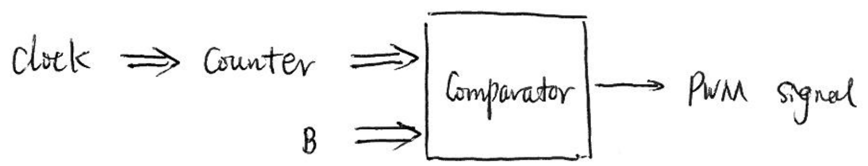
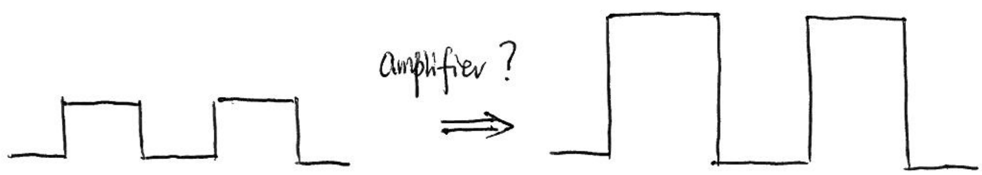
Review: In last lecture, we found a way to digitally control the duty cycle of a PWM signal.

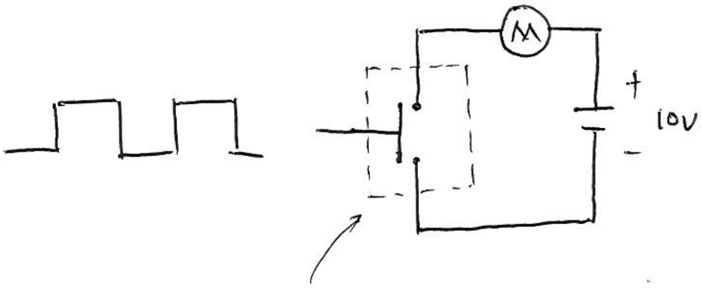


However, there is another issue. We use 5V to drive the ICs, thus the highest voltage of the pwm signal is 5V. More importantly, the power of the PWM signal is not high. However, our motor needs 9~12V and also a higher power.

We do have a 12V battery. But, how can we make the battery give power to the motor in a way similar to the PWM signal?



How about using the low voltage signal to control the high voltage signal?



So, we need a three terminal switch.

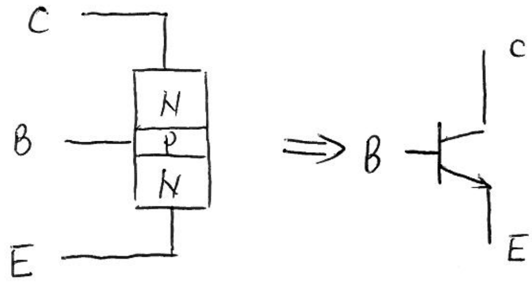
L7 Transistor & Diode Circuit.

1. A transistor is a 3-terminal device, that can be utilized as a switch.


The conductivity of two terminals is controlled by the third one.

Here, we introduce the BJT (Bipolar Junction Transistor).

1) NPN type :



B : Base

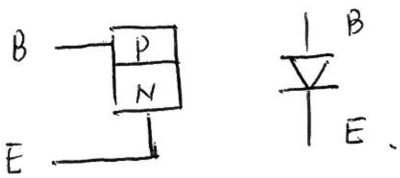
C : Collector

E : Emitter.

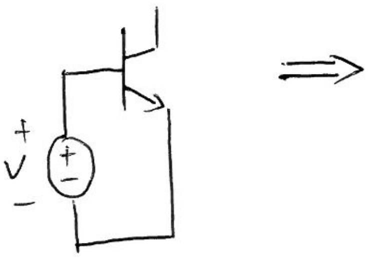
N : N-type semiconductor (with negative charges)

P : P- type semiconductor (with positive 〃)

We can imagine there is a diode between terminals B & E.

