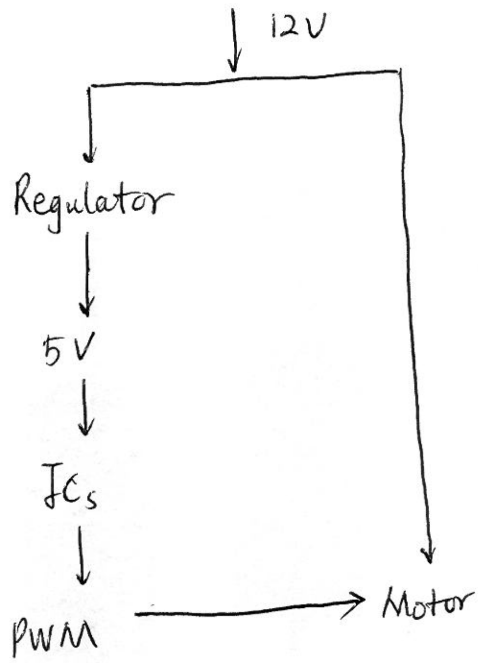
Review :

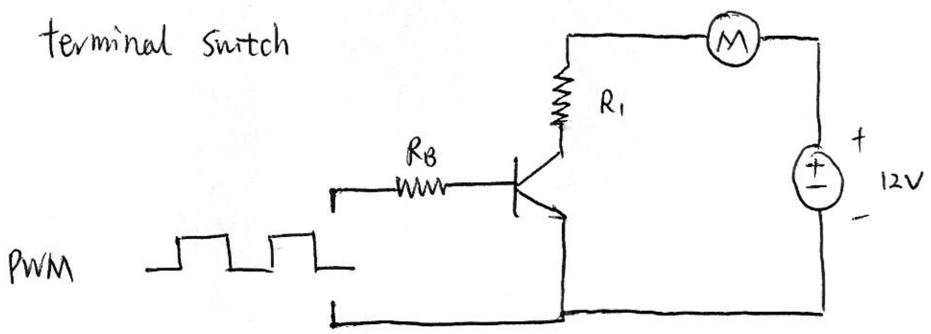


We have two problems here :

1) Power Control

2) Direction Control.

In last lecture, we have learned that transistor can work as a three terminal switch



Thus, we can use the weak PWM signal to control the high power source

L8 : Motor Control & H-Bridge

1. History of transistors : Nobel Prizes !

2. Semi-conductor material

1) A silicon atom has four electrons in its outer shell — Si —

Silicon lattice is formed as

Si
||
Si = Si = Si
||
Si

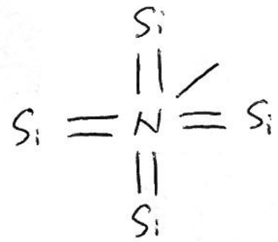
where 8 electrons form a bond.

With such a stable structure, silicon has neutral charges and the electrons are not easy to escape.

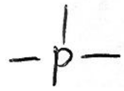
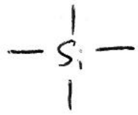
2) How about we make it not that pure by adding other atoms.

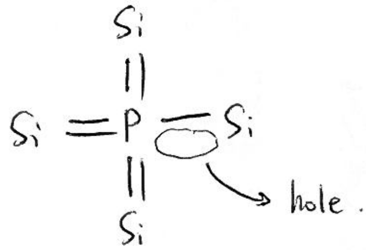
Consider the atom  which has 5 electrons in the outer shell.

Then, we have another structure



Here the additional electron is easier to escape. We call it the N-type semiconductor because it has free "Negative" charges.

