

# BJT Topologies - AC Characteristics

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Please send corrections (or suggestions) to [youngwlim@hotmail.com](mailto:youngwlim@hotmail.com).

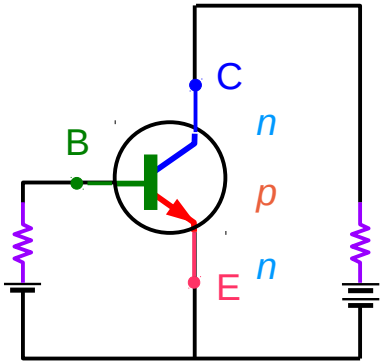
This document was produced by using OpenOffice and Octave.

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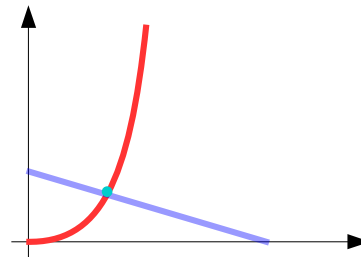
Input Characteristic Curves  
Output Characteristic Curves

# CE Amplifier : Linear Region

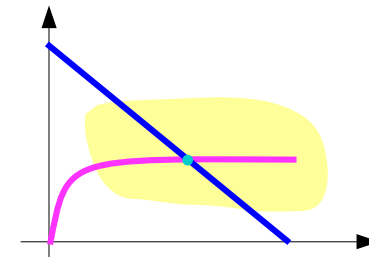
## Common Emitter



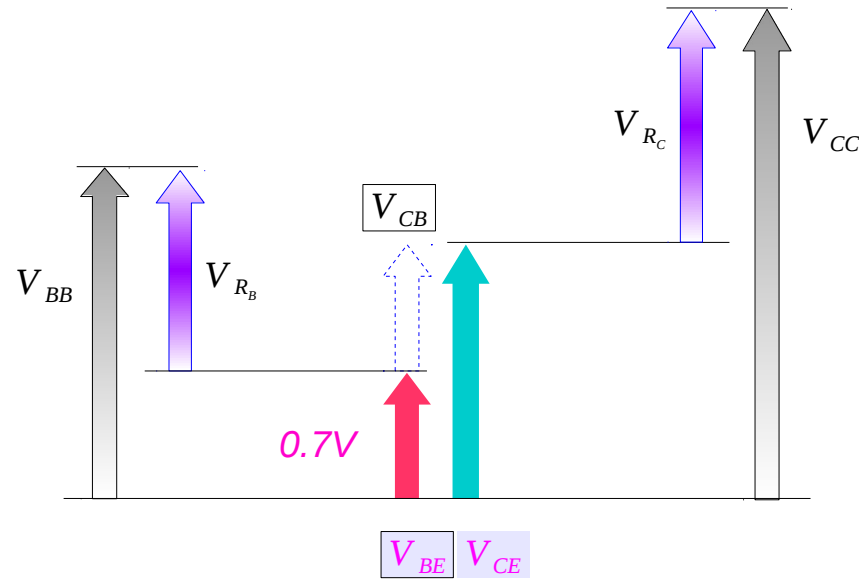
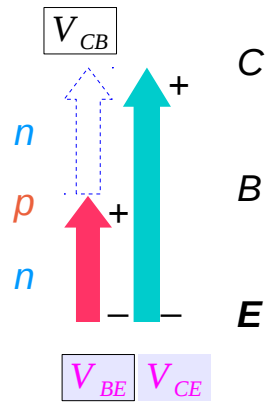
## Input Characteristics



## Output Characteristics

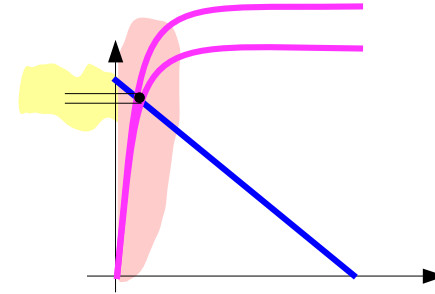
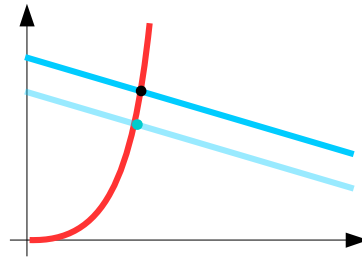
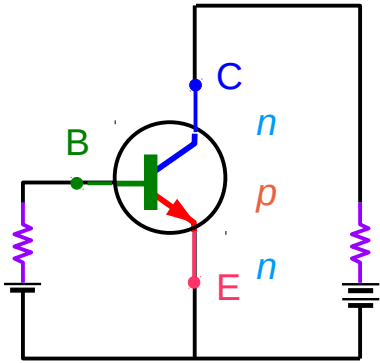


## Active region

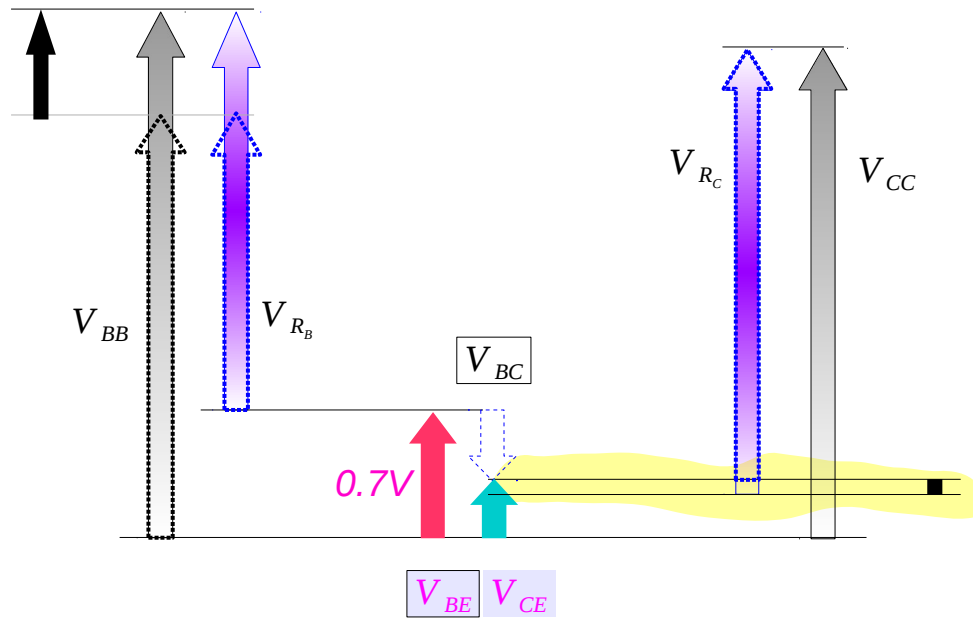
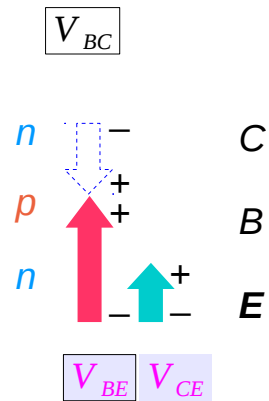


# CE Amplifier : Saturation Region

## Common Emitter

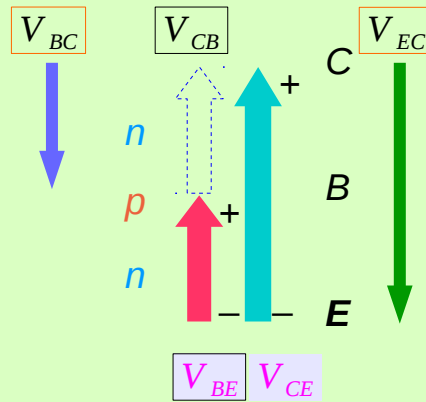
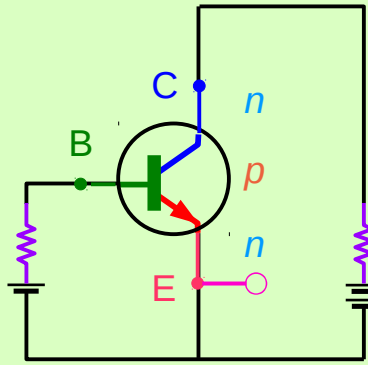


**saturation**

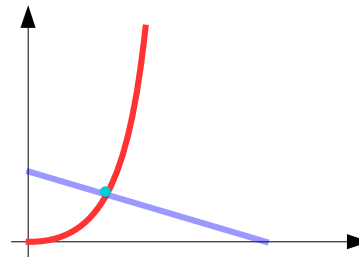


# CC Amplifier : Characteristic Curves

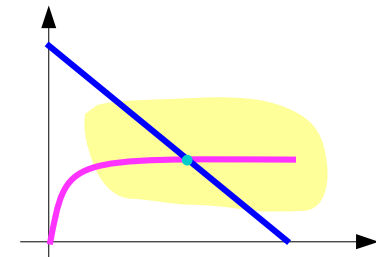
## Common Collector 3



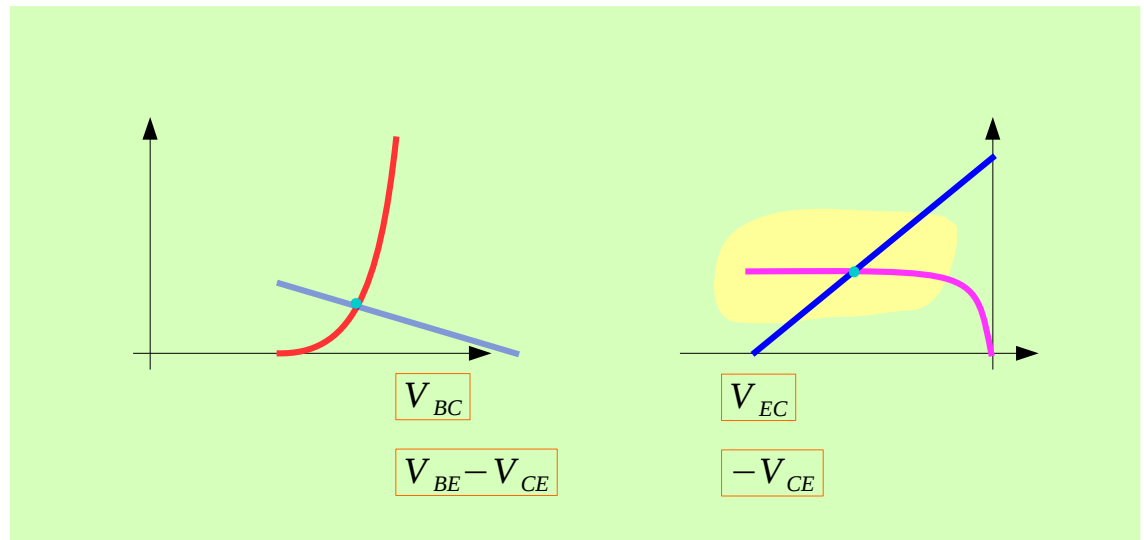
**Active region**



Input Characteristics

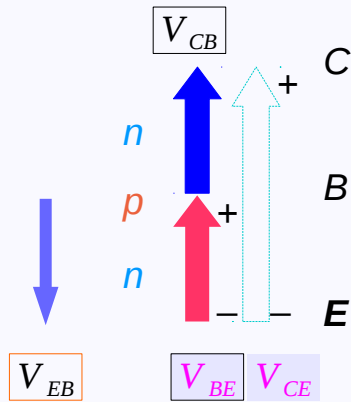
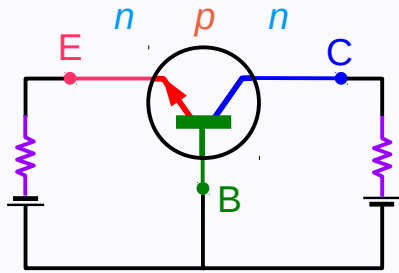


