Lecture 13

Wednesday, October 9, 2024 12:58 PM

Transistors

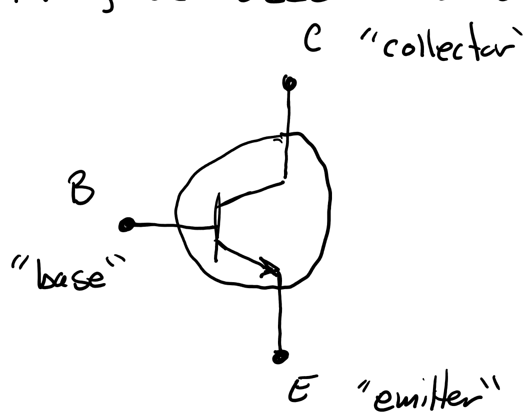
A type of semiconductor used for a very wide range of applications.

We'll focus on two types:

1. NPN
2. MOSFET

NPN transistor

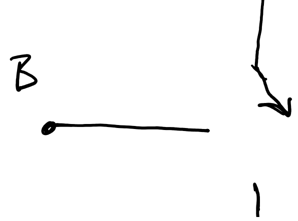
May be used as a switch or as a current amplifier.



3 modes of operation:

1. Cut off
2. Active
3. Saturation

Cut off mode: When the voltage potential between base and emitter, v_{BE}, is below v_F, the activation threshold, the NPN acts like an open switch between collecter & emitter.



Typically

$v_F \approx 0.7\ V$

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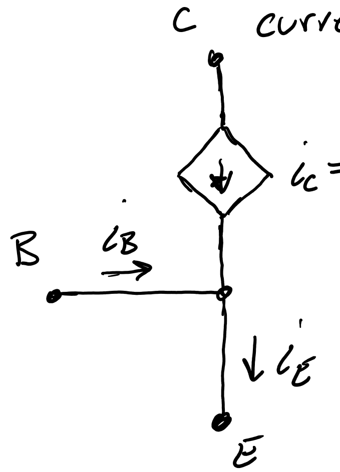
Active mode: When $v_{BE} > v_F$ and the current flow is below the threshold for saturation, then NPN goes into the "active state" and acts like a current amplifier.



$0 < \alpha_F \leq 1$

KCL:

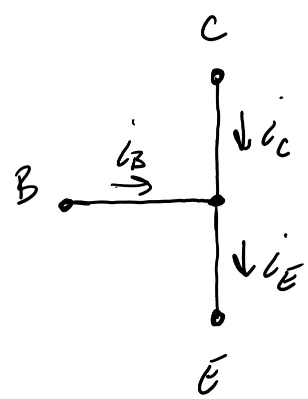
$$i_B + i_C - i_E = 0$$

$$\Rightarrow i_B + \alpha_F i_E - i_E = 0$$

$$\Rightarrow i_B + (\alpha_F - 1) i_E = 0$$

$$\Rightarrow \frac{i_E}{i_B} = \frac{1}{1-\alpha_F} > 1$$

Saturation mode: When i_B reaches the saturation threshold of the NPN, the NPN acts like a closed switch.



What is the saturation threshold, $i_{B_{sat}}$?

Saturation occurs when i_c reaches the "closed switch"

Saturation occurs when i_c reaches the "closed switch" current flow.

Apply KCL:

$$i_B + i_c - i_E = 0$$

If we're at the threshold for saturation,

$$\hat{i}_c = \alpha_F \, i_E \Rightarrow i_E = \frac{1}{\alpha_F} i_c$$

$\therefore$

$$i_B + i_c - \frac{1}{\alpha_F} i_c = 0$$

$$\Rightarrow i_B + \left(1 - \frac{1}{\alpha_F}\right) i_c = 0$$

$$\Rightarrow i_B = \frac{1-\alpha_F}{\alpha_F} i_c$$

$$i_B = -\left(1 - \frac{1}{\alpha_F}\right) i_c$$

$$= -\left(\frac{\alpha_F - 1}{\alpha_F}\right) i_c$$

$$\Rightarrow i_B = \left(\frac{1-\alpha_F}{\alpha_F}\right) i_c$$

If saturatured, the i_c equals $i_{c_{sat}}$, which is equal to the closed switch current flow into collector.