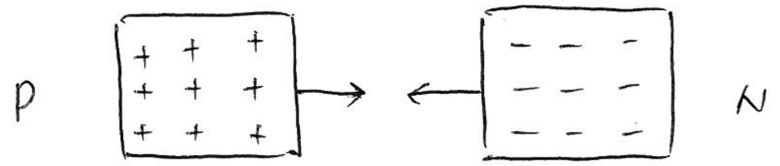
3) Similarly, we can add  to  to obtain the structure

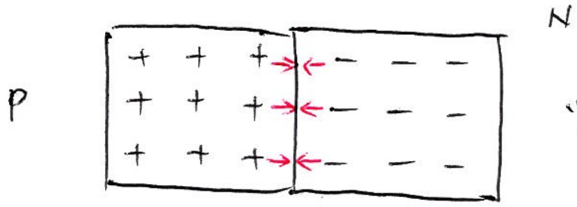


Obviously, we have one electron missing in constructing the bond. Here, "hole" can be regarded as a "Positive" charge and we call this stucture the P-type semiconductor.

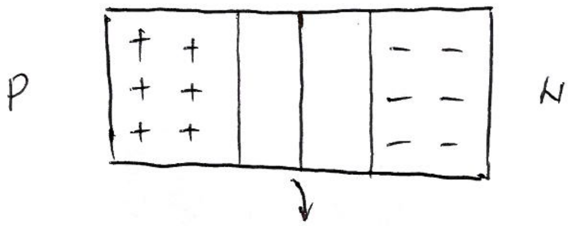
4). P-N Junction:

What if we put P-type and N-type together.



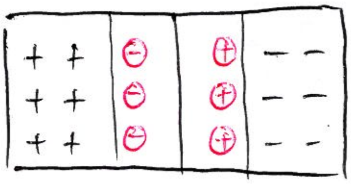


"+" + "−" = 0



depletion region.

Before meeting each other, P & N type materials are charge-neutral. After the above process, we have additional positive charges in the "N" region and negative charges in the "P" region.

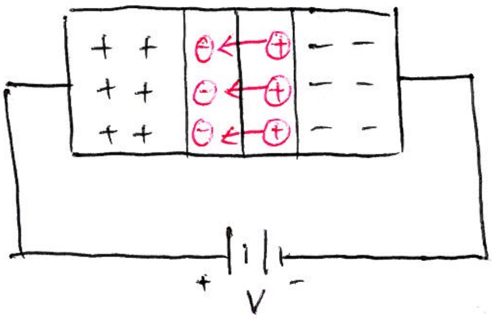


⊕ ⊖ : extra charges

+ − : free charges.

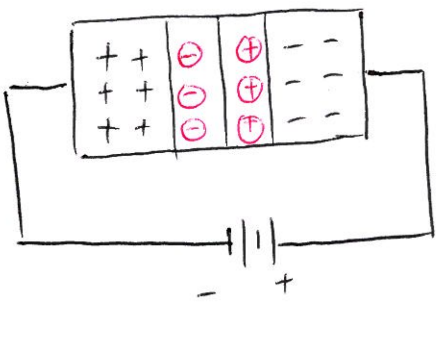
The extra charges will create an electrical field ⊖←⊕ ⊖←⊕ which prevents the free charges to further flow.

5) Now, we have a diode.

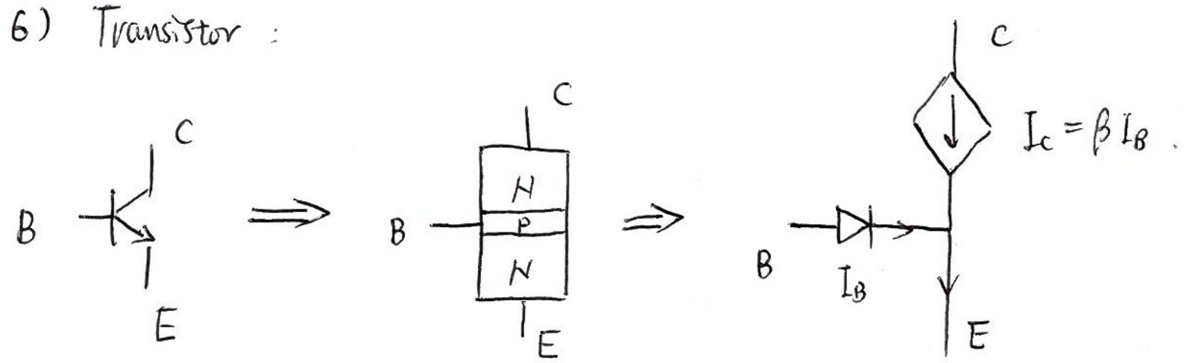


We need V to be greater than the electical potential difference created by the extra charges (V > 0.7V) to turn the diode on.