Output Characteristics

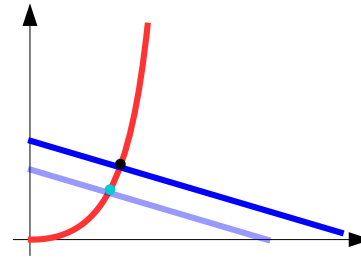


# CB Amplifier : Characteristic Curves

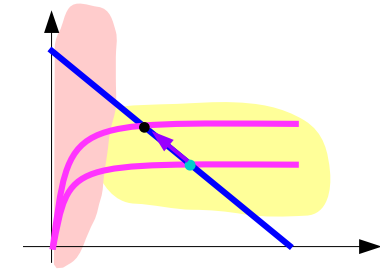
## Common Base



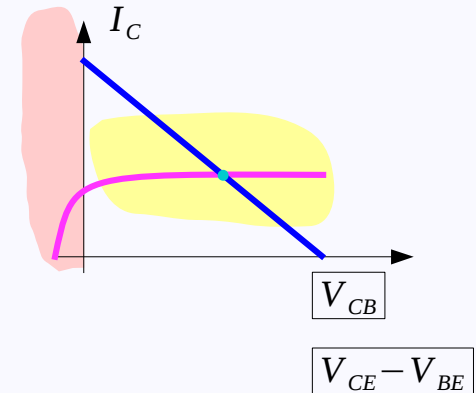
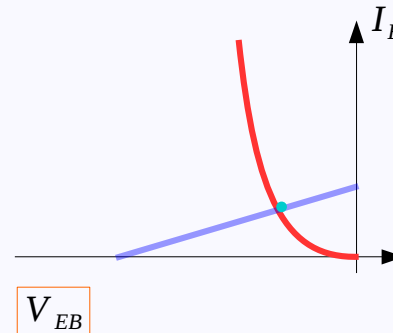
**Active region**



Input Characteristics



Output Characteristics

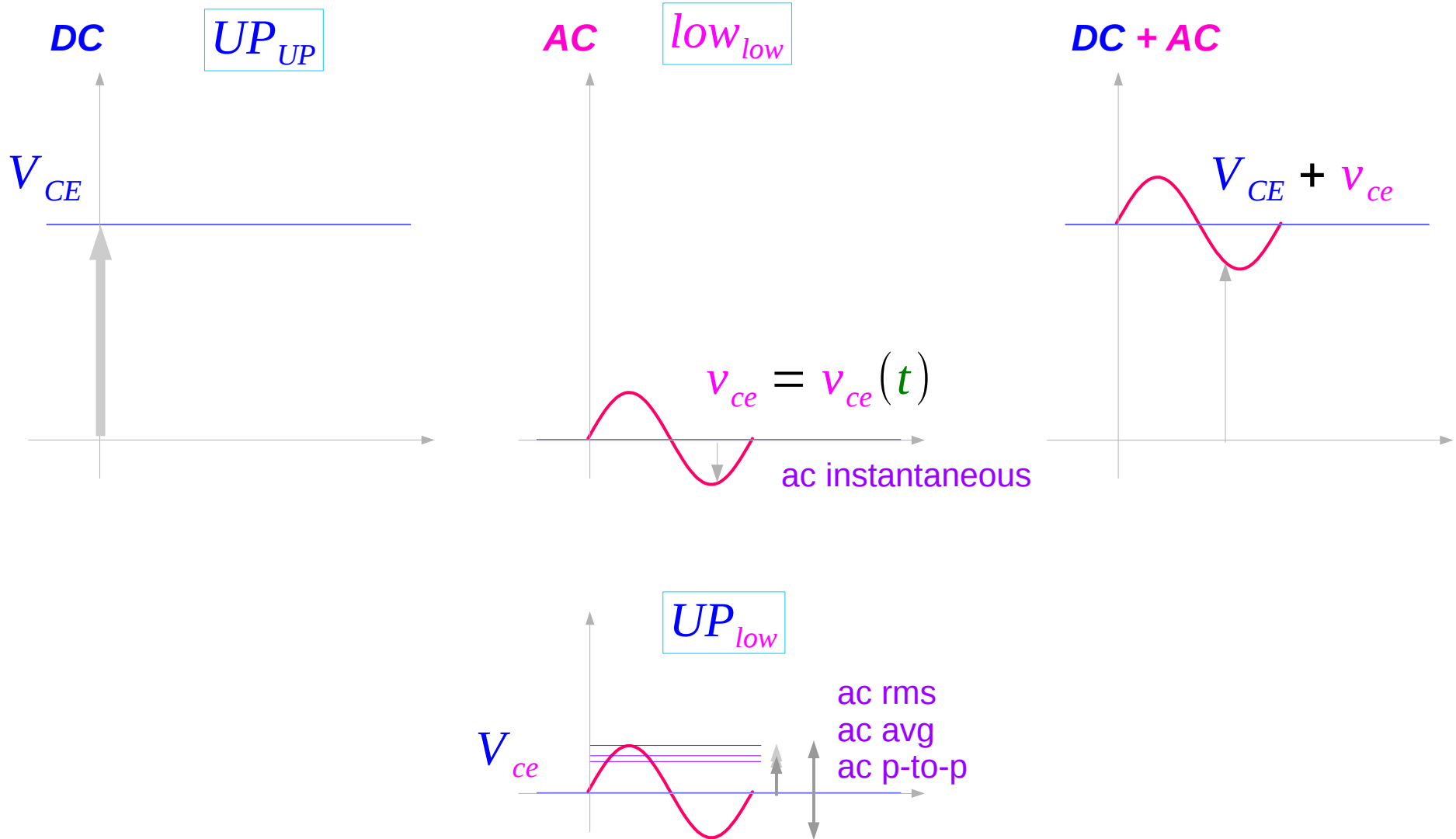


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## $V_{in}$ & $V_{out}$ Phase Relationship

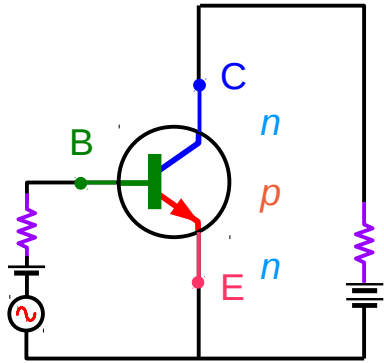


# Notations



# CE Amplifier : Phase Relationship

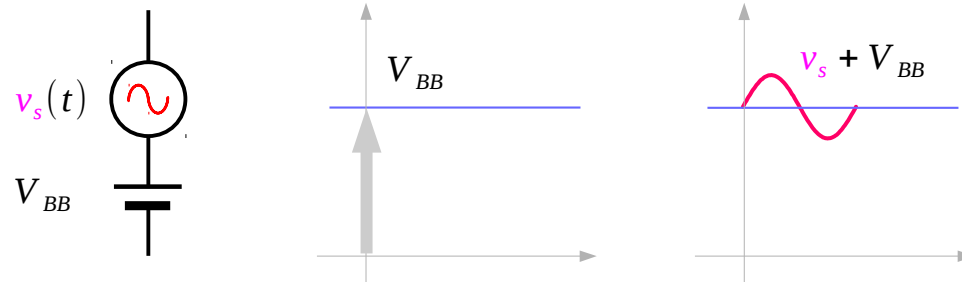
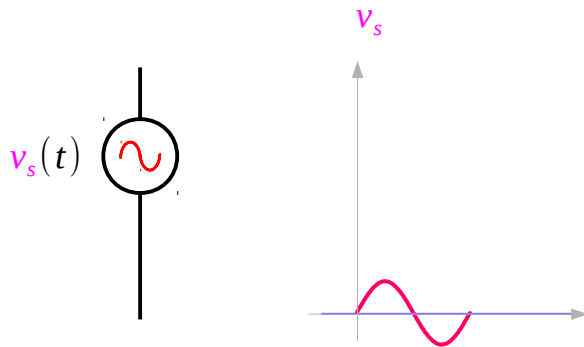
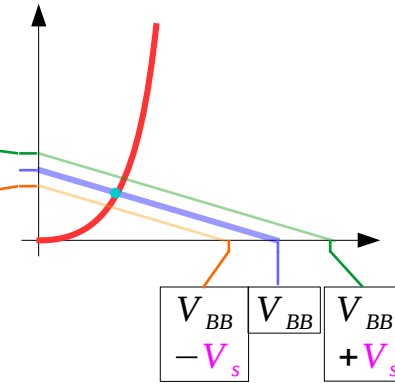
## Common Emitter



## Input Characteristics

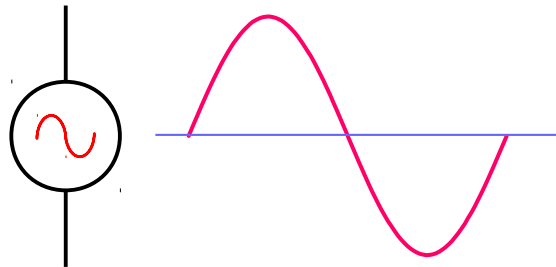
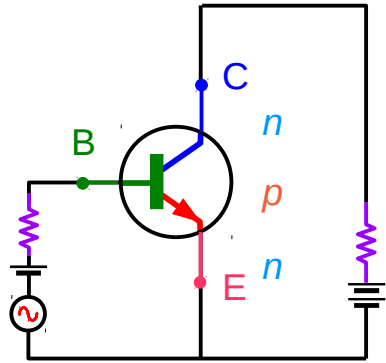
$inc I_B + I_b \rightarrow inc I_C + I_c, I_E + I_e$