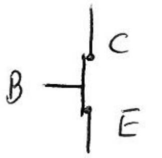


Thus,



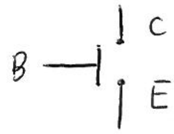
$\Longrightarrow$

$V_{BE} \geq 0.7V$



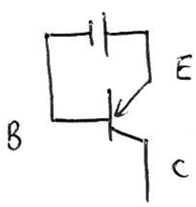
Switch ON

$V_{BE} < 0.7V$



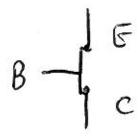
Switch OFF.

2) PNP type works in a similar way.

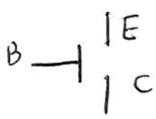


$\Longrightarrow$

$V_{EB} \geq 0.7V$

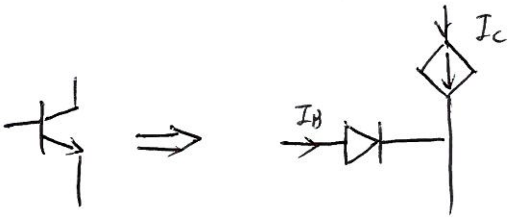


$V_{EB} < 0.7$



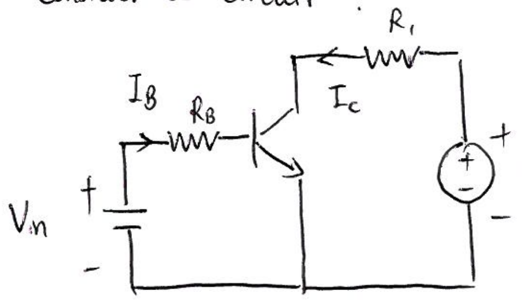
2. Transistor also works as an amplifier.

1) The NPN transistor  can be understood as a current - control current source.

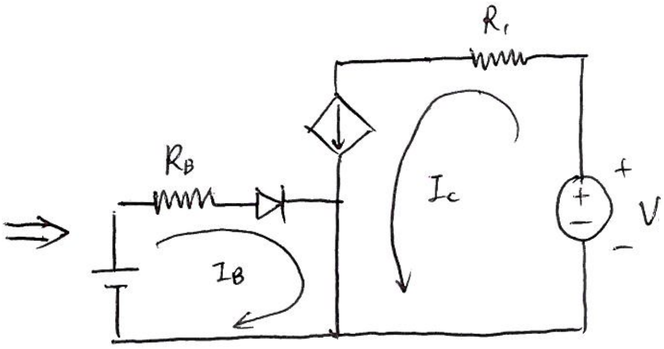


where $I_c = \beta I_B$, β is called the current gain.
in the range 20 ~ 200.

Consider a circuit

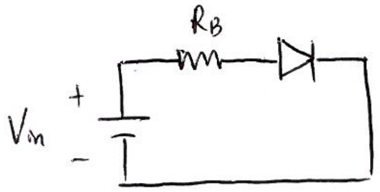


$\Rightarrow$



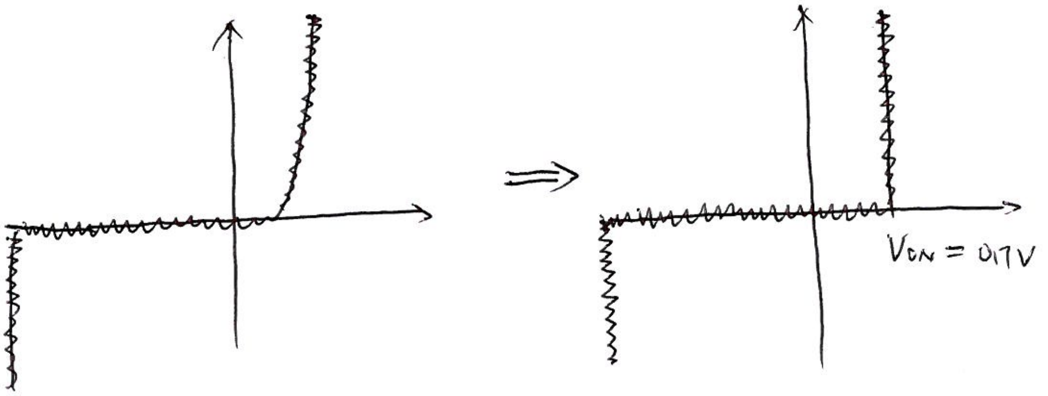
To get I_c, we need first determine I_B, :