$$i_{B_{SAT}} = \frac{1-\alpha_F}{\alpha_F} i_{c_{SAT}}$$

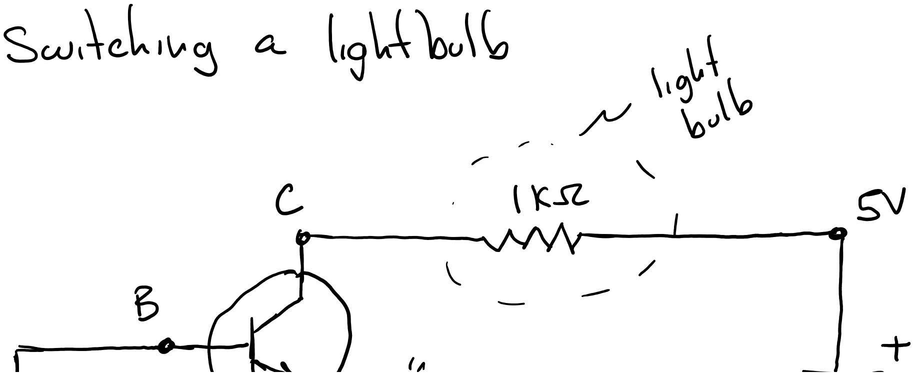
Depends on the external circuit

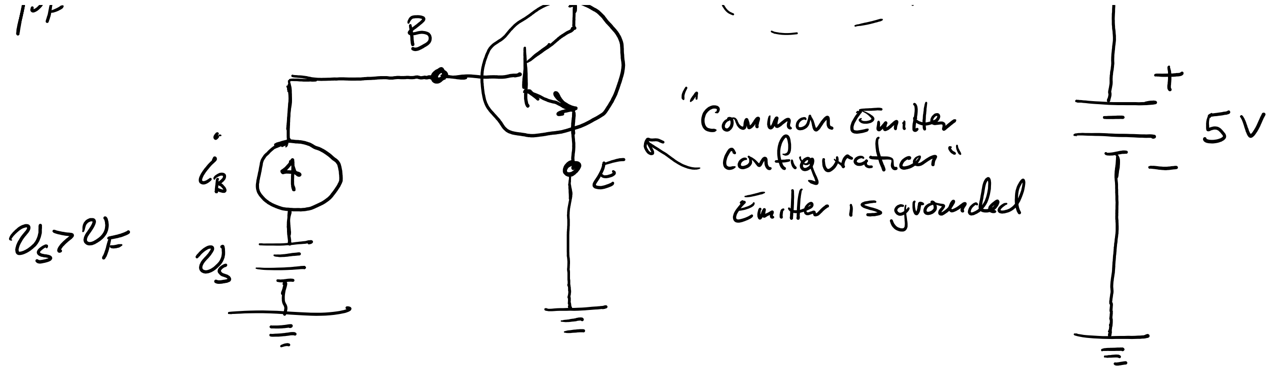
Define

$$\beta_F = \frac{\alpha_F}{1-\alpha_F} = \frac{i_c}{i_B}$$: Forward common emitter transfer ratio.

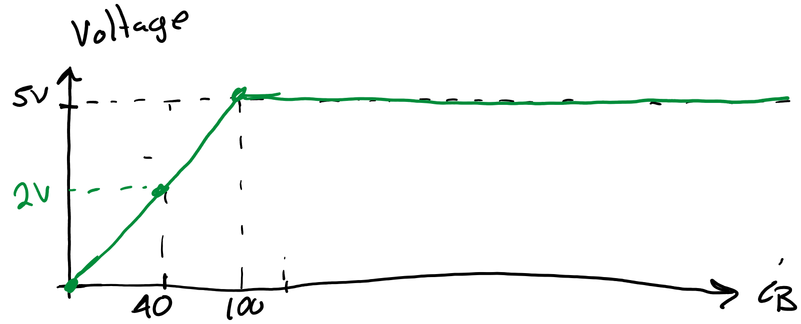
__Example:__ Switching a lightbulb

$\beta_F = 50$





Find voltage across light bulb as a function of i_B.



