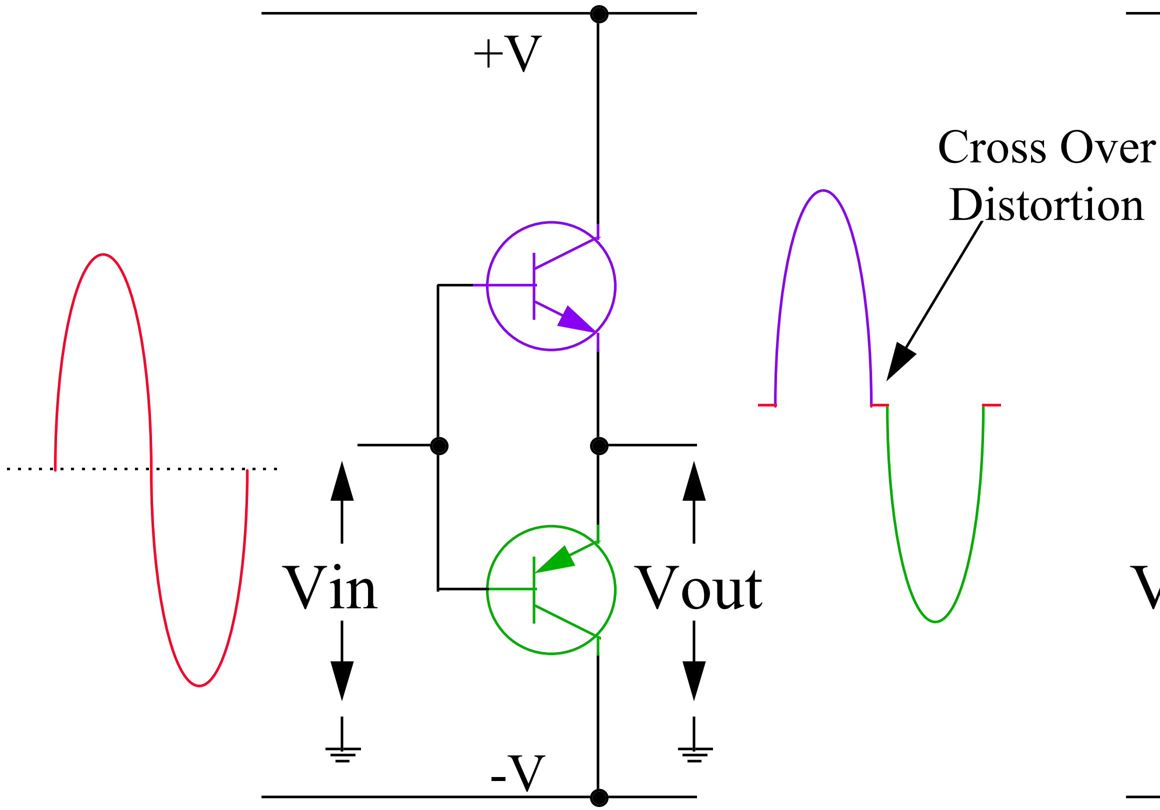
Classes

Amplifiers.

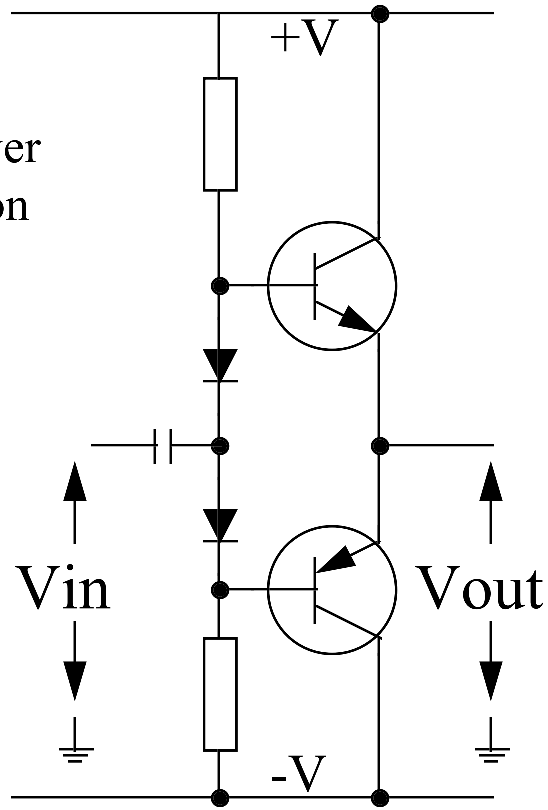
- Class "AB"
- Main Characteristics.
- The amplifier biased so that over 180^o of input signal is amplified.
- Advantages.
- Efficiency much better than Class "A"
- Subject to less Cross over distortion in output signal than Class "B".
- Disadvantages.
- Less efficient than Class "B"

Amplifiers.

