Electronic Devices

Lecture 14
Bipolar Junction Transistor

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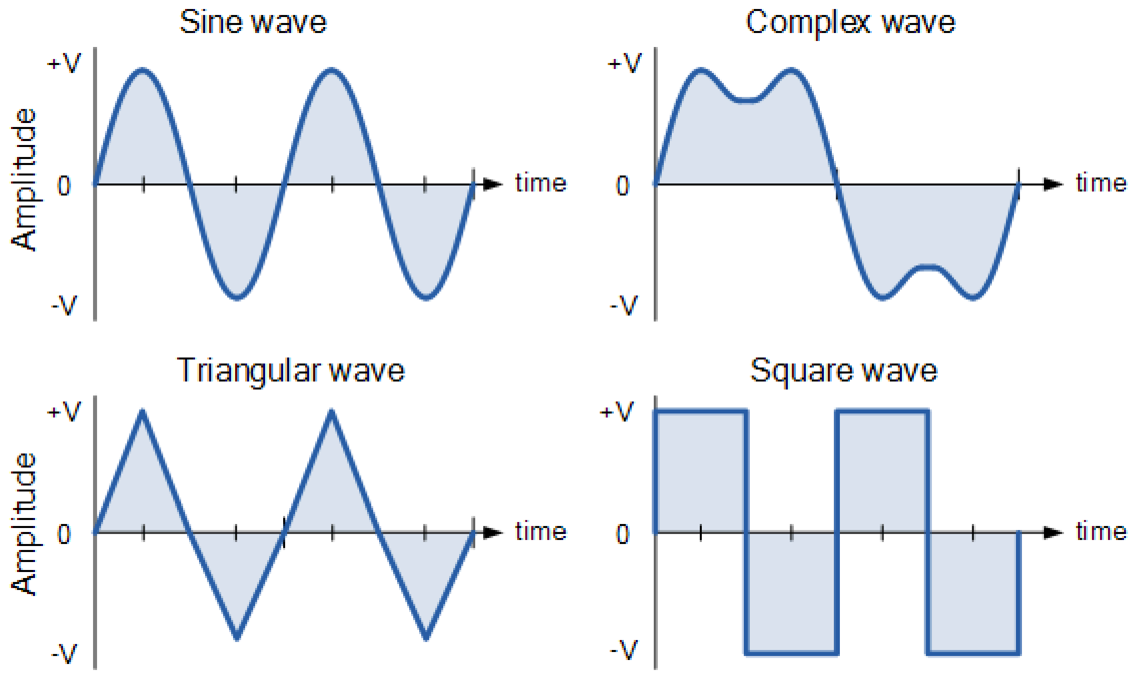
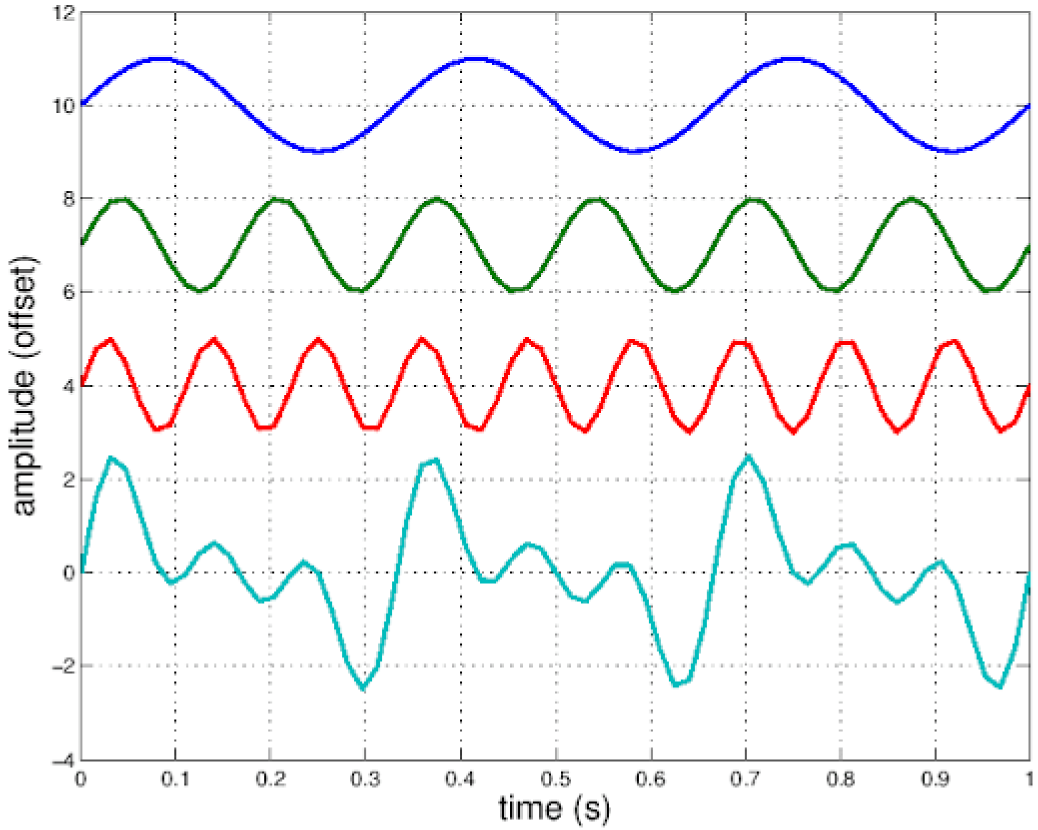
Signal

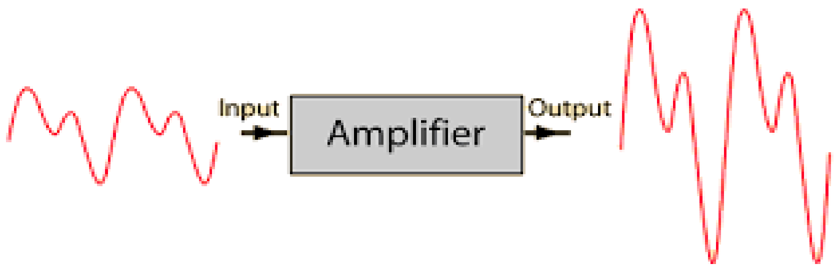
- A **signal** is a function that conveys information about a phenomenon.
- In electronics and telecommunications, it refers to any time varying voltage, current, or electromagnetic wave that carries information.





Amplifier

- An amplifier, electronic amplifier is an electronic device that can increase the power of a signal (a time-varying voltage or current).
- It is a two-port electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output.
- The amount of amplification provided by an amplifier is measured by its gain: the ratio of output voltage, current, or power to input. An amplifier is a circuit that has a power gain greater than one.