$dec I_B - I_b \rightarrow dec I_C - I_c, I_E - I_e$



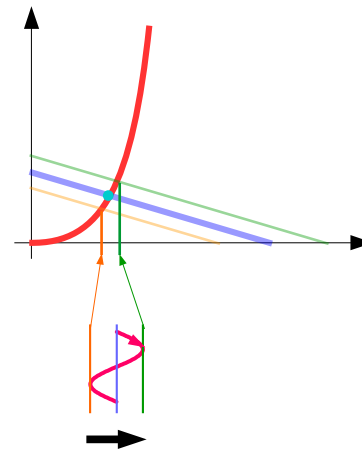
# CE Amplifier : Phase Relationship

## Common Emitter



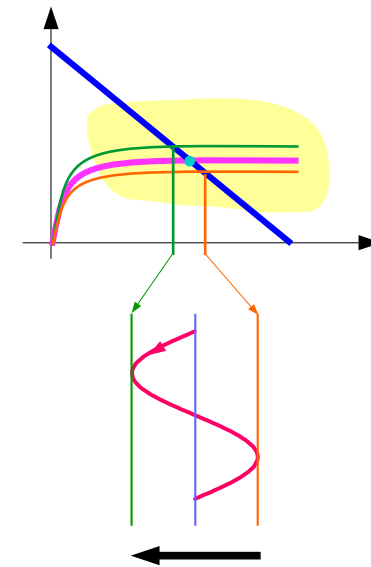
**Active region**

## Input Characteristics



increasing  $v_i$  direction

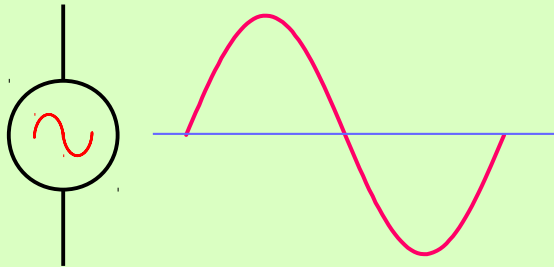
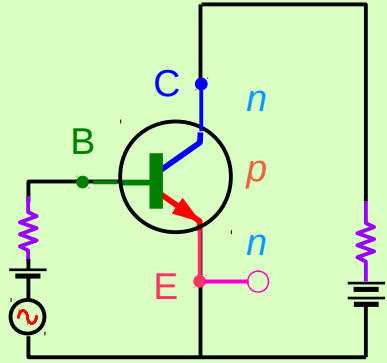
## Output Characteristics



decreasing  $v_o$  direction

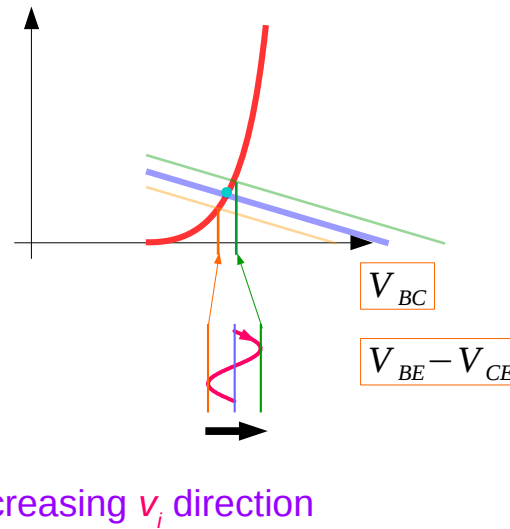
# CC Amplifier : Phase Relationship

## Common Collector 3

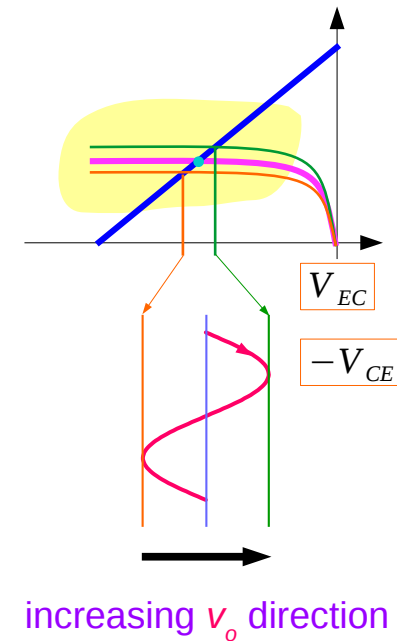


Active region

## Input Characteristics

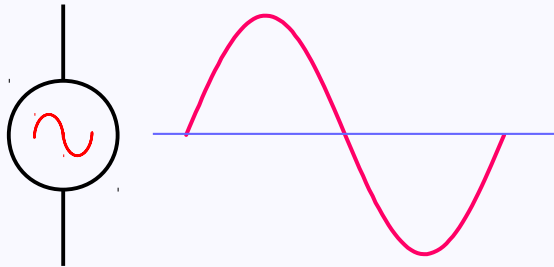
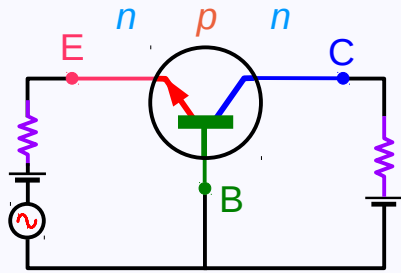


## Output Characteristics



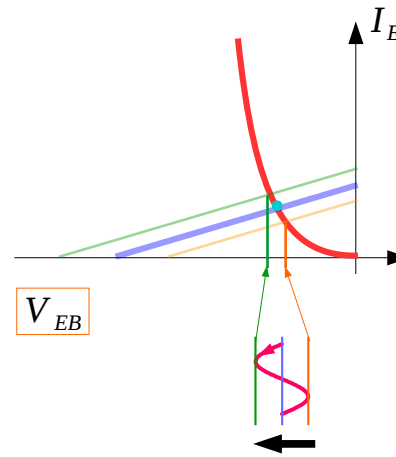
# CB Amplifier : Phase Relationship

## Common Base



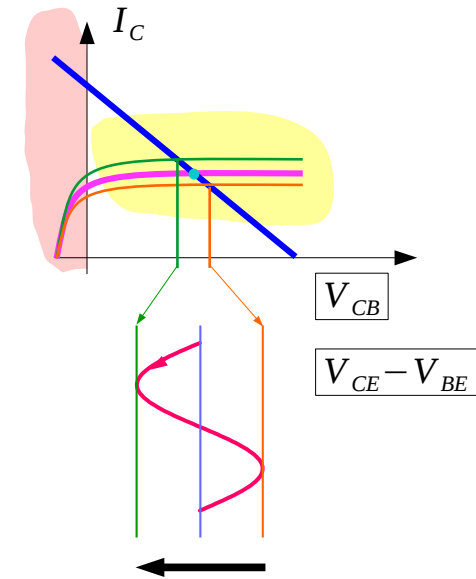
Active region

## Input Characteristics



increasing  $v_i$  direction

## Output Characteristics

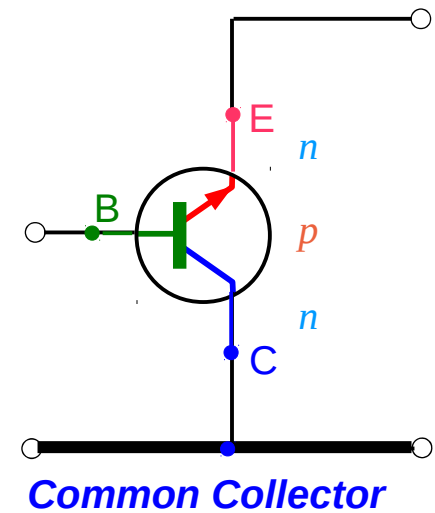
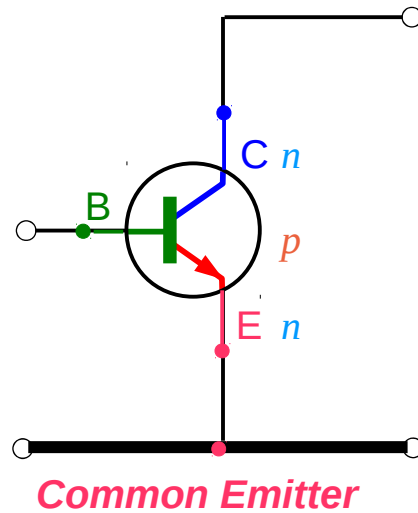
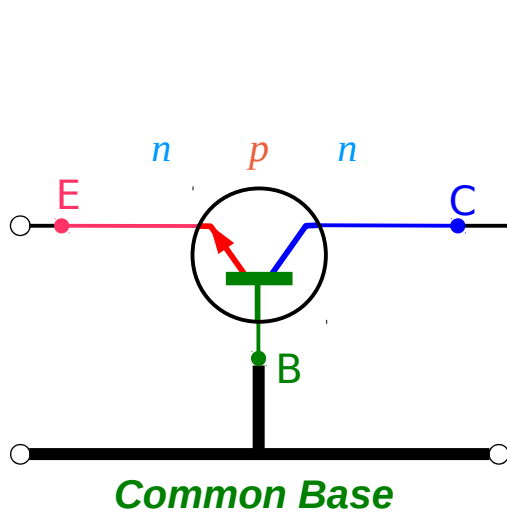
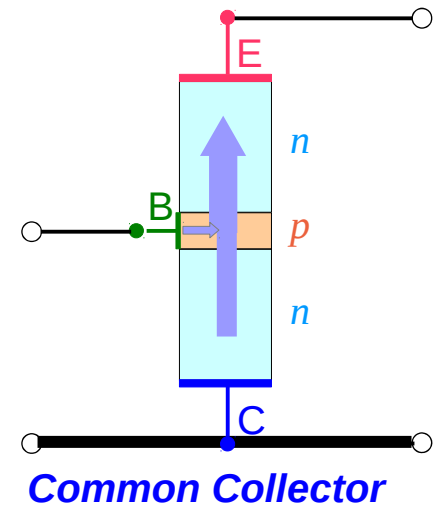
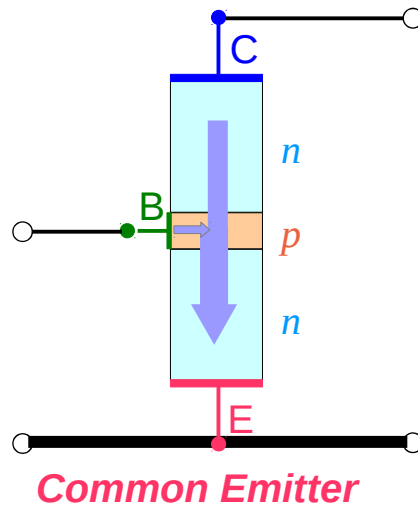
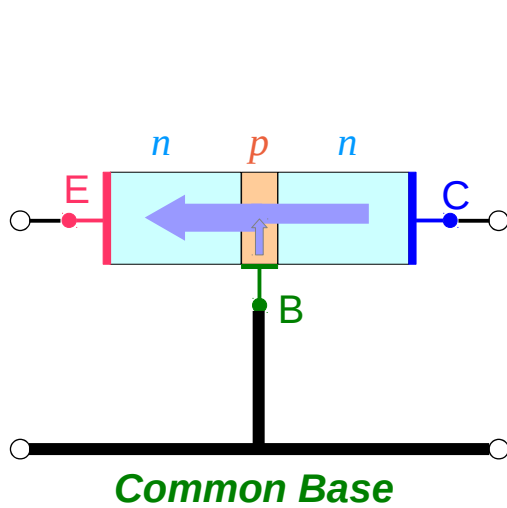


increasing  $v_o$  direction

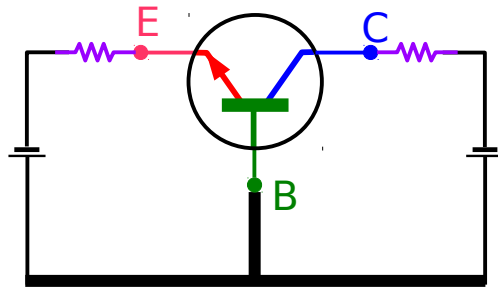
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DC bias only circuits  
DC + small AC  
AC only circuits

