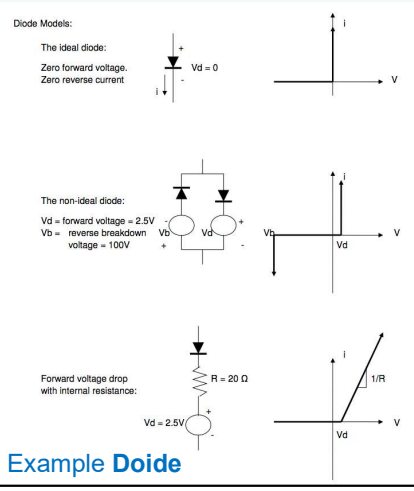
Small Signal Model & Analysis

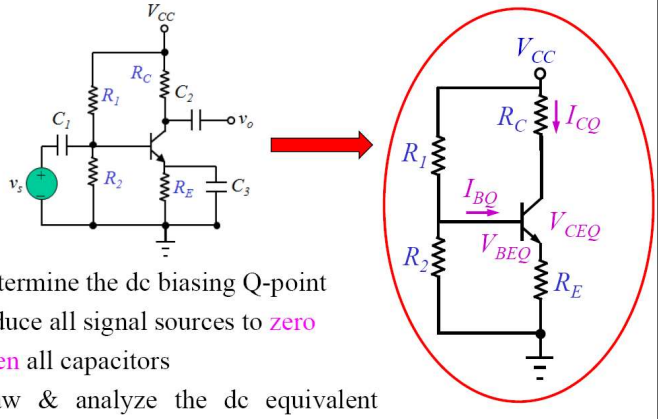
What is a MODEL of a device?

A model is the combination of circuit elements, properly chosen, that best approximates the actual behavior of a semiconductor device under specific operating conditions.



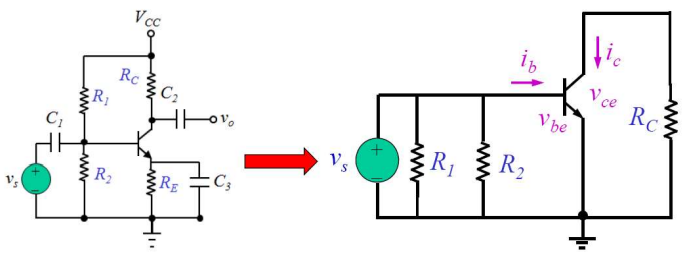
Example **Doide**

DC analysis and equivalent circuit



- To determine the dc biasing Q-point
  - Reduce all signal sources to zero
  - Open all capacitors
  - Draw & analyze the dc equivalent circuit

AC analysis and equivalent circuit

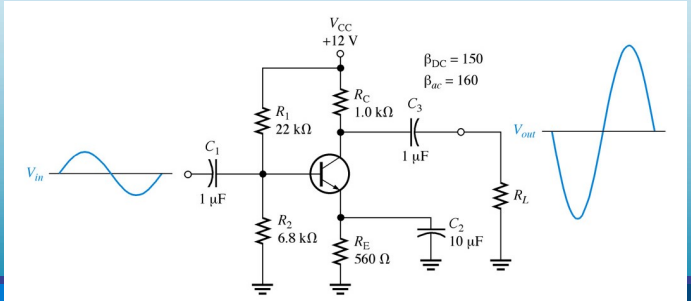


- To determine the ac characteristics (e.g., small-signal voltage gain, input & output impedances, frequency response, etc.)
  - Reduce all dc voltage sources to zero
  - Short all capacitors
  - Draw & analyze the ac equivalent circuit

The Common-Emitter Amplifier

The common-emitter amplifier exhibits high voltage and current gain. The output signal is 180º out of phase with the input.

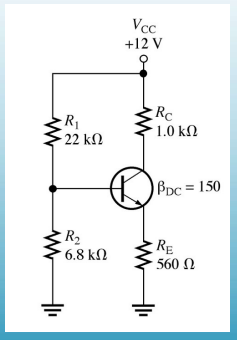
Now let's use our dc and ac analysis methods to view this type of transistor circuit.



