Lecture 22

Bipolar Junction Transistors (BJT): Part 6

Understanding BJT Circuits - Clearing up some Confusion

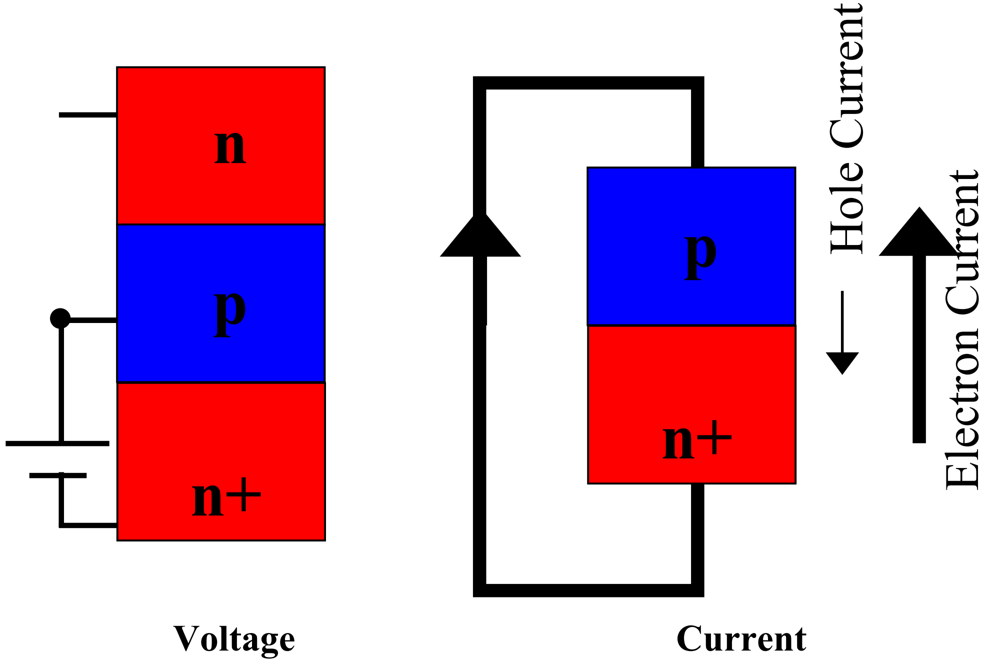
Reading:

Notes

Understanding a BJT Circuit

Why is the base current so much smaller than the emitter and collector currents in forward active mode?

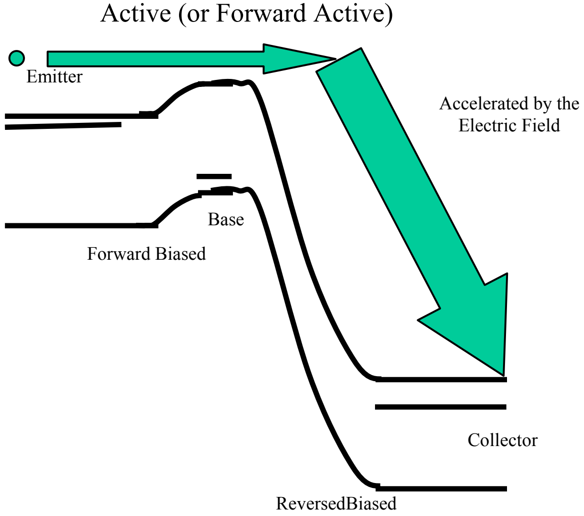
If the collector of an npn transistor was open circuited, it would look like a diode.



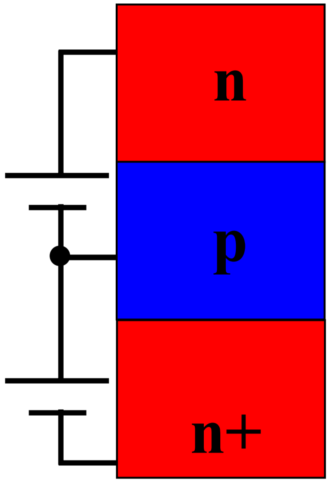
When forward biased, the current in the base-emitter junction would consist of holes injected into the emitter from the base and electrons injected into the base from the emitter. But since there are MANY more electrons in the emitter than holes in the base, the vast majority of the current will be due to electrons.