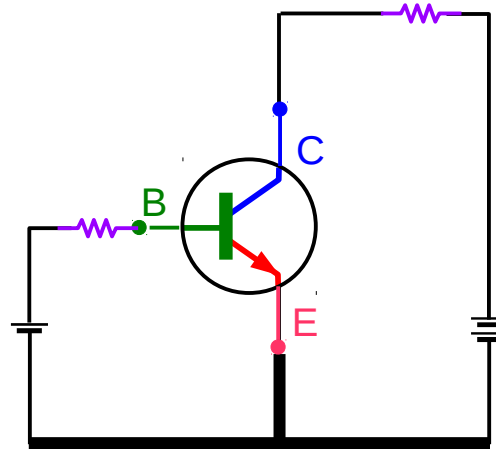
# BJT Amplifier Configurations



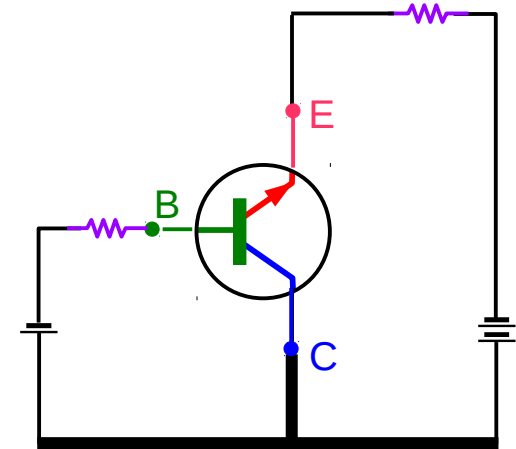
# Basic BJT Configuration Circuits



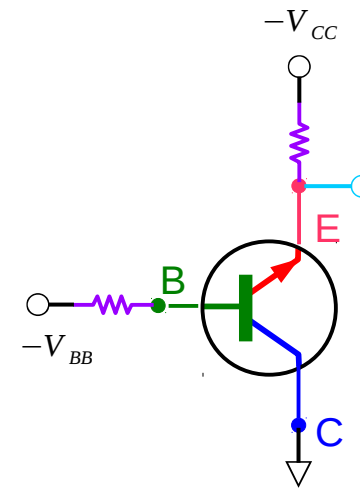
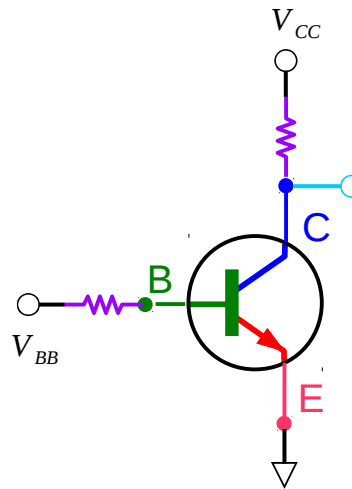
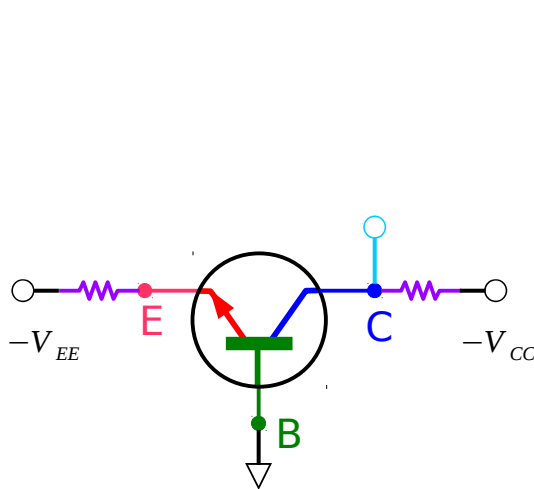
*Common Base*