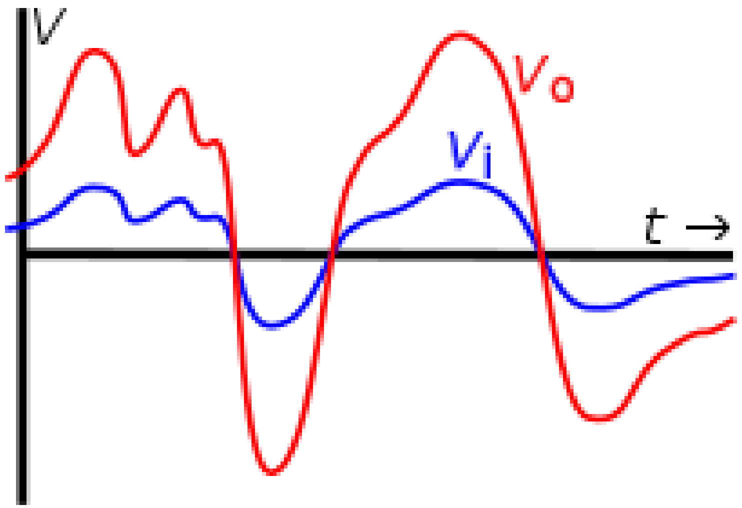


Amplifier

Amplification means increasing the amplitude (voltage or current) of a time-varying signal by a given factor, as shown here.

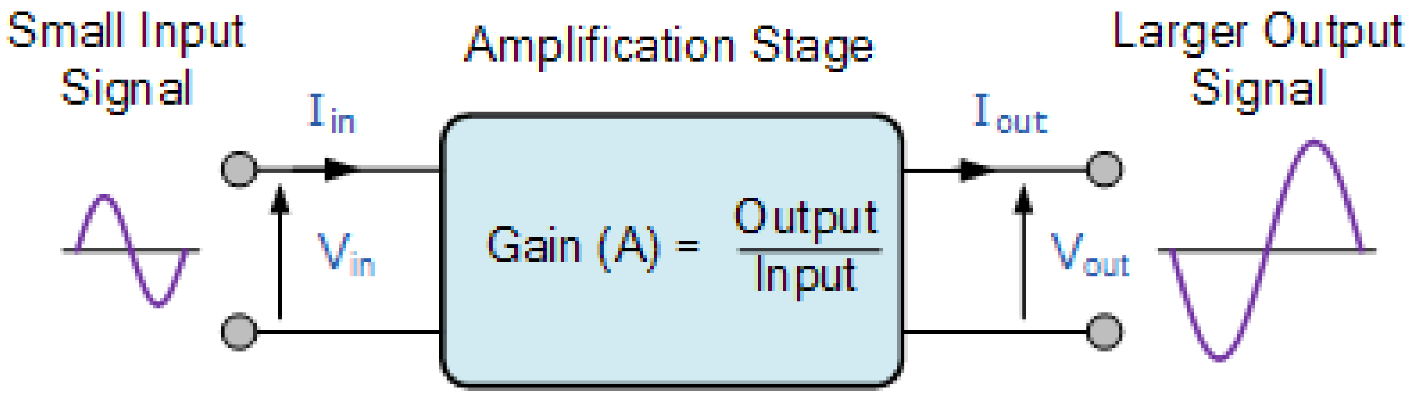
The graph shows the input (blue) $V_i(t)$ and output voltage (red) $V_o(t)$ of an ideal linear amplifier with an arbitrary signal applied as input. In this example the amplifier has a voltage gain of 3; that is at any instant

$$V_o = 3\,V_i$$



$$v_o(t) = Av_i(t)$$

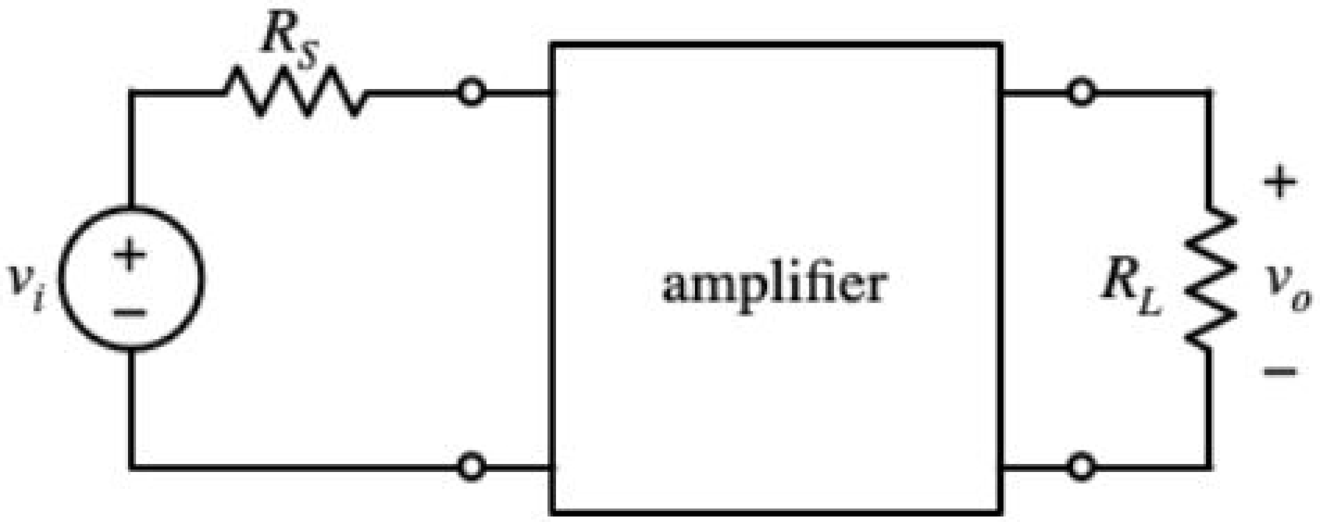
Amplifier gain



Amplifier

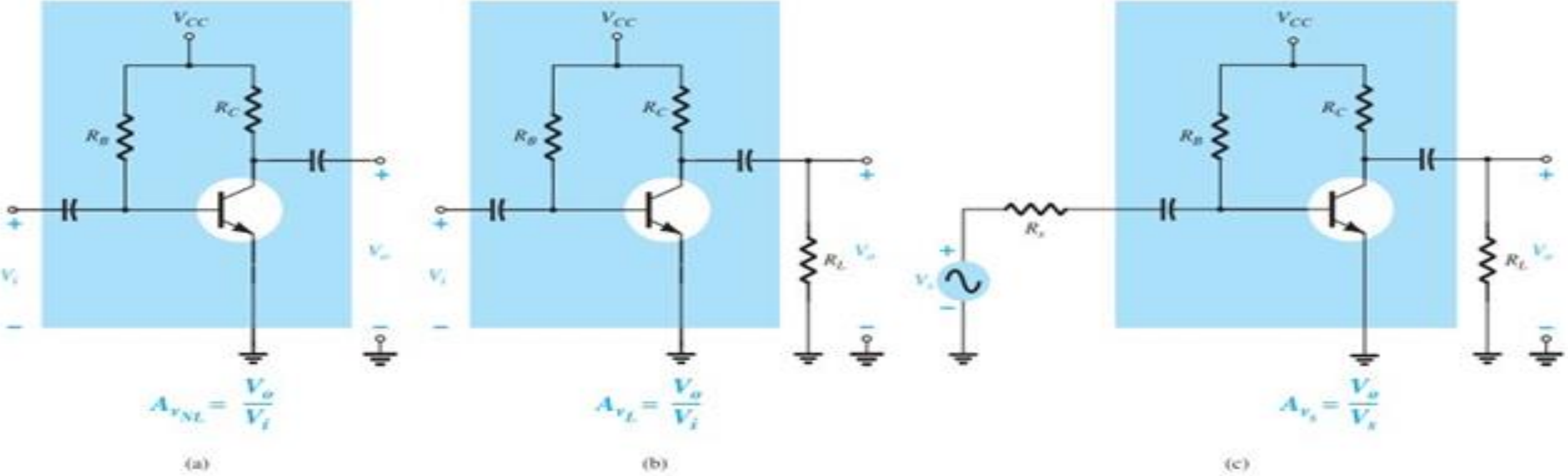
- **The Effect of R_s & R_L**

This amplifier fed with a signal source having an open-circuit voltage V_i and internal resistance R_s. The amplifier has load resistance R_L connected to the output terminal