Why is the base current so much smaller than the emitter and collector currents in forward active mode?

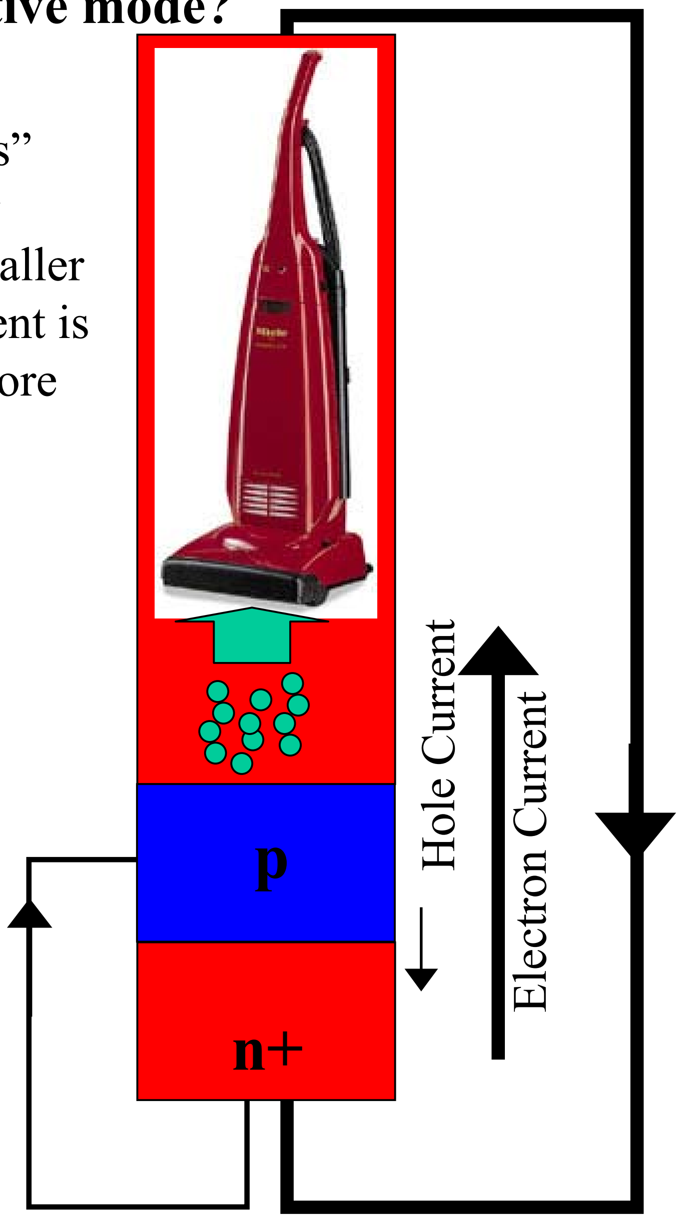
When the reverse biased collector is added, it "sucks" the electrons out of the base. Thus, the base-emitter current is due predominantly to hole current (the smaller current component) while the collector-emitter current is due to electrons (larger current component due to more electrons from the n+ emitter doping).



Energy Band Diagram



Voltage



Current

When to use which Model

Ebers-Moll model:

Always valid!

Cutoff, saturation, forward active (active) and reverse active (inverse)

Simplified Ebers-Moll:

Forward active only for DC solution. Requires iteration.

β Analysis (assume a turn on voltage when given β):

Forward active DC solution only. Note: β only has meaning in forward active mode!