$i_B = 0$: $\quad i_C = \beta_F i_B \Rightarrow i_C = 0$

$i_B = 40\mu A$:

$$i_C = \beta_F i_B = 50\,(40\,\mu A) = 2mA$$

$$v_C = 5V - i_C(1K\Omega) = 5V - (2mA)\,1K\Omega = 3V$$

$$v_{bulb} = 5V - v_C = 5V - 3V = 2V$$

$i_B = 100\,\mu A$:

$$i_C = \beta_F i_B = 50\,(100\,\mu A) = 5mA$$

$$v_C = 5V - i_C(1K\Omega) = 5 - (5mA)\,1K\Omega = 0$$

At saturation threshold

$$v_{bulb} = 5V - v_C = 5V$$

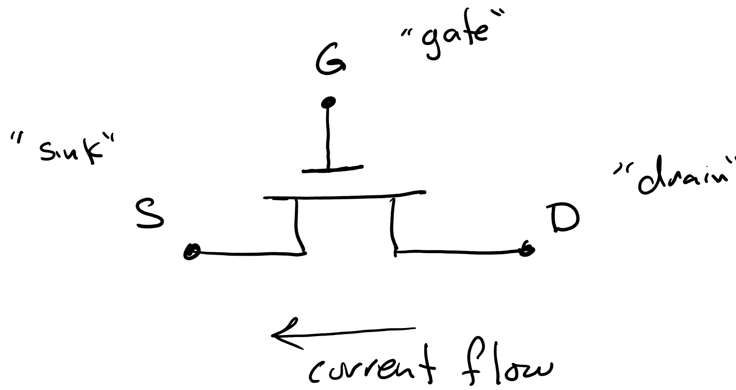
$i_B = 200\mu A$: In deep saturation $i_B > i_{Bsat}$

i_C remains at closed switch current level

MOSFET

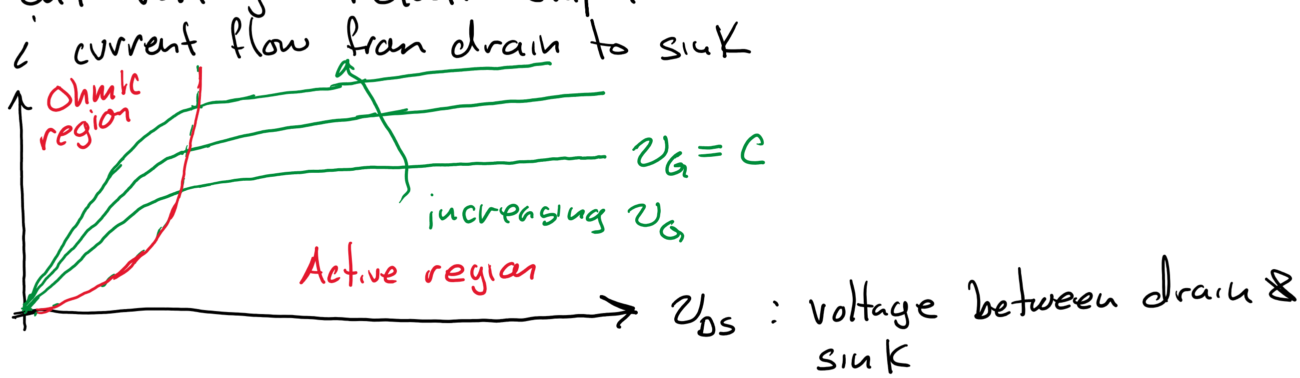
MOSFET

Often used as variable resistors (but there are other creative uses).



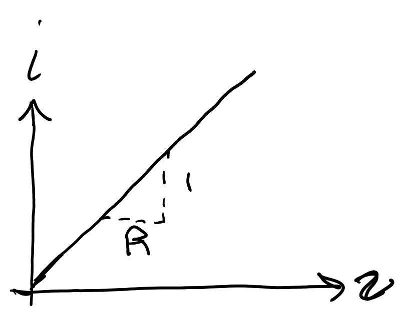
No current flow through the gate.

Current-voltage relationship:



MOSFET behaves like a resistor in Ohmic region.

Effective resistance is controlled by v_G.



$v = iR$

$\Rightarrow i = \frac{1}{R} v$

We'll cover an example application when discussing LED driver circuits.

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