Amplifier

- **The Effect of R_s & R_L**



Amplifier configurations: (a) unloaded; (b) loaded; (c) loaded with a source resistance.

$$\boxed{A_{v_{NL}} = \frac{V_o}{V_i}}$$

$$\boxed{A_{v_L} = \frac{V_o}{V_i}} \quad \text{with } R_L$$

$$\boxed{A_{v_s} = \frac{V_o}{V_s}} \quad \text{with } R_L \text{ and } R_s$$

Amplifier

- **The Effect of R_s & R_L**

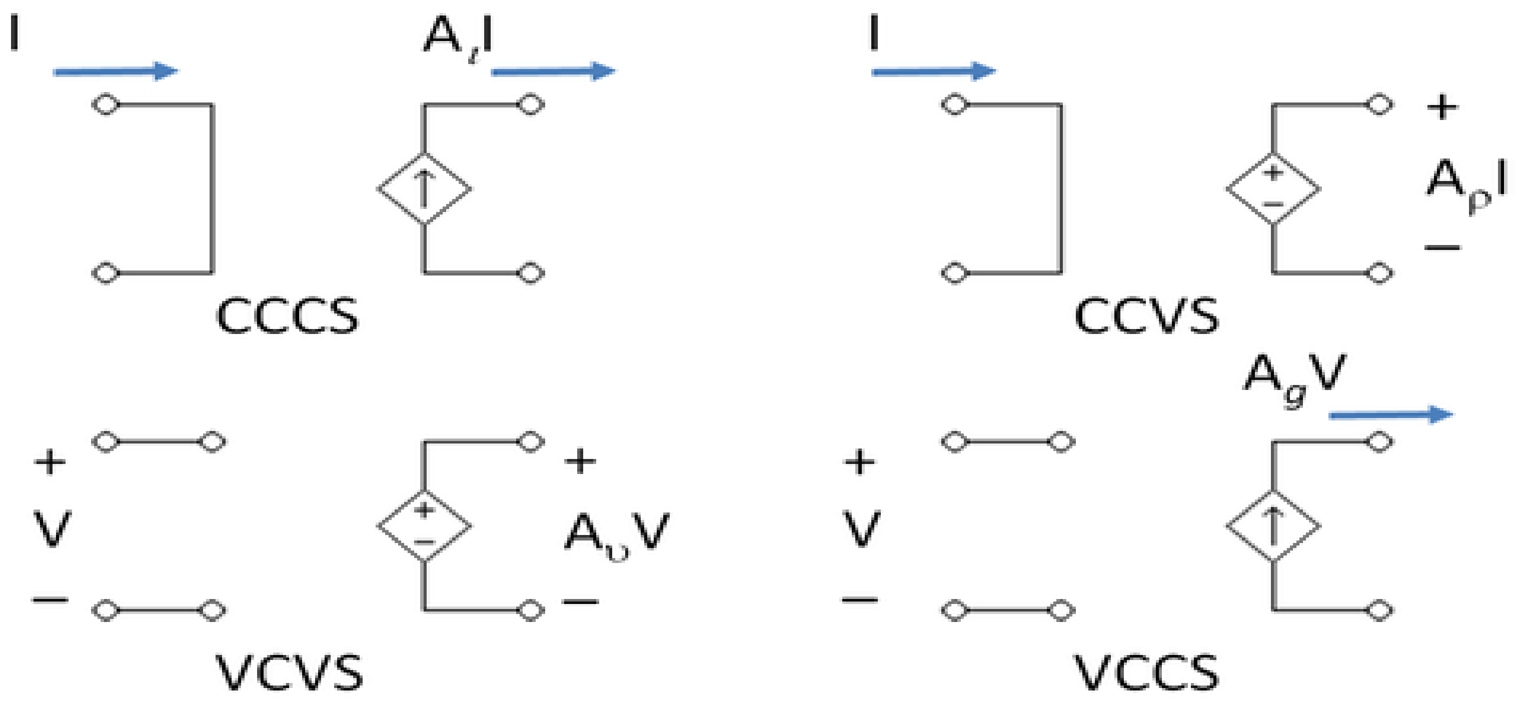
- The loaded voltage gain of an amplifier is always less than the no-load gain.
- The gain obtained with a source resistance in place will always be less than that obtained under loaded or unloaded conditions due to the drop in applied voltage across the source resistance.
- For the same configuration $A_{vNL} > A_{vL} > A_{vs}$.
- For a particular design, the larger the level of RL , the greater is the level of ac gain.
- For a particular amplifier, the smaller the internal resistance of the signal source, the greater is the overall gain.
- For any network that have coupling capacitors, the source and load resistance do not affect the dc biasing levels.

Amplifier

- A dependent source is a current or voltage source whose value is not fixed, but rather which depends on some other circuit current or voltage.
- The general form for the value of a dependent source is Y=kX where X and Y are currents and/or voltages and k is the proportionality factor.
- For example, the value of a dependent voltage source may be a function of a current, so instead of the source being equal to, say, 10 volts, it could be equal to twenty times the current passing through a particular resistor, or V=20I.
- There are four possible dependent sources: the voltage-controlled voltage source (VCVS), the current-controlled voltage source (CCVS), the voltage-controlled current source (VCCS), and the current-controlled current source (CCCS).

Amplifier

- The source and control parameters are the same for both the VCVS and the CCCS so kk is unitless (although it may be given as volts/volt and amps/amp, respectively).
- For the VCCS and CCVS, kk has units of amps/volt and volts/amp, respectively. These are referred to as the trans-resistance and transconductance of the sources with units of ohms and siemens.