Small Signal Models (y-parameter, hybrid-π, etc…)

Forward active mode solving for the small signal (AC) solution only

Model Sub-Classifications

Ebers-Moll model (Always Applies):

Simplified Ebers-Moll model (Assume FA mode and neglect small terms. Used for DC, or transient solutions):

CVD model using β analysis (Assume a turn on voltage for the Base-emitter junction and solve the DC solution based on β or α):

Simplified Ebers-Moll model adjusted for Base width modulation (Add $(1+V_{CE}/V_A)$ terms. Used for DC, or transient solutions):

Small Signal Models (Y-parameter, VCCS and CCCS versions of the Hybrid-pi: Used for AC small signals only)

Term Confusion

V_A is the applied voltage across a Diode

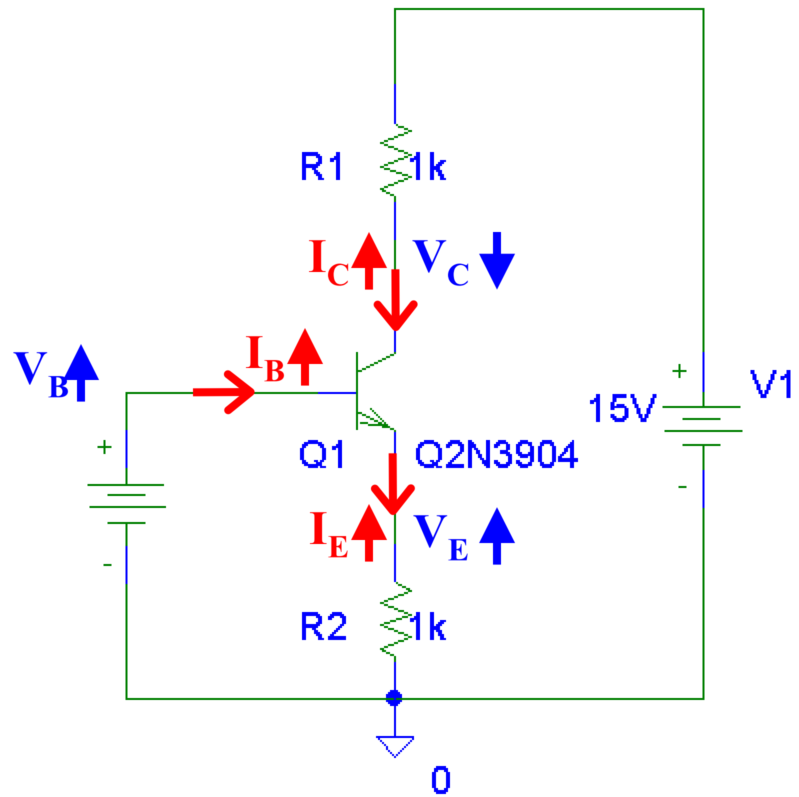
V_A is also the Early voltage for a BJT

V_T is the thermal voltage (kT/q) but…

V_T will be used later for the Threshold voltage of a MOSFET

$\beta=\beta_{DC}=\beta_{FO}$ and $\beta_o \sim \beta_F$ (neglecting variations in β_F with i_C)

Understanding a BJT Circuit



Symbol Key

Increasing Voltage

Increasing Current

Decreasing Voltage

Decreasing Current

Direction of Current

An increase in base voltage will…

1.) produce an increase in base current which will do two things

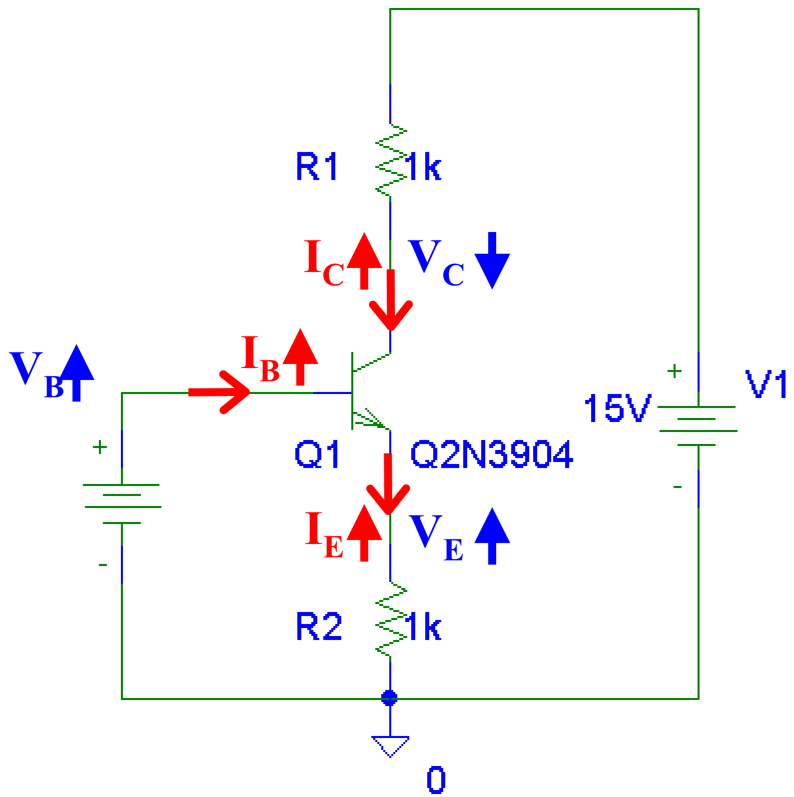
a.) produce an increase in emitter current which will…