2)

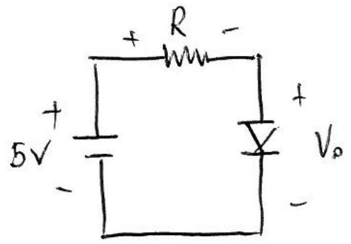


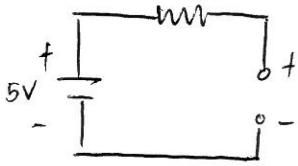
This is a diode circuit.

We first simplify the I-V characteristics of a diode to its offset model.



A general diode has two states, ON or OFF. How can we determine which mode it is in? We take assumption.

Consider 

First, we assume the diode is off. Then, we have 

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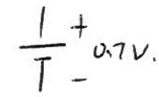
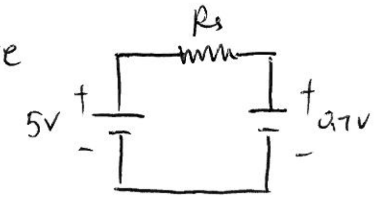
We determine $V_o = 5V > 0.7V$. Thus, the assumption "OFF" is not correct.

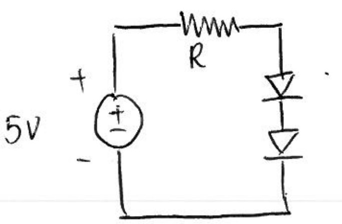
Then, we try another assumption "ON", where the diode works as a battery. 

Thus, we have 

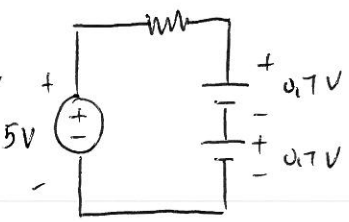
This, assumption is correct, because the current flows in the right direction.

Then, according to Ω's law, $I_B = \frac{5 - 0.7}{R_s}$

※ Exercise: How about two diodes?

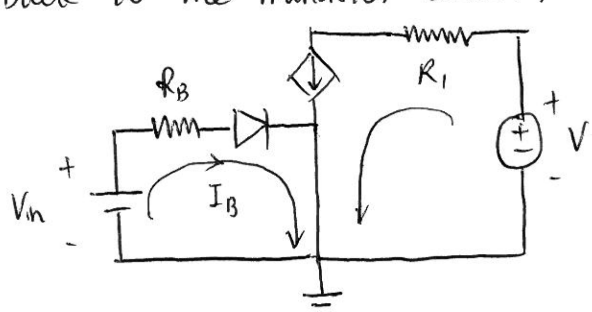


Assume "ON"

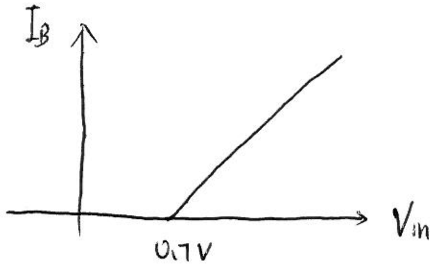


$V_s \geq 1.4V$, assumption correct. Otherwise, not.

3) Back to the transistor circuit.



$I_B = \frac{V_{in} - 0.7}{R_B}$.