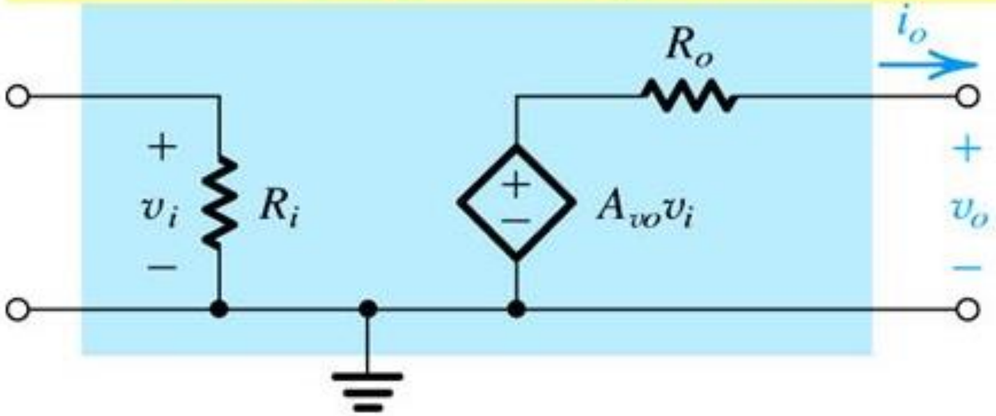


Amplifiers Types

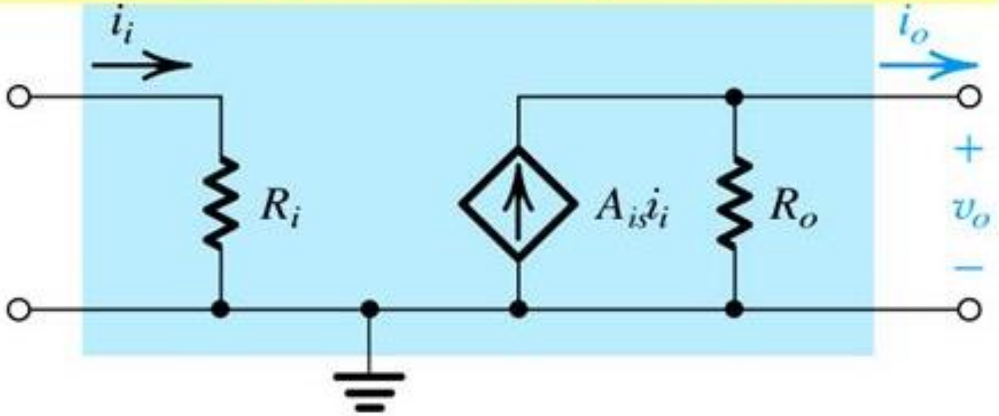
- Although amplifiers are sometimes classified according to input and output parameters (we'll get to that), there are 4 basic types, which are:
- **Current Amplifier:** As the name suggests, an amplifier that makes the given input current higher. It is characterized by a low input impedance and high output impedance.
- **Voltage Amplifier:** An amplifier that amplifies given voltage for a larger voltage output. It is characterized by a high input impedance and low output impedance.
- **Transconductance Amplifier:** An amplifier that changes output current according to changing input voltage.
- **Transresistance Amplifier:** An amplifier that changes output voltage according to changing input current. It is also known as a current-to-voltage converter.

Amplifiers Types

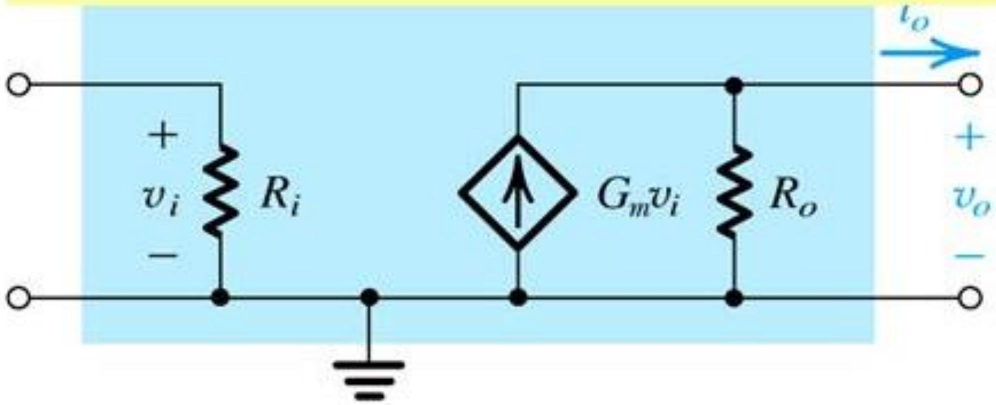
voltage amplifier



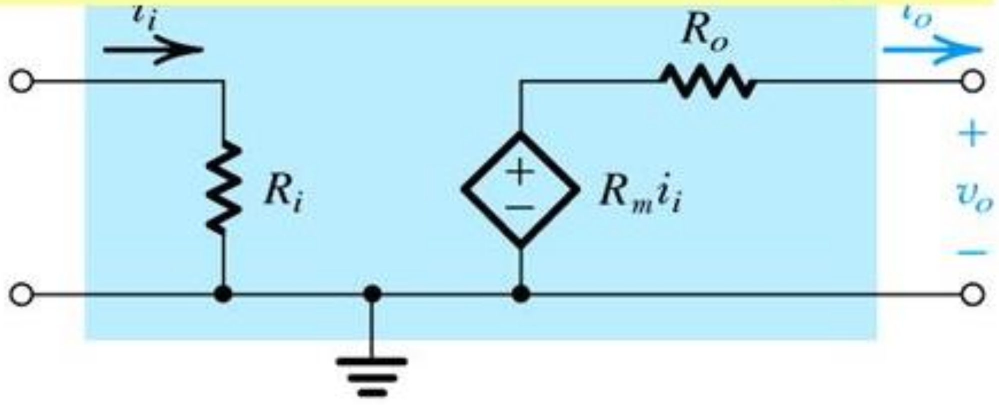
current amplifier



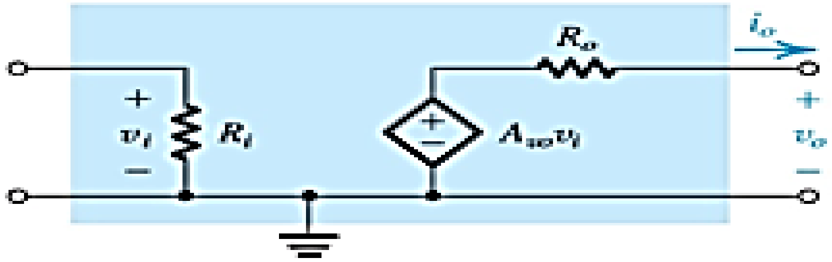
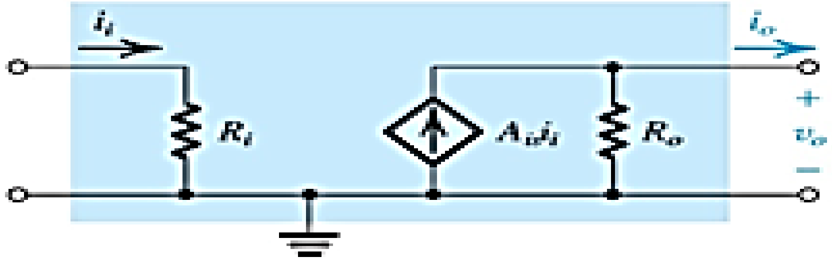
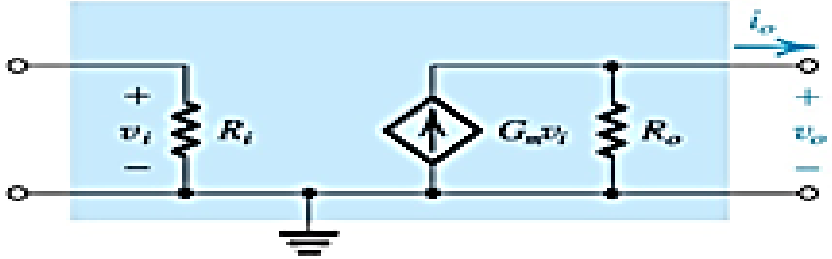
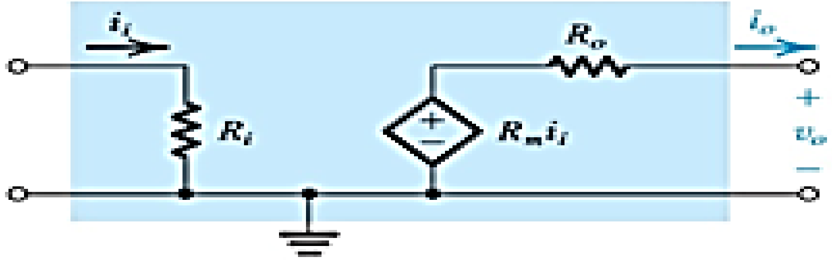
transconductance amp.



transresistance amp.