i) develop a larger voltage across R2 raising voltage V_E

b.) produce an increase in collector current which will…

i) develop a larger voltage across R1 lowering voltage V_C

Understanding a BJT Circuit



Symbol Key

Increasing Voltage

Increasing Current

Decreasing Voltage

Decreasing Current

Direction of Current

Conclusion:

V_E will "follow" V_B (as V_B increases so does V_E)

V_C will take the inverse action of V_B (as V_B increases V_C will decrease).

Use PSPICE and circuit:

Qualitative understanding of a BJT Circuit#1 without emitter resistor" to simulate this to yourself

Understanding a BJT Circuit

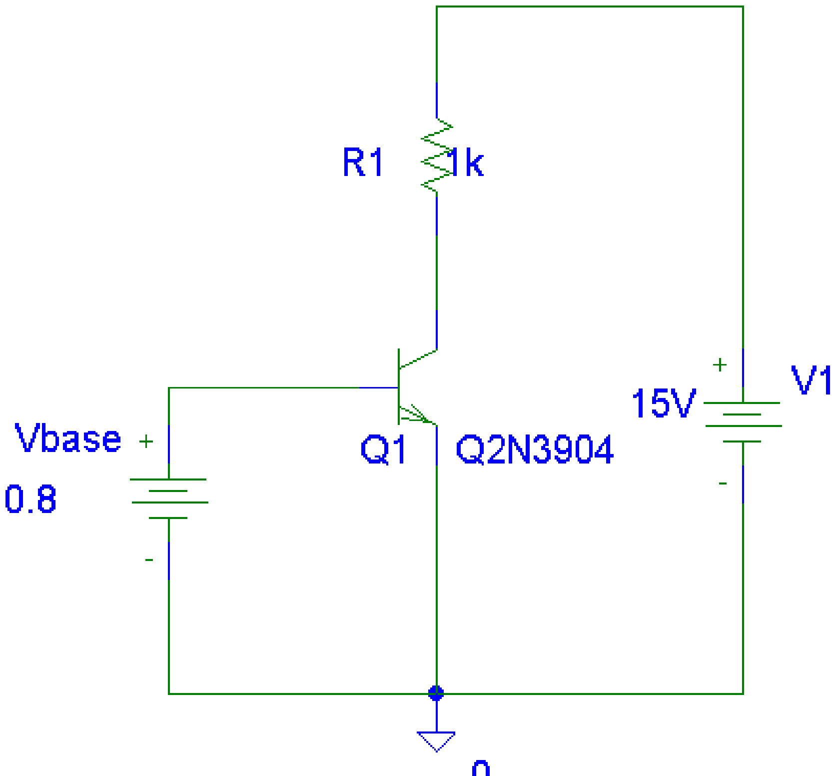
Use PSPICE and circuits:

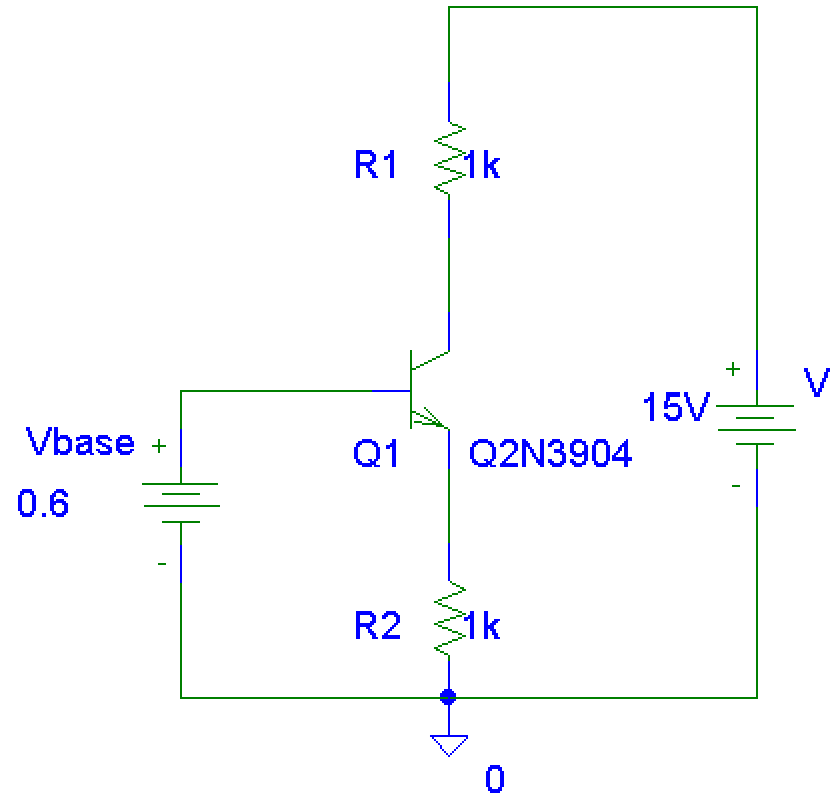
"Qualitative understanding of a BJT Circuit#1 without emitter resistor.cir"

and

"Qualitative understanding of a BJT Circuit#2 with emitter resistor.cir"

to simulate the DC bias points of this circuit by varying the value of Vbase





Use Vbase=0.0, 0.6V, 0.7V, 0.8V

Cutoff Active Saturation

>>> Very Sensitive <<<

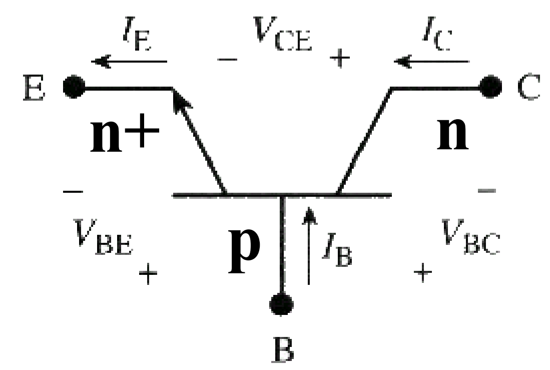
Use Vbase=0.0, 0.7V, 5.0V

Cutoff Active

>>> Less Sensitive <<<

Understanding a BJT Circuit

What mode is the circuit in?



NPN Transistor Mode Determination*

Mode	Emitter-Base	Collector-Base	V_{BE}	I_B	V_{CE} $(=V_{BE}+V_{CB})$	I_C	I_E
Active	Forward	Reverse	~0.65	>0	$>V_{BE}$	$= I_B\beta$	$= I_C/\alpha$
Saturated	Forward	Forward	>0.7	$>I_C/\beta$	$V_{CE}<V_{BE}$ V_{CE} small(~0.2)	Controlled by circuit (not βI_B)	Controlled by circuit (not I_C/α)
Cutoff	Reverse	Reverse	<0.0	<0	Controlled by circuit	~0	~0
Inverted	Reverse	Forward	<0.0	**Not Normally Used**			

* For pnp, simply reverse V_{BE} and V_{CB} etc… to V_{EB} and V_{BC}