Then, how about zener diode ?

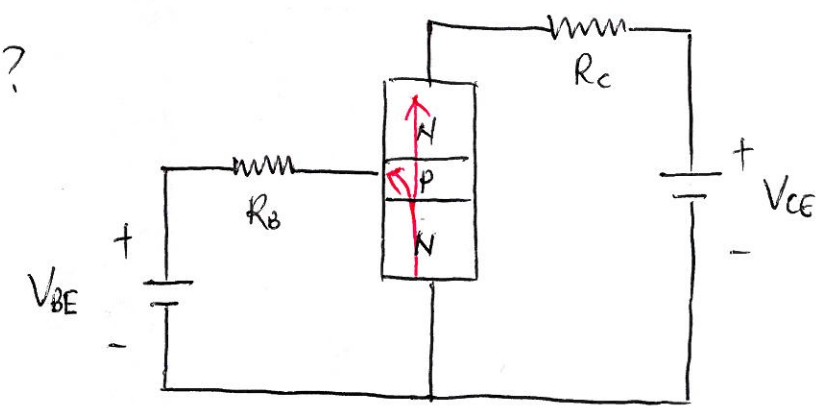


6) Transistor :



How does it work ?

layer P is very thin.



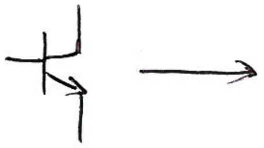
3. Voltage control or current control

We can use V_{BE} to control I_c $\qquad I_c = \beta \dfrac{V_{BE} - 0.7}{R_B}$

But, I_c is linearly related to I_B, so normally we use current control

$$I_c = \beta I_B .$$

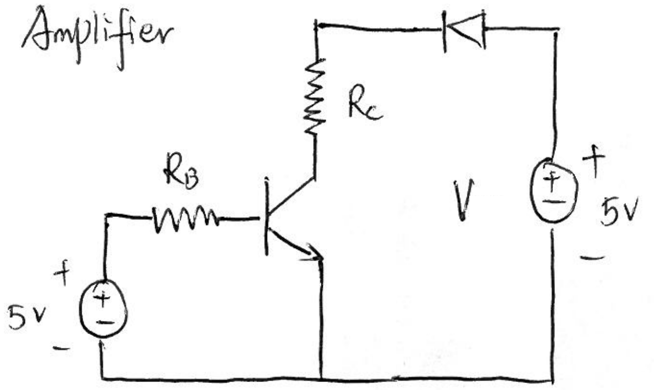
4. A transistor can be used either as a switch or an amplifier.



$$\begin{cases} \text{Amplifier}: & I_c = \beta I_B \\ \text{Switch}: & I_c = \begin{cases} I_{cmax}, & I_B > \bar{I}_B \\ 0, & I_B = 0 \end{cases} \end{cases}$$

Look at two cases.

1) Amplifier

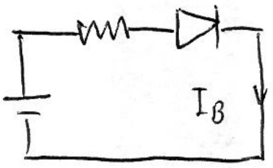


$R_B = 1.08\ M\Omega$

$R_c = 170\ \Omega$

$\beta = 100$

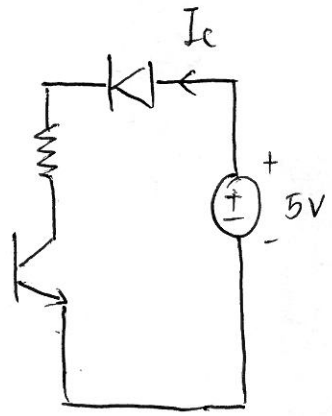
Find I_B :



$I_B = \dfrac{5-0.7}{1.08\times10^6} \doteqdot 4\ \mu A$.

$I_c = \beta \cdot I_B = 100 \times 4 \times 10^{-6} = 0.4\ mA$.

Can we get $I_c = 0.4\ mA$ from V ?