Amplifiers Types

Type	Circuit Model	Gain Parameter	Ideal Characteristics
Voltage Amplifier		Open-Circuit Voltage Gain $A_{vo} \equiv \left.\frac{v_o}{v_i}\right\vert_{i_o=0}$ (V/V)	$R_i = \infty$ $R_o = 0$
Current Amplifier		Short-Circuit Current Gain $A_{is} \equiv \left.\frac{i_o}{i_i}\right\vert_{v_o=0}$ (A/A)	$R_i = 0$ $R_o = \infty$
Transconductance Amplifier		Short-Circuit Transconductance $G_m \equiv \left.\frac{i_o}{v_i}\right\vert_{v_o=0}$ (A/V)	$R_i = \infty$ $R_o = \infty$
Transresistance Amplifier		Open-Circuit Transresistance $R_m \equiv \left.\frac{v_o}{i_i}\right\vert_{i_o=0}$ (V/A)	$R_i = 0$ $R_o = 0$

AC Analysis of BJT

- AC analysis of BJT included the large signal and small signal.
- Here we deal with small signal (large signal used power amplifiers).
- The analysis is complex so, we use a small signal model to replace the BJT.
- The total response = the dc response + the AC response.
- A model is an equivalent circuit that represents the AC characteristics of the transistor.
- A model uses circuit elements that approximate the behavior of the transistor.
- There are two models commonly used in small signal AC analysis of a transistor:

– re model

– Hybrid model

BJT Modeling

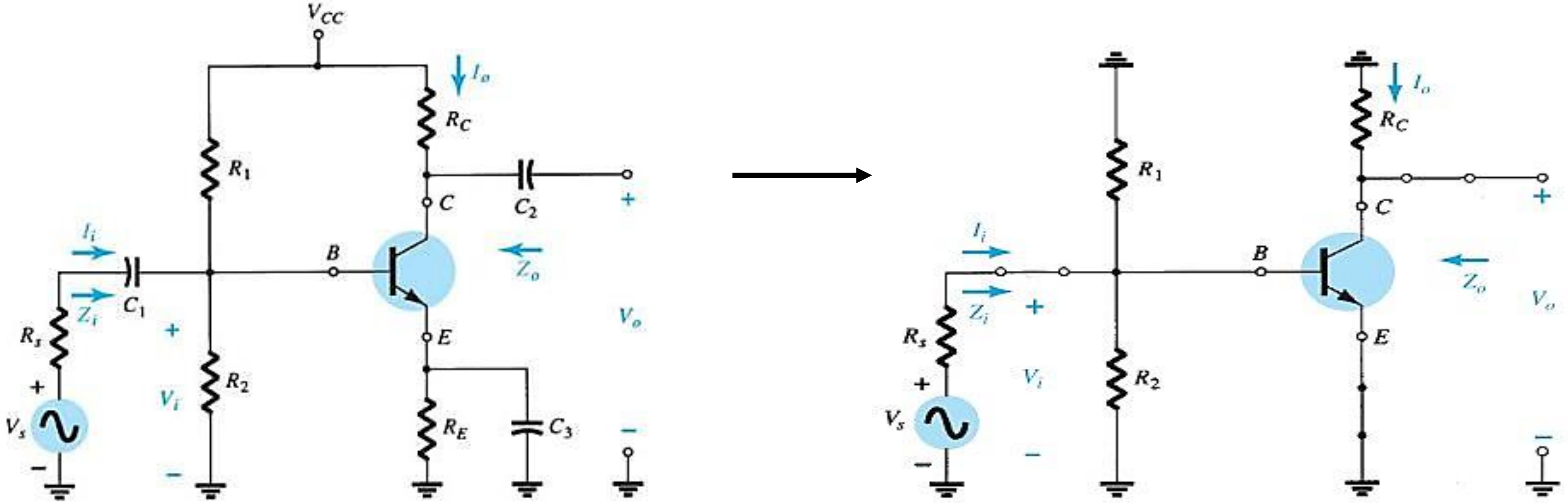
The ac equivalent of a transistor network is obtained by:

1- Setting all dc sources to zero and replacing them by a short-circuit equivalent

2- Replacing all capacitors by a short-circuit equivalent

3- Removing all elements bypassed by the short-circuit equivalents introduced by steps 1 and 2