*Common Emitter*

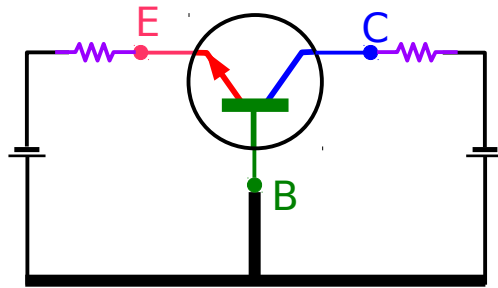


*Common Collector*

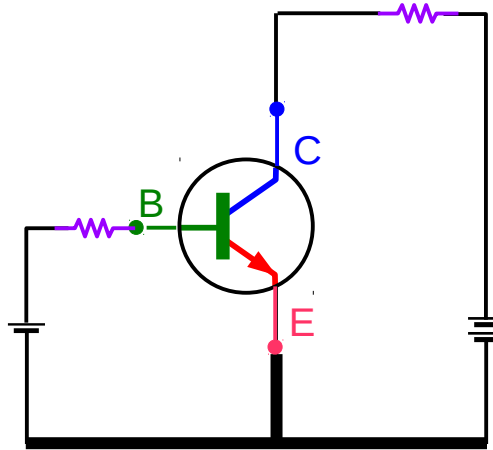




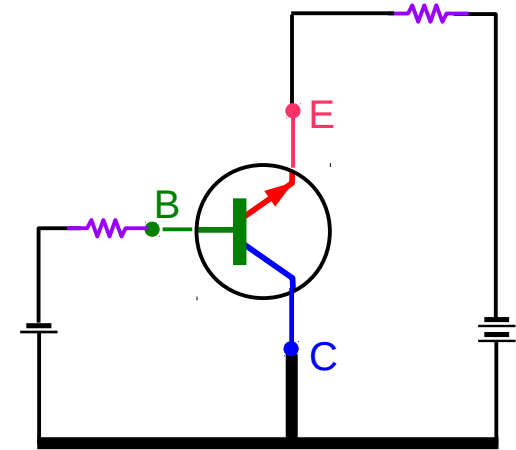
# DC Bias



*Common Base*

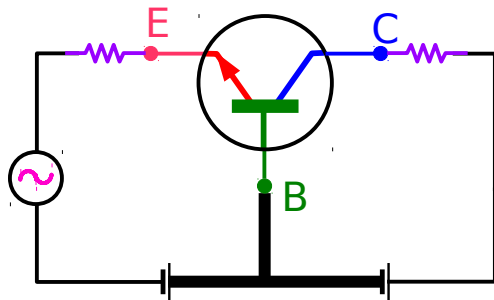


*Common Emitter*

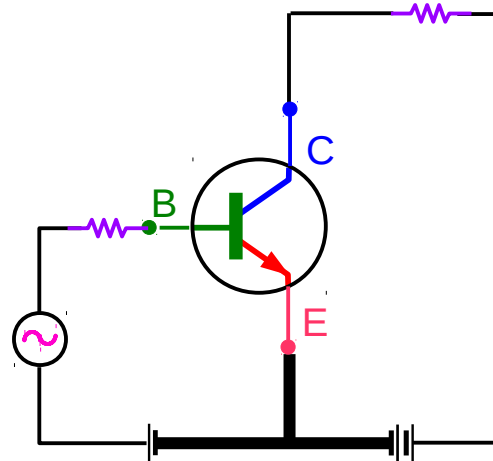


*Common Collector*

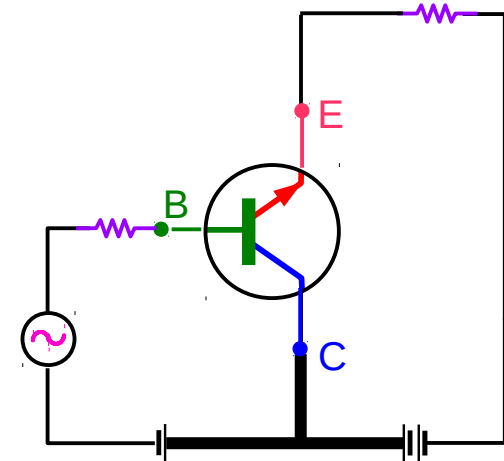
# DC Bias + AC Small Signal



*Common Base*

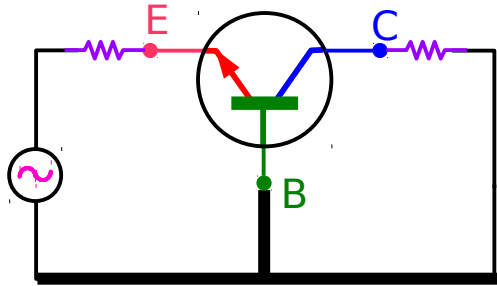


*Common Emitter*

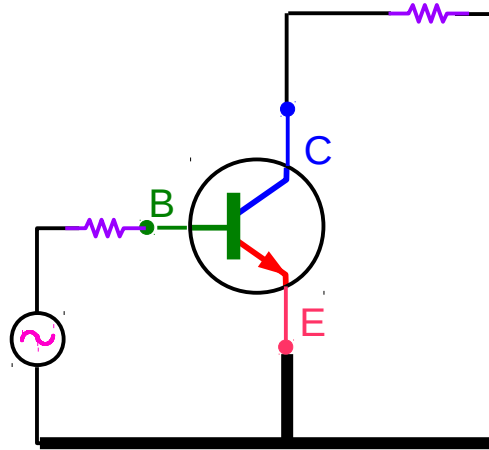


*Common Collector*

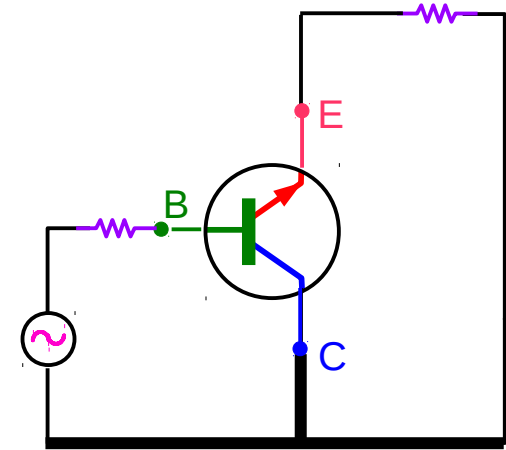
# AC Equivalent Circuits



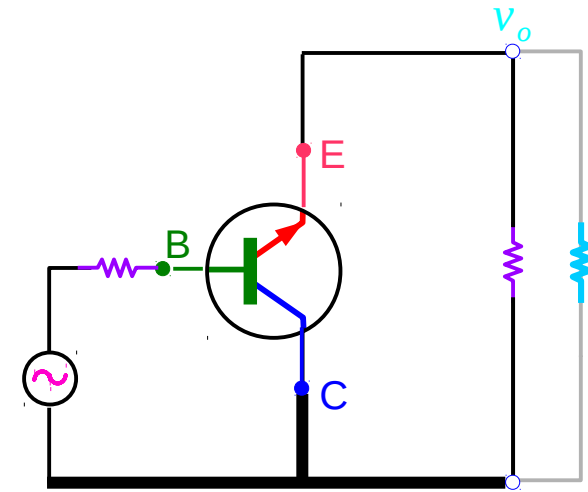
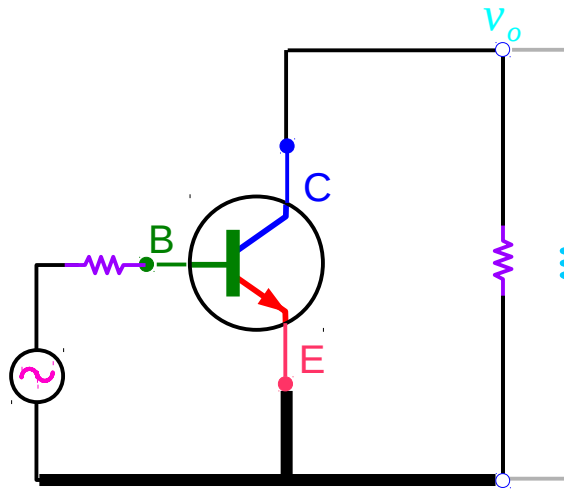
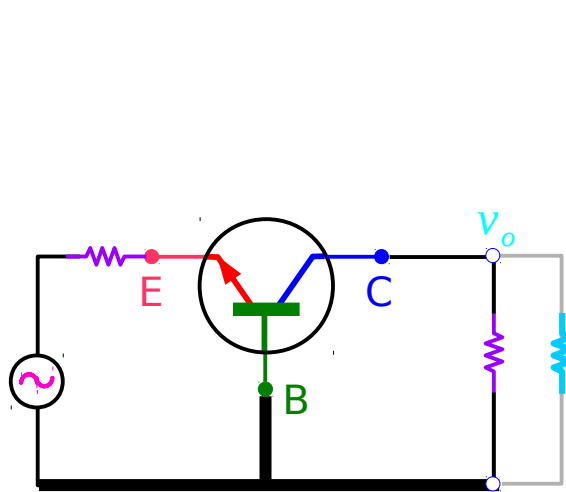
Common Base



Common Emitter



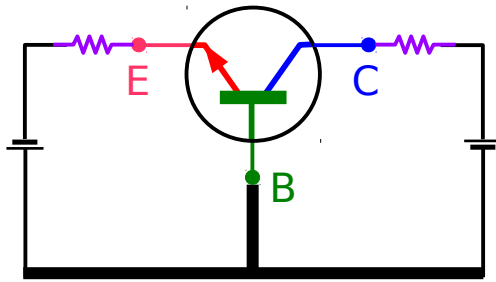
Common Collector



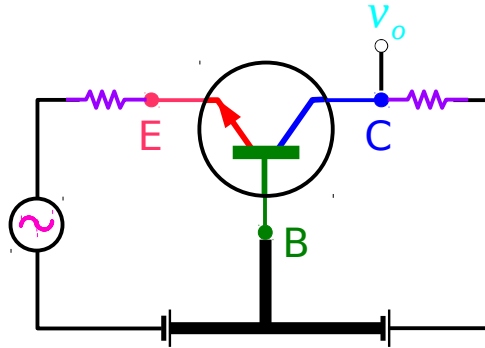
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CB Amplifiers – DC Bias, AC Signal, Output Load  
CE Amplifiers – DC Bias, AC Signal, Output Load  
CC Amplifiers – DC Bias, AC Signal, Output Load