- Push Pull Amplifiers (Class B or AB).



Class “B” Amplifier



Class “AB” Amplifier
Not Thermally Stable

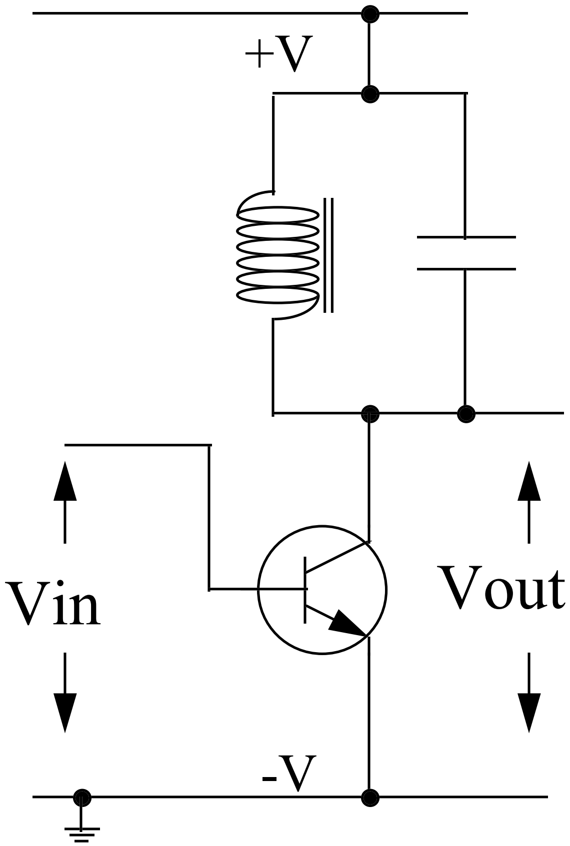
Classes

Amplifiers.

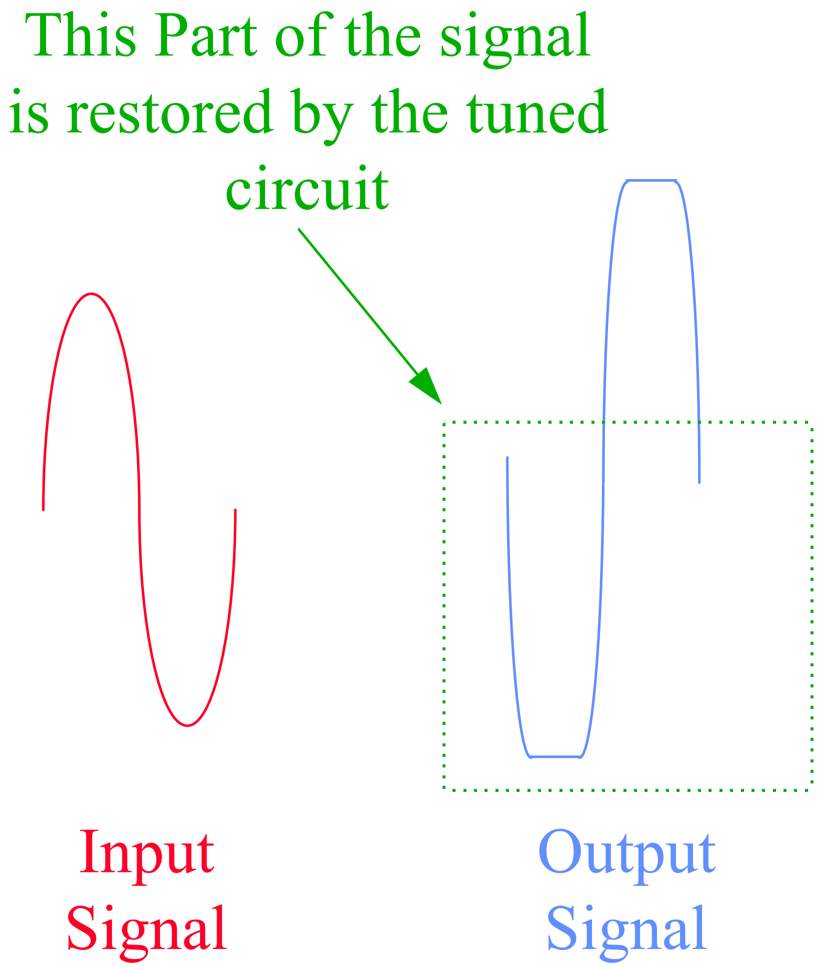
- Class "C"
- Main Characteristics.
- The amplifier biased so that only part of input signal is amplified. Restoration of signal by Tuned Circuits
- Advantages.
- Up to 100% efficient.
- Disadvantages.
- Subject to significant distortion in output signal if input signal not symmetrical.

Amplifiers.

- Class “C” Amplifiers.



Class “C” Amplifier



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Revision Page

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