4- Redrawing the network in a more convenient and logical form

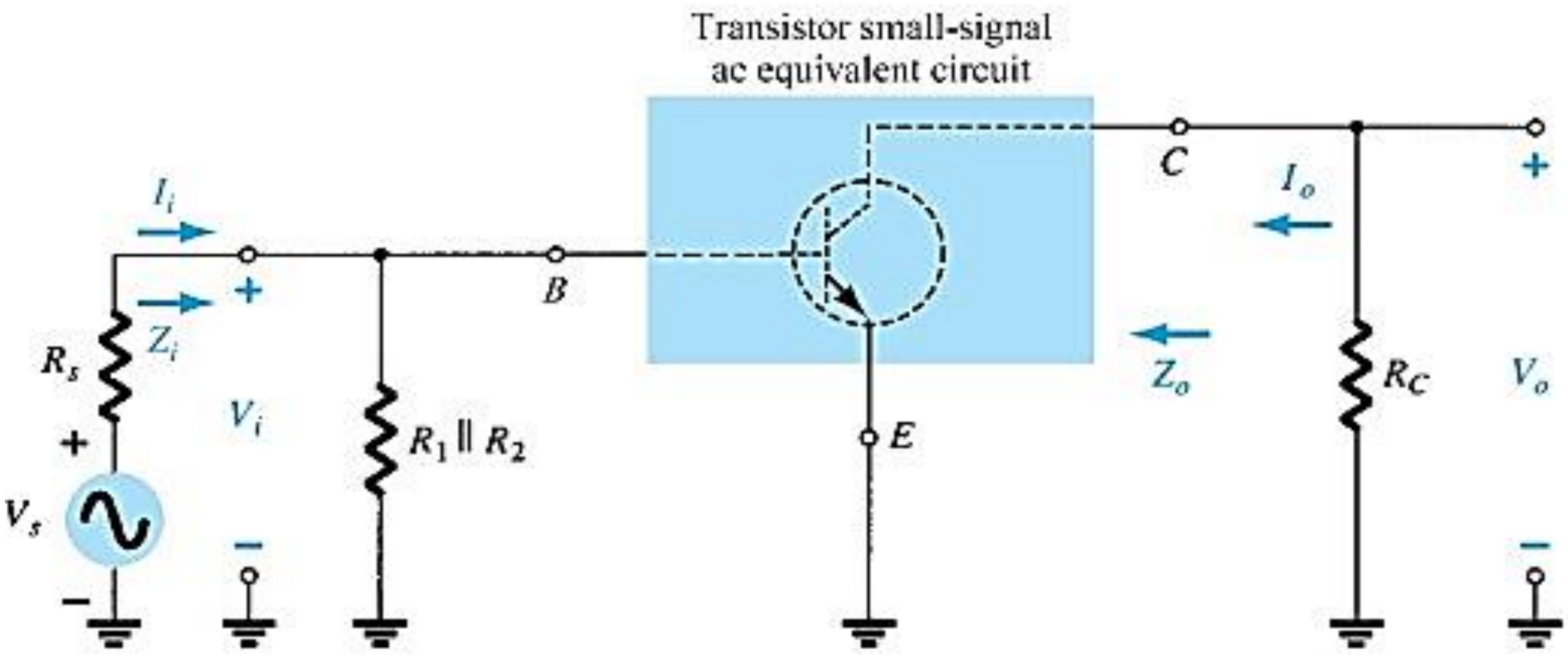


BJT small signal Modeling

5- replacing the BJT with appropriate model

– re transistor model

– Hybrid model



RE Transistor Model

- BJTs are basically current-controlled devices; therefore the re model uses a diode and a current source to duplicate the behavior of the transistor.

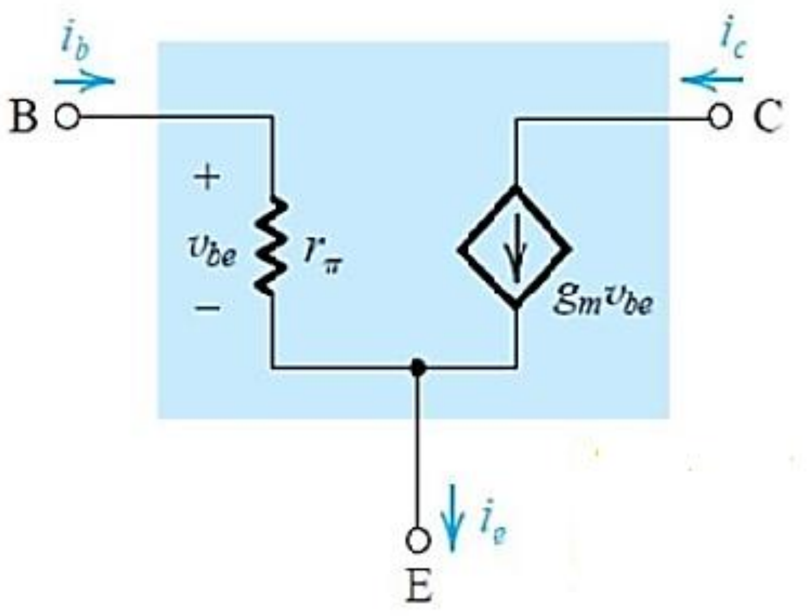
- One disadvantage to this model is its sensitivity to the DC level. This model is designed for specific circuit conditions.

Hybrid model

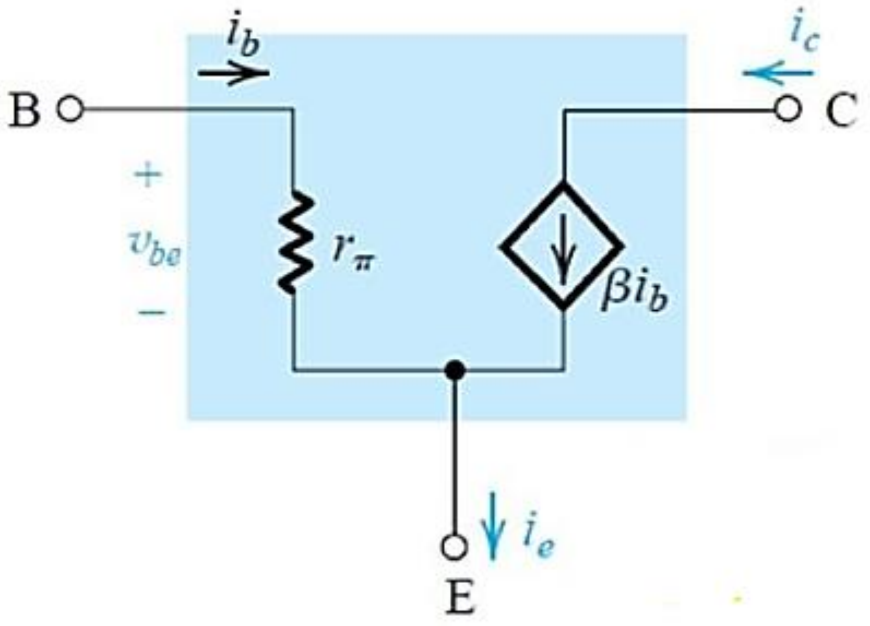
- The hybrid **π** model is most useful for analysis of high-frequency transistor applications.

- At lower frequencies the hybrid **π** model closely approximate the re parameters, and can be replaced by them.

Hybrid π model



Voltage Controlled Current Source "VCCS"



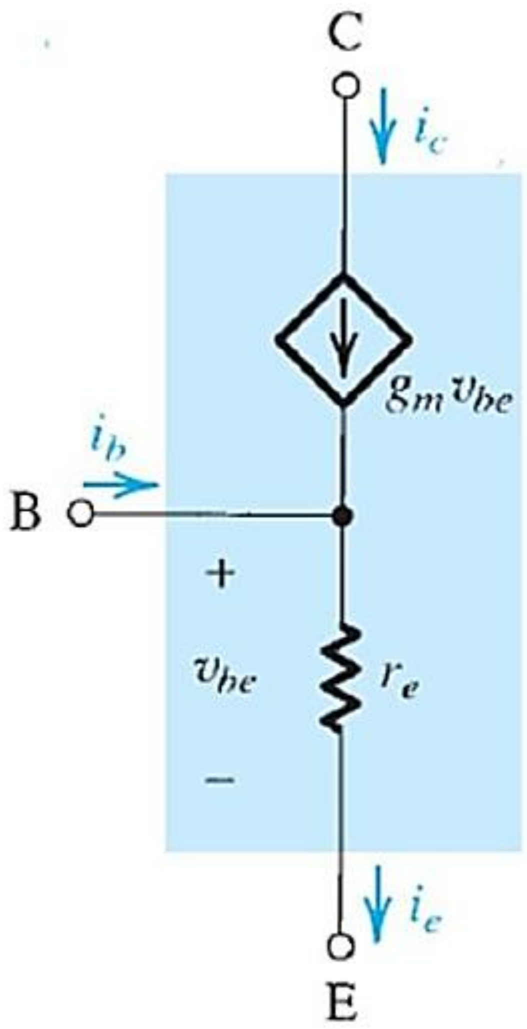
Current Controlled Current Source "CCCS"