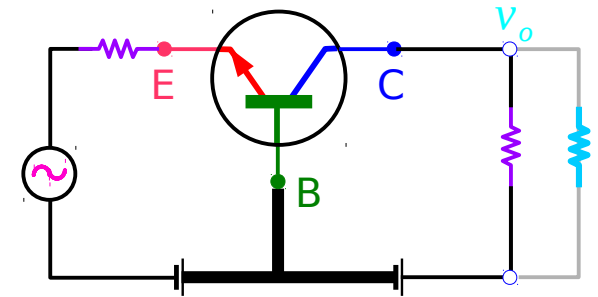
# Common Base



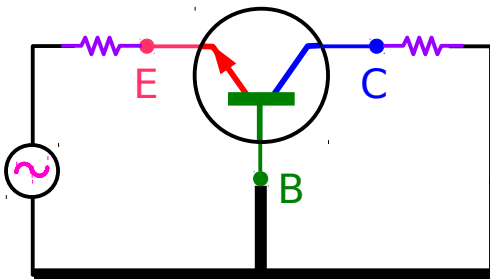
*DC Bias*



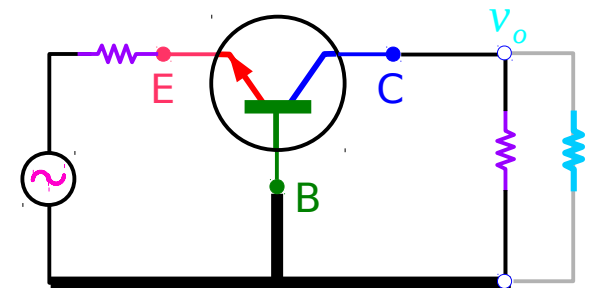
*DC Bias + AC Signal*



*DC Bias + AC Signal + Load*

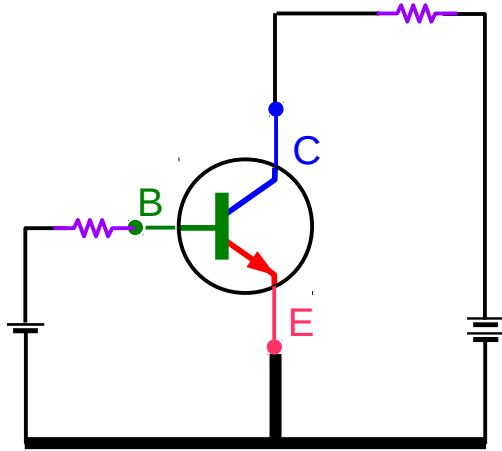


*AC Signal*

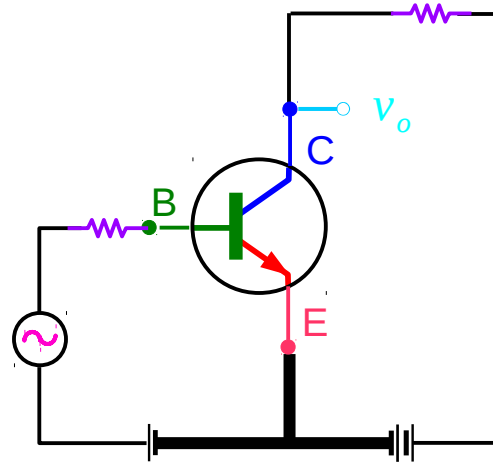


*AC Signal + Load*

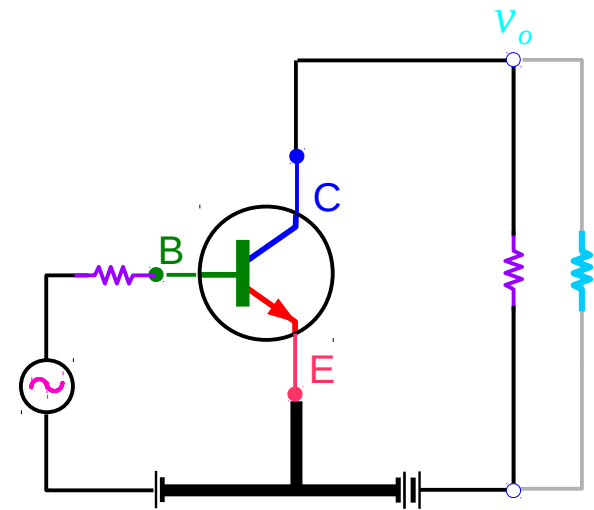
# Common Emitter



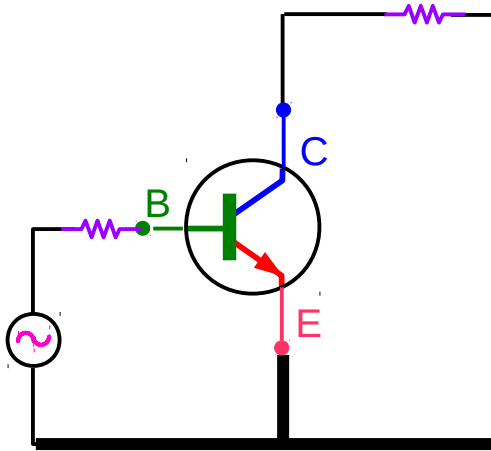
*DC Bias*



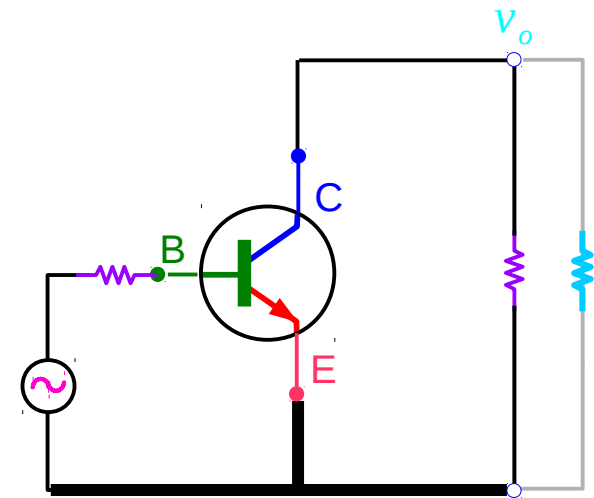
*DC Bias + AC Signal*



*DC Bias + AC Signal + Load*

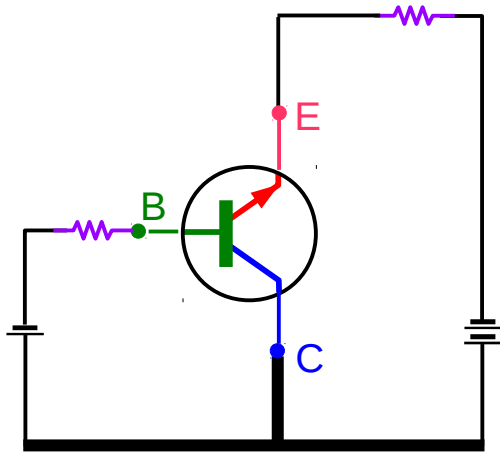


*AC Signal*

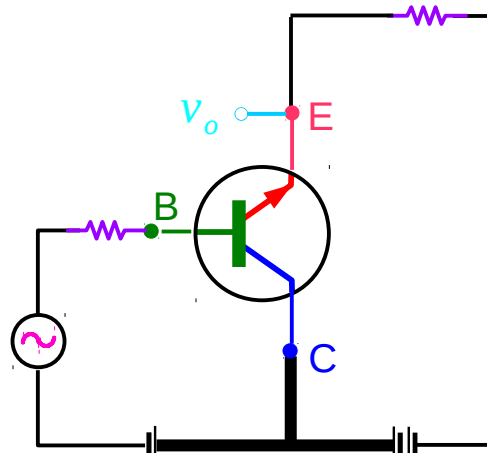


*AC Signal + Load*

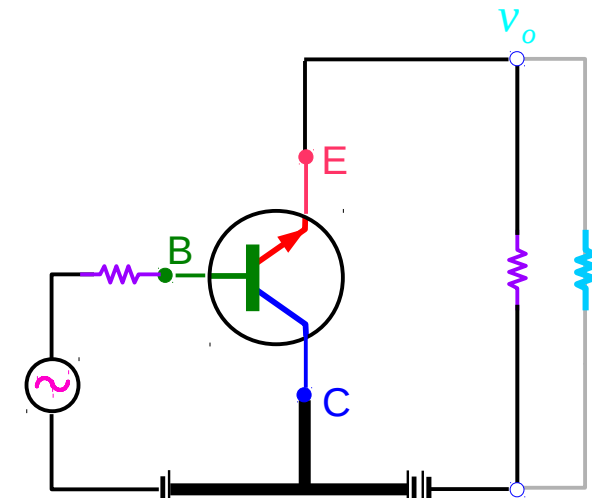
# Common Collector



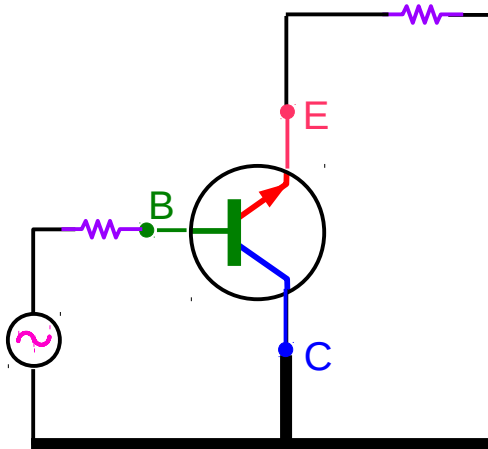
*DC Bias*



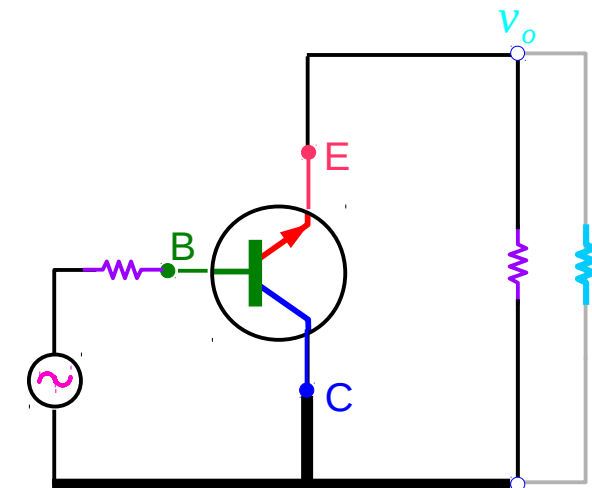
*DC Bias + AC Signal*



*DC Bias + AC Signal + Load*



*AC Signal*



*AC Signal + Load*

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AC Equivalent Model

T-model

Pi-model

Input Impedance

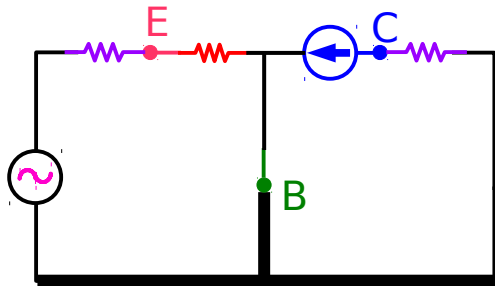
Output Impedance

Voltage Gain

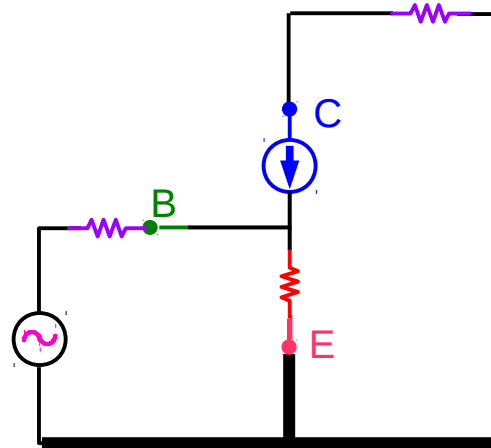
Current Gain



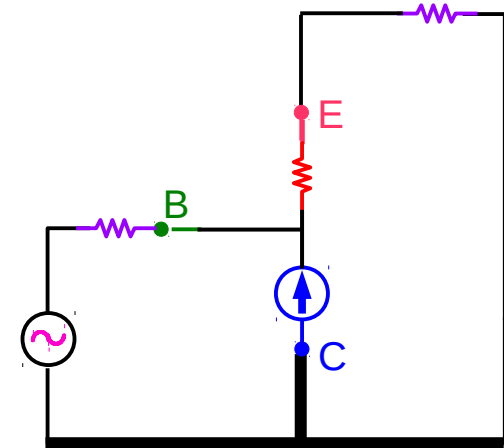
# AC t & pi models



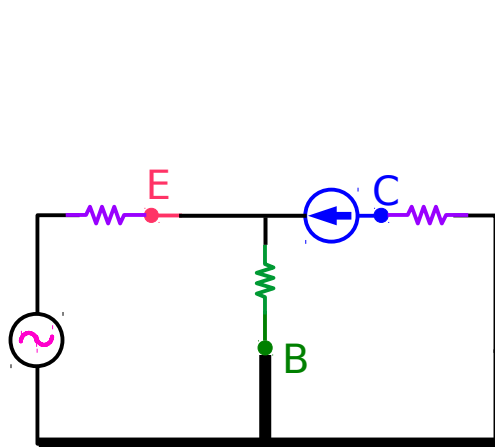
Common Base



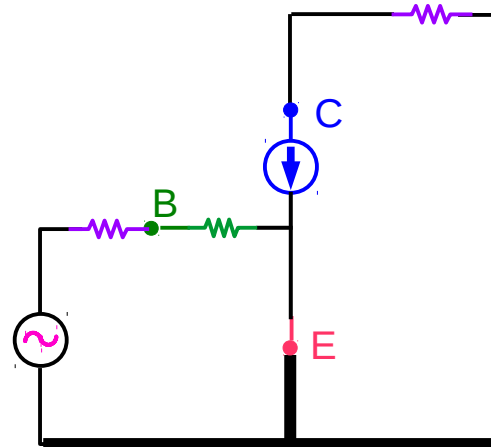
Common Emitter



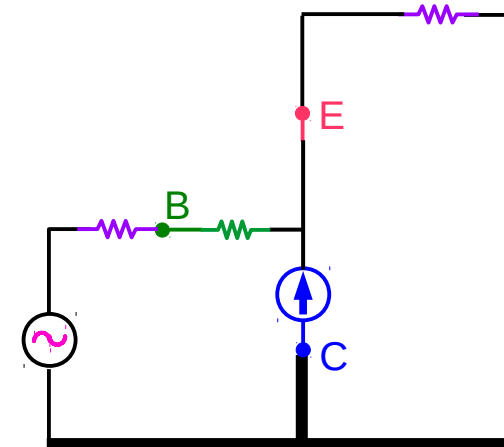
Common Collector



Common Base

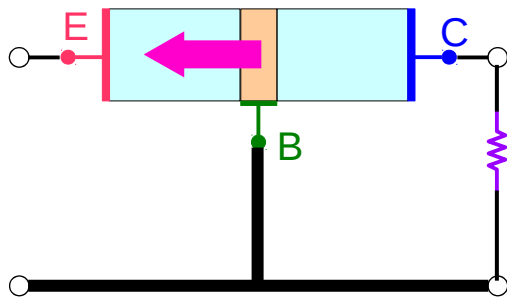


Common Emitter



Common Collector

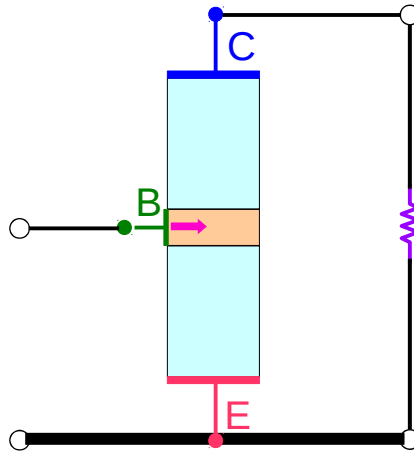
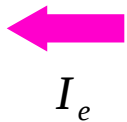
# Input Impedance $Z_{in}$