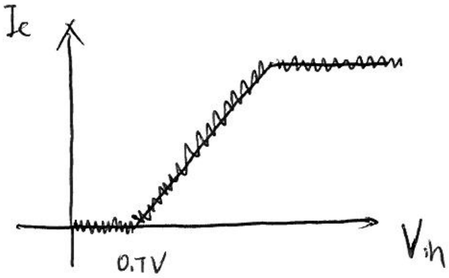
$V_{in} \leqslant 0.7V$ $\quad I_B = 0 \Rightarrow I_C = 0 \Rightarrow$ "OFF"

$0.7V < V_{in} < ?$ $\quad I_B$ small $\Rightarrow I_C = \beta I_B \Rightarrow$ "Active"

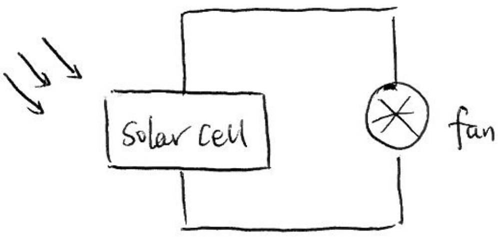
$? < V_{in}$ $\quad I_B$ large $\Rightarrow I_C = I_{C\,max} \Rightarrow$ "fully on"

$\downarrow$

This is determined by ?

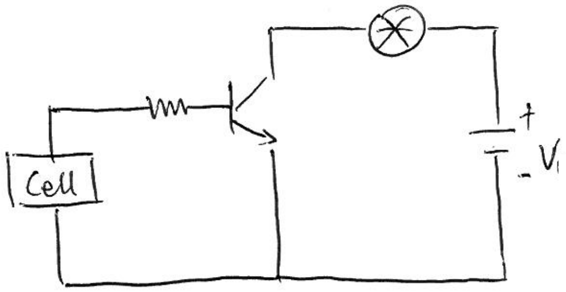


Consider the case where we want to turn a fan ON/OFF according to the light intensity.



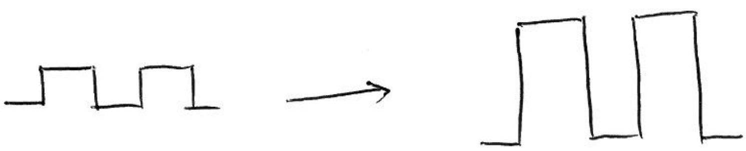
This doesn't work !

Because the voltage from the cell is low.

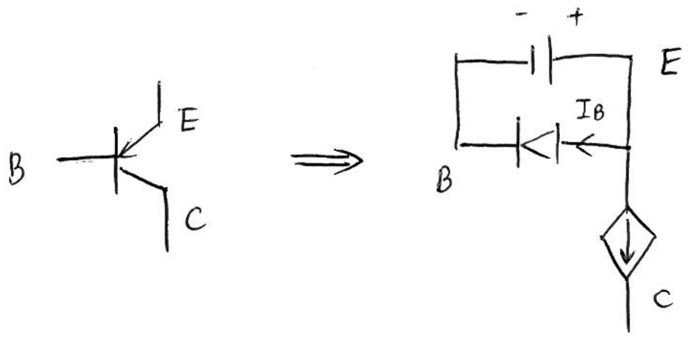


We use a small voltage from the cell to control the high voltage V_{CE}.

"Amplification"

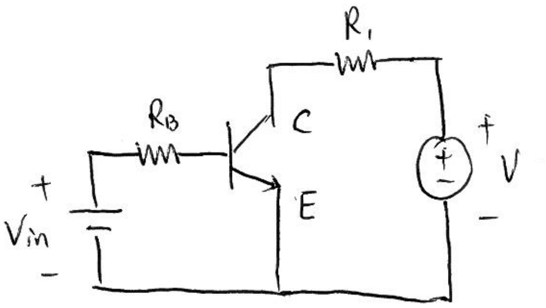


4) PNP is similar.

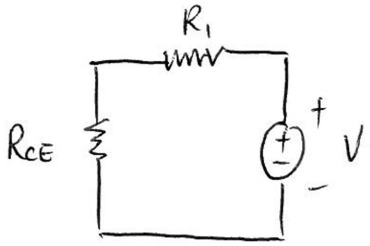


$I_c = \beta \cdot I_B$.

Challenge



If we imagine there is a resistor between C and E,



What is the resistance R_{CE} ?

$$R_{CE} = \frac{V}{I_c} - R_1 \Rightarrow R_{CE} = \frac{V}{\beta \cdot I_B} - R_1$$

Transistor ⇒ A resistor whose resistance can be transformed.