$$g_m = \frac{I_C}{V_T}$$

$$r_\pi = \frac{V_T}{I_B}$$

$$r_\pi = \frac{\beta}{g_m}$$

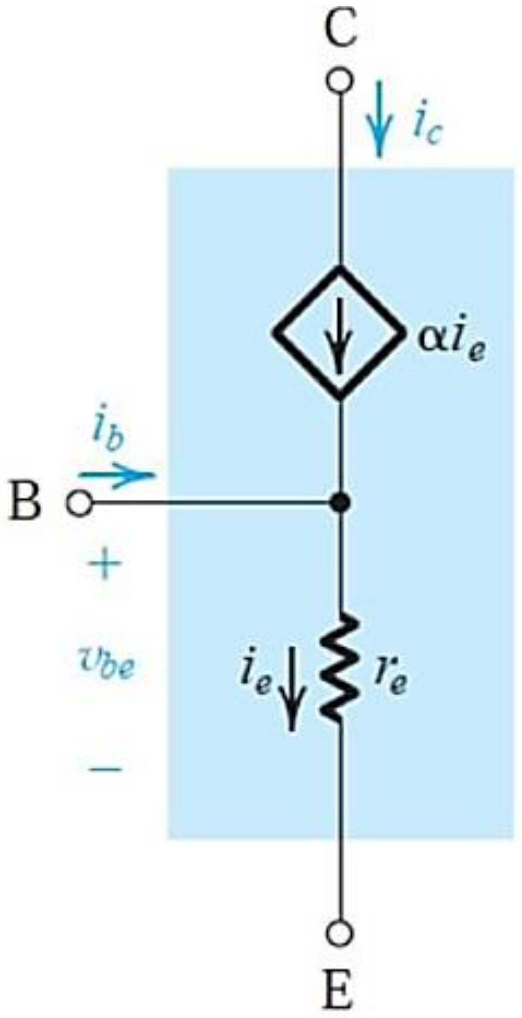
Hybrid T model



Voltage Controlled Current Source "VCCS"

$$g_m = \frac{I_C}{V_T}$$

$$r_e = \frac{V_T}{I_E} = \frac{\alpha}{g_m}$$



Current Controlled Current Source "CCCS"

The steps for solving AC analysis of BJT

- **First DC Analysis**

Using the DC analysis to calculate the parameters of small signal model $g_m, r_{\boldsymbol{\pi}}$ and r_e .

- **Second AC Analysis**

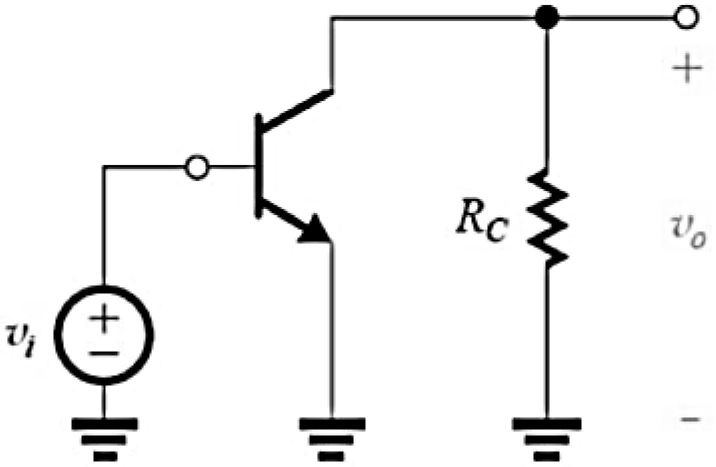
1- Replace all the capacitors by short circuits, the inductors by open circuits.

2-replace the voltage Dc source by short circuit, and replace the current DC source by open circuit.

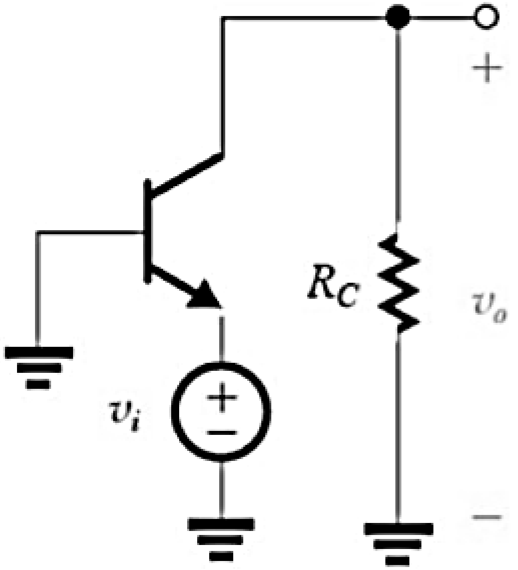
3- replace the BJT with one of small signal models.

4- Analyze the circuit to determine the amplifier gain.