Common Base

$Z_{in}$  : low  $r_e'$

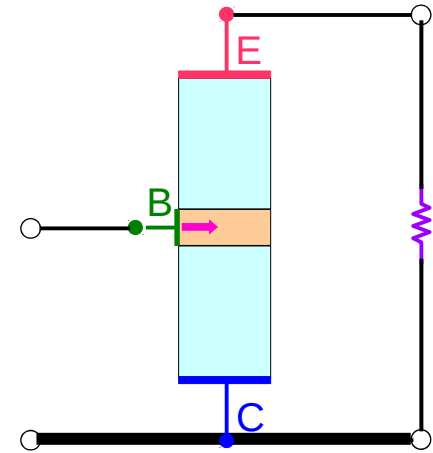
$I_e$  : Large



Common Emitter

$Z_{in}$  : high  $\beta r_e'$

$I_b$  : Small



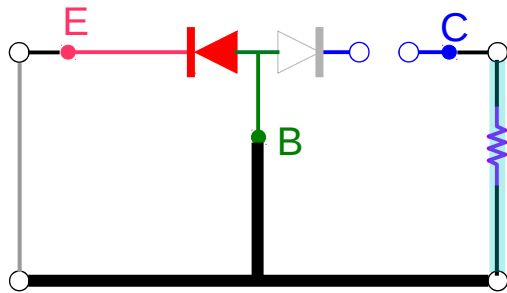
Common Collector

$Z_{in}$  : high  $\beta(r_e' + R_E)$

$I_b$  : Small



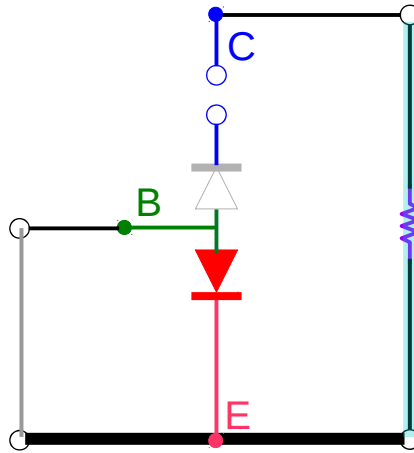
# Output Impedance $Z_{in}$



Common Base

$$Z_{out} : \text{high } R_C$$

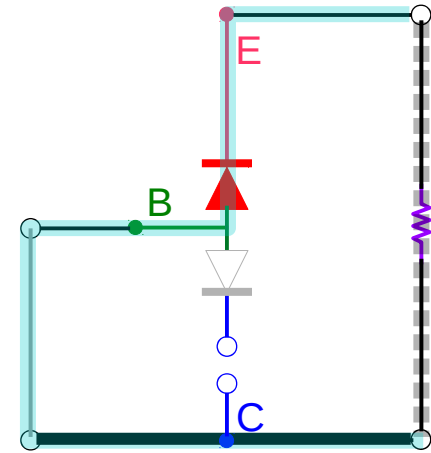
Thevenin  $R$



Common Emitter

$$Z_{out} : \text{high } R_C$$

Thevenin  $R$

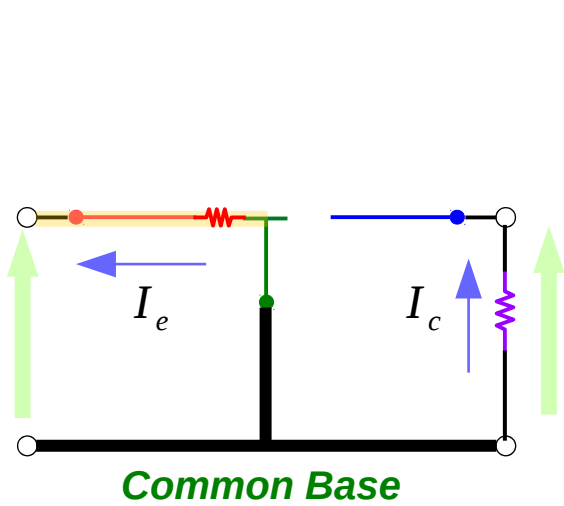


Common Collector

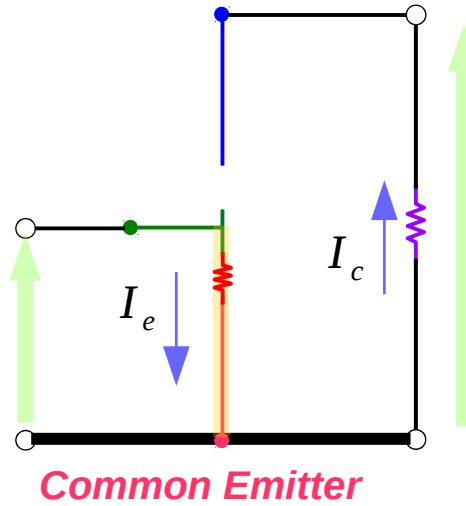
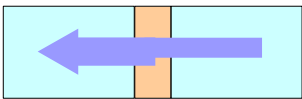
$$Z_{out} : \text{low } r_e'$$

Thevenin  $R$

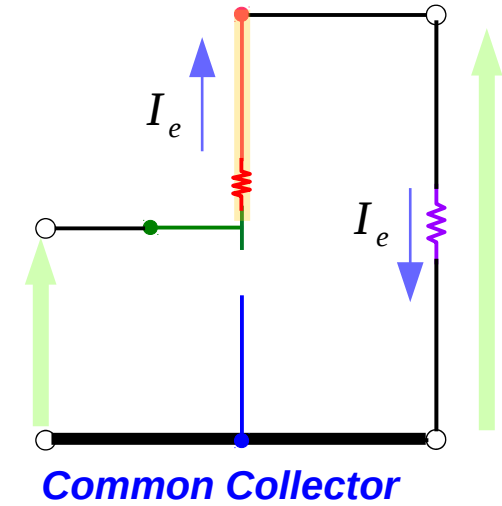
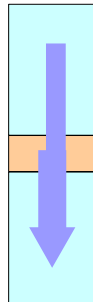
# Voltage Gain $A_v$



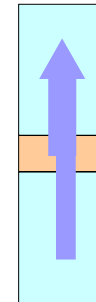
$A_v$  : high  $R_C/r_e'$



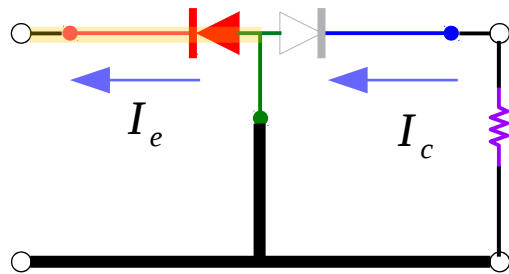
$A_v$  : high  $R_C/r_e'$



$A_v$  : unity 1

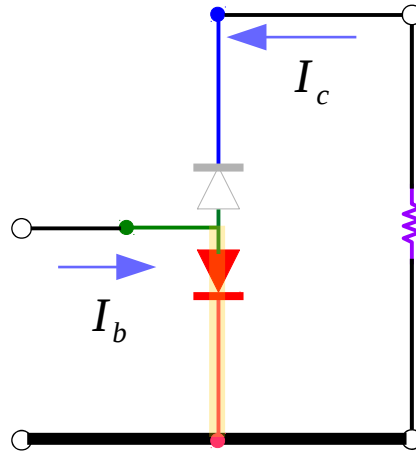


# Current Gain $A_i$



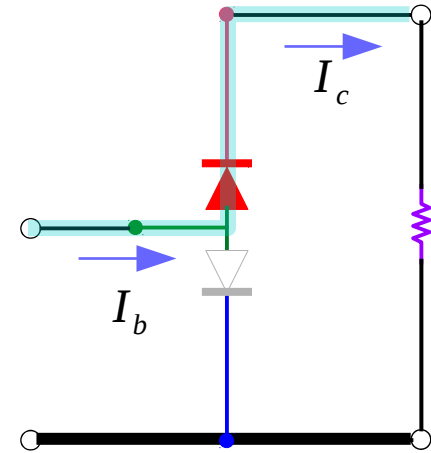
Common Base

$A_i$  : unity    1



Common Emitter

$A_i$  : high     $\beta$



Common Collector

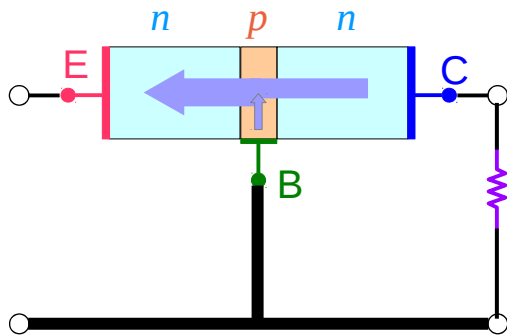
$A_i$  : high     $\beta$

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## BJT Configuration Properties

# BJT Configuration Properties (1)

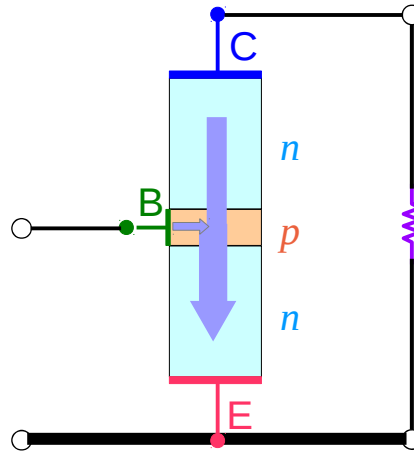
Low  $Z_{in}$   $\Rightarrow$



**Common Base**

input  $Z$  : low EB  
 output  $Z$  : high CB  
 voltage gain : high  
 current gain : unity

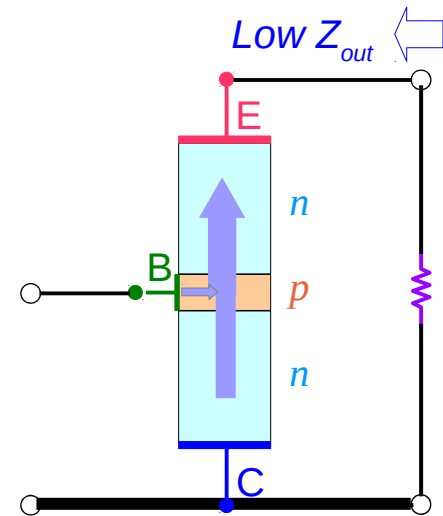
RF Applications



**Common Emitter**

input  $Z$  : high BE  
 output  $Z$  : high CE  
 voltage gain : high  
 current gain : high