What is the largest I_c ?

$I_{cmax} = \dfrac{5 - V_{CE} - 0.7}{170} < \dfrac{5-0.7}{170} = 25\ mA$

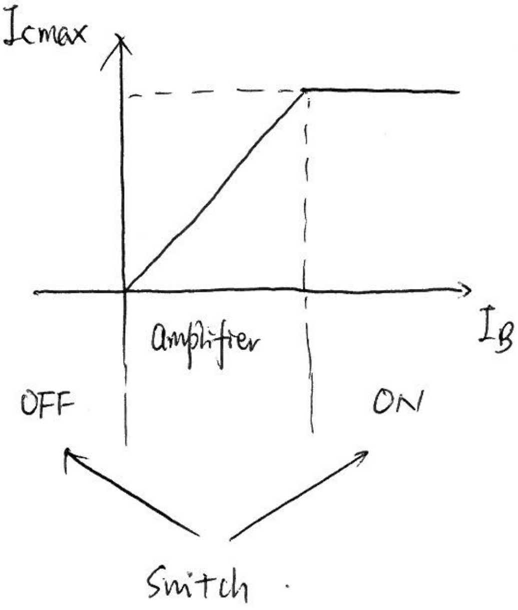
$0.4 < 25$, so OK !

2) Change $R_B = 10\ K\Omega$.

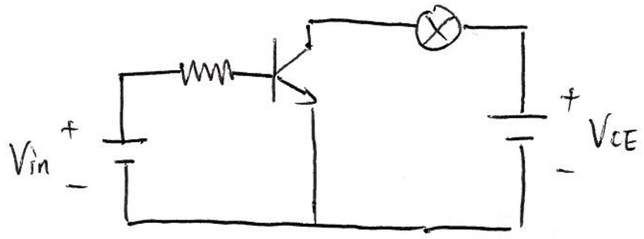
$I_B = \dfrac{5-0.7}{10\times10^3} = 0.43\ mA$

$I_c = \beta \cdot I_B = 0.43 \times 100 = 43\ mA > 25\ mA$

Not able to get it !



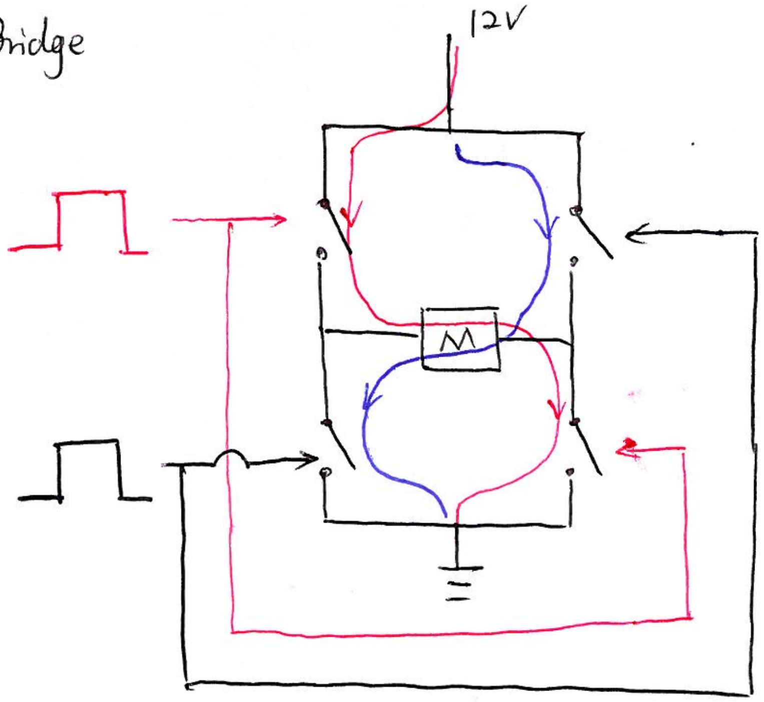
How to make the transistor work as an amplifier / switch ?



5. How to control the direction of the motor ?

Change the current going through the motor .

H- Bridge



Those switches are transistors .

Challenge : How does micro-phone work ?