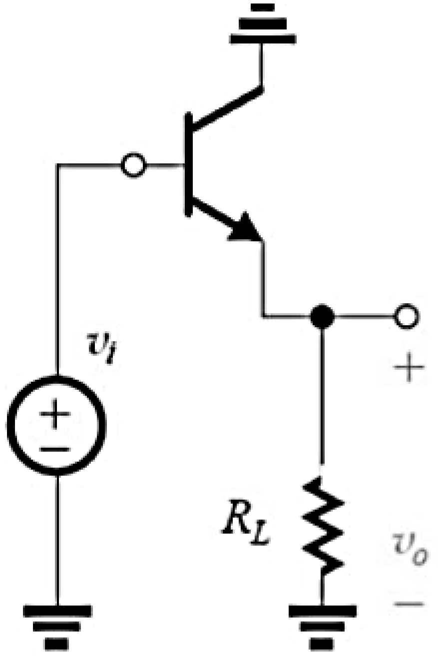
BJT Configurations



Common Emitter



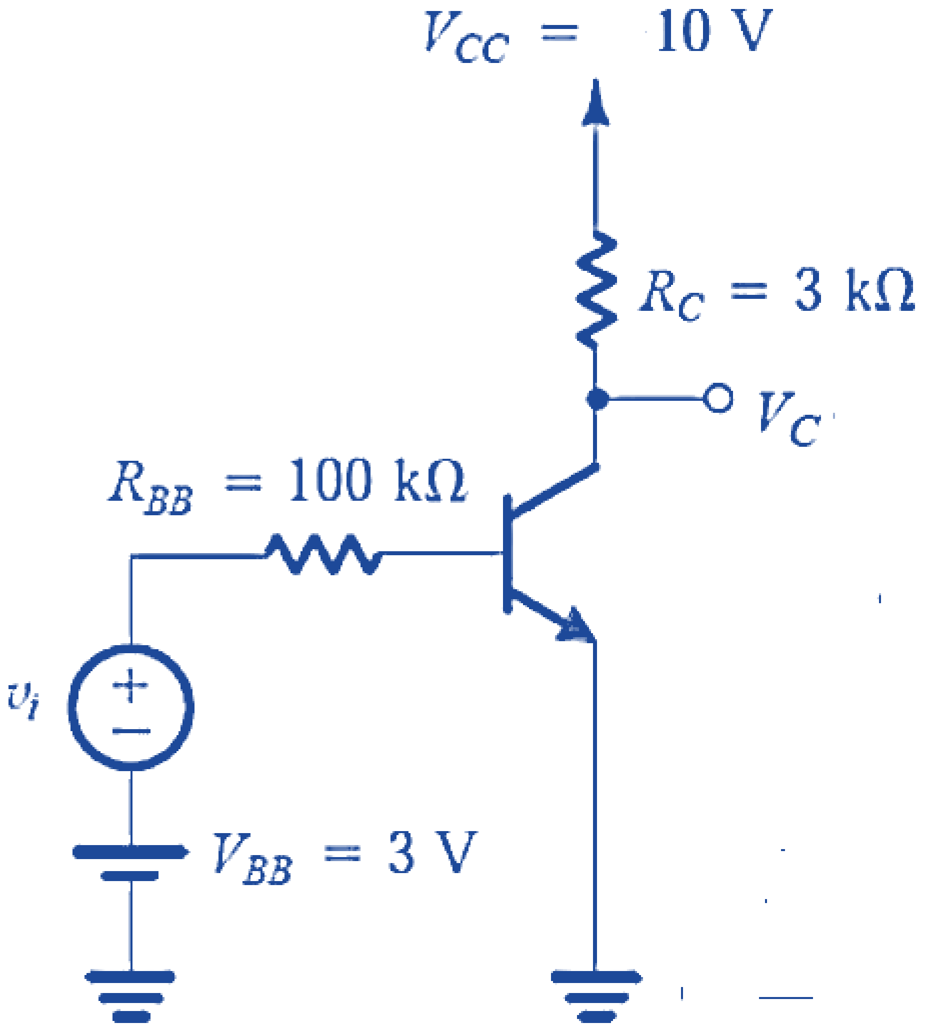
Common Base



Common Collector

Example

Determine the gain of the following amplifier as β = 100



Solution

1- Using the DC analysis to determine the Q point

Assuming Active mode

By KVL in input loop:

-3 +100$I_B + 0.7 = 0$

$I_B = \frac{3-0.7}{100}$ = 0.023mA

$I_C = \beta I_B = 2.3$mA

$I_E = I_C + I_B = 2.323mA$

$V_o = V_c = V_{cc} - I_C R_c = 10 - (2.3)(3)$=3.1V

V_c > 0.7 then our assumption is true

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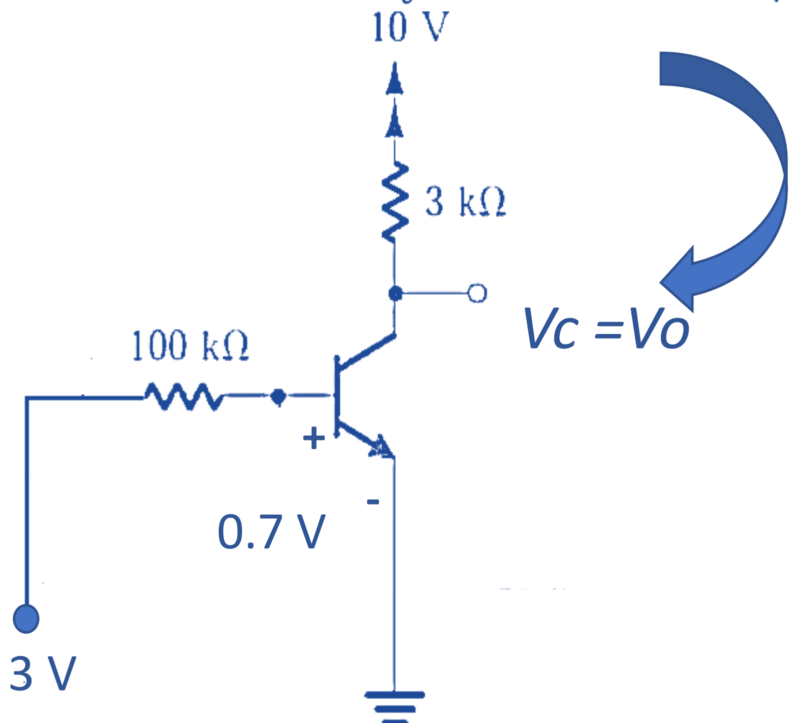
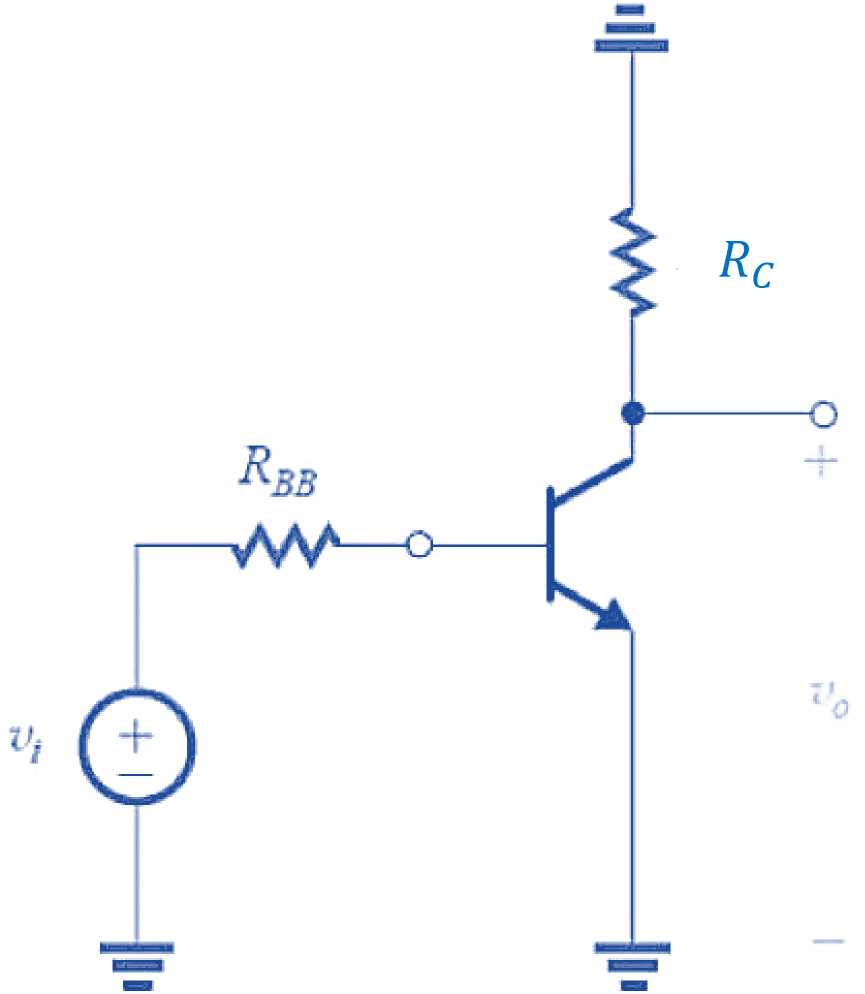


Solution

2- Determine the AC parameters.

$$g_m = \frac{I_C}{V_T} = \frac{2.3mA}{26mv} = 88\text{mA/v}$$

$$r_\pi = \frac{V_T}{I_B} = \frac{26mv}{0.023mA} = 1.13\text{k}\Omega$$



3- Draw the circuit with AC model (**π** Model)

Note: short circuit the DC voltage source and open circuit the DC current source

Solution

4- Analyze the small signal equivalent circuit

v_o= -$g_m v_{be}\, R_C$

v_{be} = $(\frac{r_\pi}{R_{BB}+r_\pi})v_i$= $(\frac{1.13}{101.13})v_i$ =0.011v_i

v_o= -(88)(0.011) v_i(3) = -2.94 v_i

$A_v = \frac{v_o}{v_i}$ = $|-2.94|$= 2.94