Widely used

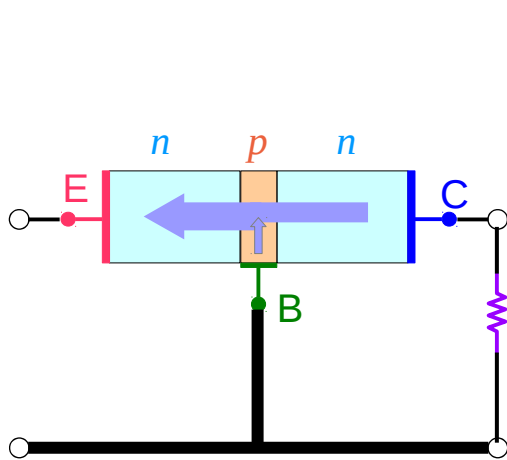


**Common Collector**

input  $Z$  : high BC  
 output  $Z$  : low EC  
 voltage gain : unity  
 current gain : high

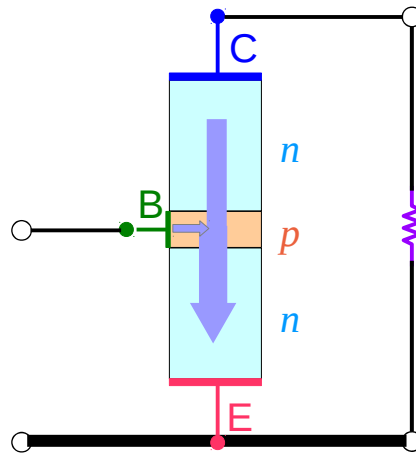
Emitter Follower  
 Buffer to  
 Low Impedance Load

# BJT Configuration Properties (2)



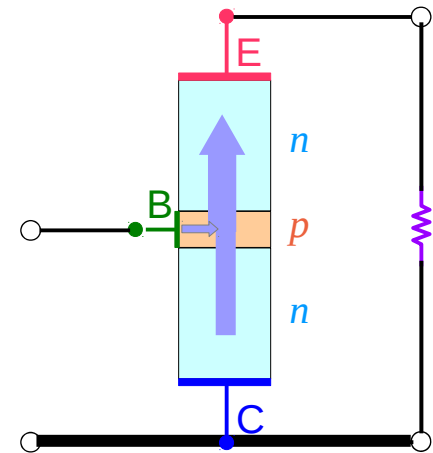
**Common Base**

$Z_{in} : \text{low}$        $r_e'$   
 $Z_{out} : \text{high}$        $R_C$   
 $A_v : \text{high}$        $R_C/r_e'$   
 $A_i : \text{unity}$       1



**Common Emitter**

$Z_{in} : \text{high}$        $\beta r_e'$   
 $Z_{out} : \text{high}$        $R_C$   
 $A_v : \text{high}$        $R_C/r_e'$   
 $A_i : \text{high}$        $\beta$



**Common Collector**

$Z_{in} : \text{high}$        $\beta(r_e' + R_E)$   
 $Z_{out} : \text{low}$        $r_e'$   
 $A_v : \text{unity}$       1  
 $A_i : \text{high}$        $\beta$



# BJT Configuration Properties

## Common Base

## Common Emitter

## Common Collector

$Z_{in}$	CB : low	$r_e'$	CE : high	$\beta r_e'$	CC : high	$\beta(r_e' + r_E)$
$Z_{out}$	CB : high	$R_C$	CE : high	$R_C$	CC : low	$r_e'$
$A_v$	CB : high	$R_C/r_e'$	CE : high	$R_C/r_e'$	CC : unity	1
$A_i$	CB : unity	1	CE : high	$\beta$	CC : high	$\beta$



$Z_{in}$	CB : low	$r_e'$	CE : high	$\beta r_e'$	CC : high	$\beta(r_e' + R_E)$
$Z_{out}$	CC : low	$r_e'$	CE : high	$R_C$	CB : high	$R_C$
$A_v$	CC : unity	1	CE : high	$R_C/r_e'$	CB : high	$R_C/r_e'$
$A_i$	CB : unity	1	CE : high	$\beta$	CC : high	$\beta$

# BJT Configuration Properties

	<b>Common Base</b>	<b>Common Emitter</b>	<b>Common Collector</b>
$Z_{in}$	CB : low $r_e'$	CE : high $\beta r_e'$	CC : high $\beta(r_e' + r_E)$
$Z_{out}$	CB : high $R_C$	CE : high $R_C$	CC : low $r_e'$
$A_v$	CB : high $R_C/r_e'$	CE : high $R_C/r_e'$	CC : unity 1
$A_i$	CB : unity 1	CE : high $\beta$	CC : high $\beta$

	<b>Common Base</b>	<b>Common Emitter</b>	<b>Common Collector</b>
$Z_{in}$	CB : low $r_e$	CE : med $r_{\pi} = (\beta + 1)r_e$	CC : high $(\beta + 1)[r_e + (r_o    R_L)]$
$Z_{out}$	CB : high $R_C$	CE : med $R_C    r_o$	CC : low $r_o    [r_e + \frac{R_s}{\beta + 1}]$
$A_v$	CB : high $\frac{\alpha R_C}{(R_s + r_e)}$	CE : med $\frac{\beta(R_C    r_o)}{(R_s + r_{\pi})}$	CC : unity $\frac{(\beta + 1)(R_L    r_o)}{R_s + (\beta + 1)[r_e + (R_L    r_o)]}$
$A_i$	CB : unity $\alpha$	CE : med $\frac{\beta r_o}{(R_c + r_o)}$	CC : high $\frac{(\beta + 1)r_o}{r_o + R_L}$

$r_o, R_s, R_E$  are used

# BJT Configuration Properties

## Common Base

## Common Emitter

## Common Collector

$Z_{in}$	CB : low	$r_e'$	CE : high	$\beta r_e'$	CC : high	$\beta(r_e' + r_E)$
$Z_{out}$	CB : high	$R_C$	CE : high	$R_C$	CC : low	$r_e'$
$A_v$	CB : high	$R_C/r_e'$	CE : high	$R_C/r_e'$	CC : unity	1
$A_i$	CB : unity	1	CE : high	$\beta$	CC : high	$\beta$

## Common Base

## Common Emitter

## Common Collector

$Z_{in}$	CB : low	$r_e \parallel R_E \approx r_e$	CE : med	$R_1 \parallel R_2 \parallel \beta r_e$	CC : high	$R_1 \parallel R_2 \parallel \beta(r_e + R_E)$
$Z_{out}$	CB : high	$R_C$	CE : med	$R_C$	CC : low	$(r_e + \frac{R_s}{\beta}) \parallel R_E = \frac{R_s}{\beta} \parallel R_E$
$A_v$	CB : high	$\frac{R_C}{r_e}, \frac{R_C \parallel R_L}{r_e}$	CE : med	$\frac{R_C}{r_e}, \frac{R_C \parallel R_L}{r_e}$	CC : unity	$\frac{R_E}{(r_e + R_E)} \approx 1$
$A_i$	CB : unity		CE : med		CC : high	

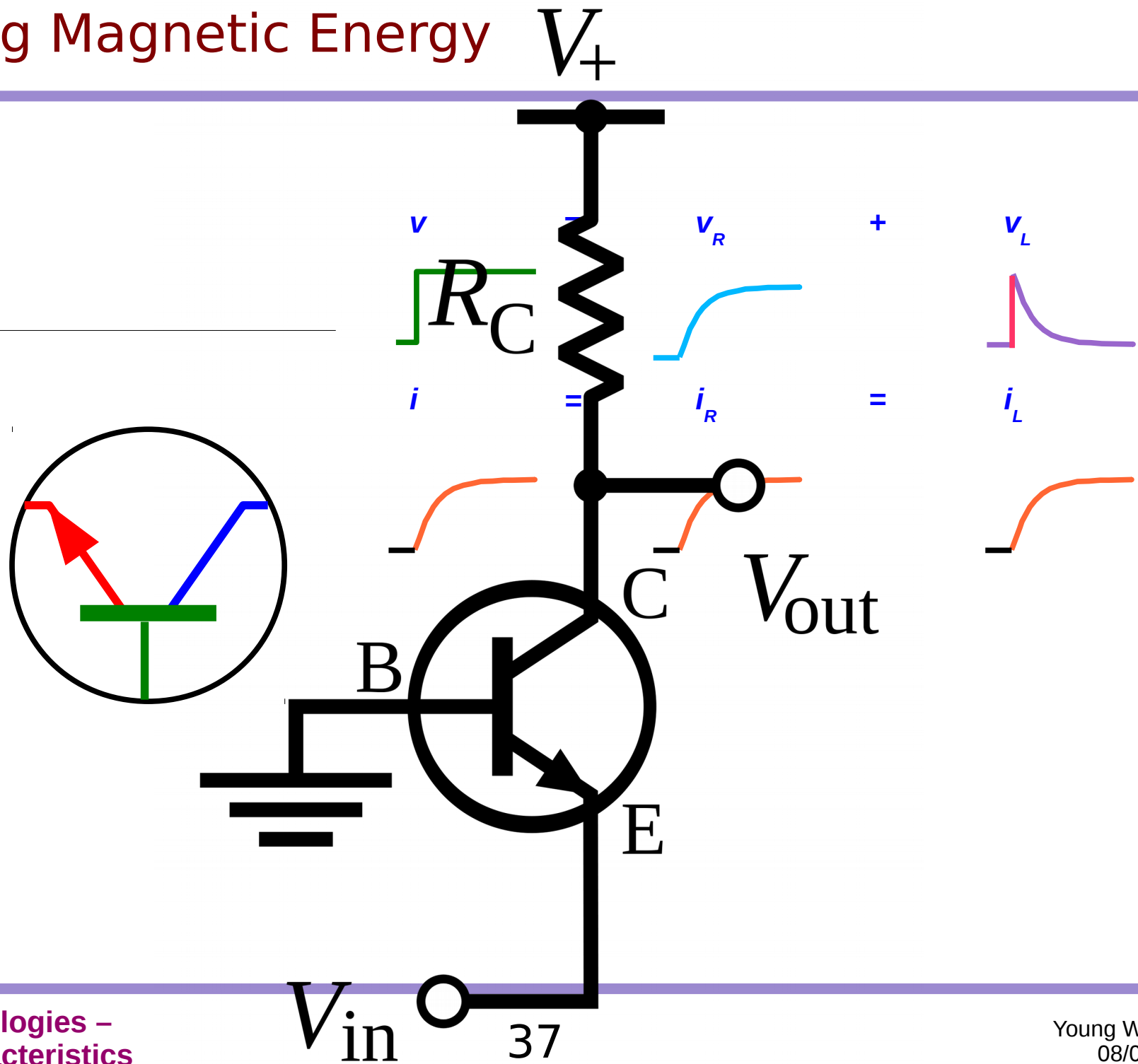
VDB

# AC Equivalent Circuits

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Input Characteristic Curves  
Output Characteristic Curves

# Storing Magnetic Energy



## References

[1] <http://en.wikipedia.org/>

[2] J.H. McClellan, et al., Signal Processing First, Pearson Prentice Hall, 2003