The Common Emitter Amplifier DC Analysis

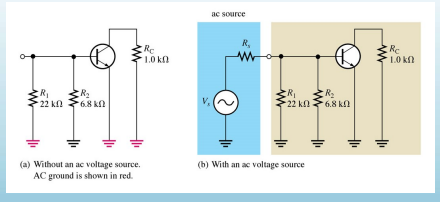
The dc component of the circuit "sees" only the part of the circuit that is within the boundaries of C_1, C_2, and C_3 as the dc will not pass through these components. The equivalent circuit for dc analysis is shown.

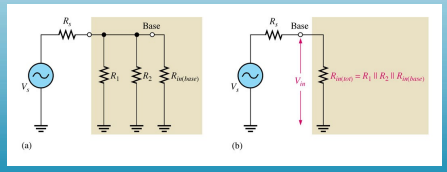
The methods for dc analysis are just are the same as dealing with a voltage-divider circuit.



Common Emitter Amplifier AC Equivalent Circuit

The ac equivalent circuit basically replaces the capacitors with shorts, being that ac passes through easily through them. The power supplies are also effectively shorts to ground for ac analysis.





Common Emitter Amplifier AC Equivalent Circuit

We can look at the input voltage in terms of the equivalent base circuit (ignore the other components from the previous diagram). Note the use of simple series-parallel analysis skills for determining V_{in}.

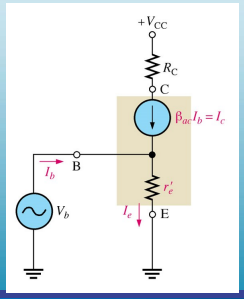
$$V_{in} = \frac{R_{in}}{R_S + R_{in}} V_S$$

Common Emitter Amplifier AC Equivalent Circuit

The **input resistance** as seen by the input voltage can be illustrated by the ***r*** parameter equivalent circuit. The simplified formula below is used.

$R_{in(base)} = \beta_{ac} r'_e$

The **output resistance** is for all practical purposes the value of $R_c = R_C || R_L$.



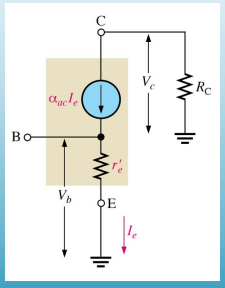
Common Emitter Amplifier AC Equivalent Circuit

Voltage gain can be easily determined by dividing the ac output voltage by the ac input voltage.

$A_v = V_{out}/V_{in} = V_c/V_b$

Voltage gain can also be determined by the simplified formula below.

$A_v = R_C / r'_e$



Common Emitter Amplifier AC Equivalent Circuit

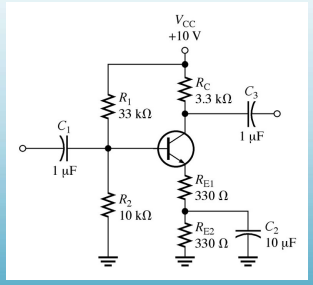
Taking the **attenuation** from the ac supply internal resistance and input resistance into consideration is included in the overall gain.

$A'_v = (V_b/V_s)A_v$

or

$$A'_v = \frac{R_{in(total)}}{R_s + R_{in(total)}} A_v$$

$$A_i = \frac{I_C}{I_S}, I_S = \frac{V_S}{R_S + R_{in}}$$



$$A_p = A_v A_i$$

Summary

- Most transistors amplifiers are designed to operate in the linear region.
- Transistor circuits can be view in terms of its ac equivalent for better understanding.
- The common-emitter amplifier has high voltage and current gain.
- The common-collector has a high current gain and voltage gain of 1. It has a high input impedance and low output impedance.
- The common-base has a high voltage gain and a current gain of 1. It has a low input impedance and high output impedance

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Hybrid Equivalent Model

The hybrid parameters: hie, hre, hfe, hoe are developed and used to model the transistor. These parameters can be found in a specification sheet for a transistor.