CSCB58 Lecture 1

Class	CSCB58
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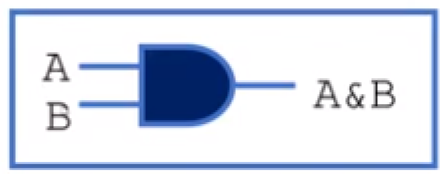
Type	Lecture

Basic Logic Gates

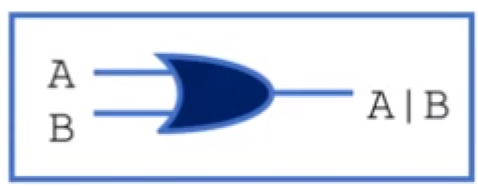
Recall Logic from Math Courses

e.g., G = (A & B) | (C & D)

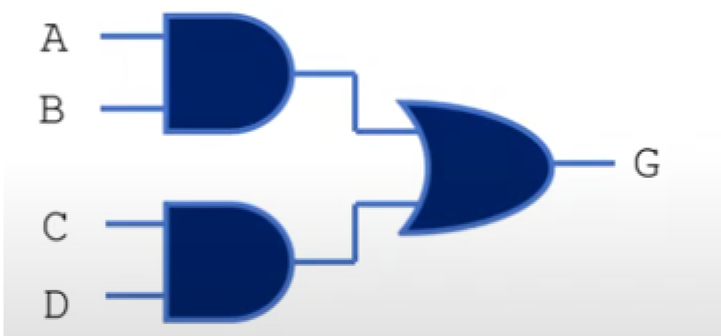
Here, the A & B can be implemented with the `AND` Gate



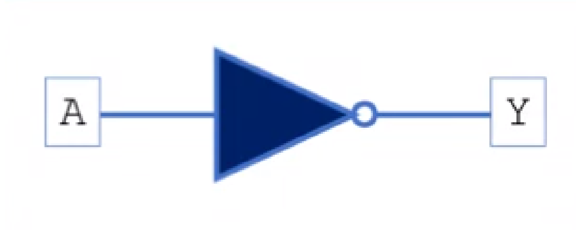
And A | B can be implemented with the `OR` Gate.



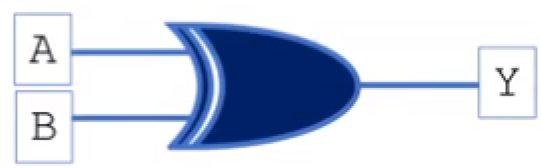
By combining the two, we can replicate our logic variable G, these gates are equivalent to boolean logic, if we know the logical expression, we then already know logic gates together to form a circuit.



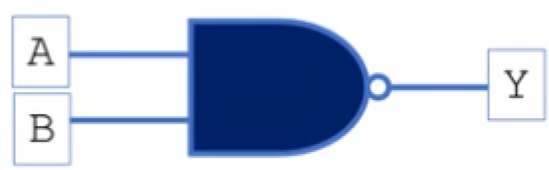
Another common gate used is the `NOT` Gate, this simplify inverts the input value.



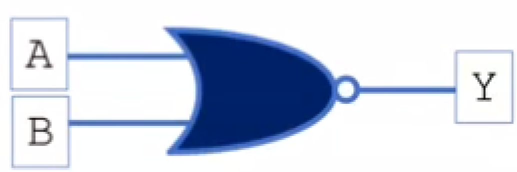
The `XOR` Gate representing exclusive or.



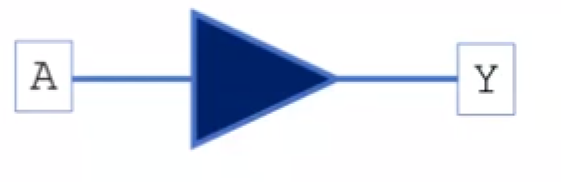
The `NAND` Gate representing `NOT AND` . We see that this is simply reversing the output values of the `AND` Gate.



The `NOR` Gate representing `NOT OR`. We see that the small circle represents the ¬ we see in boolean algebra.

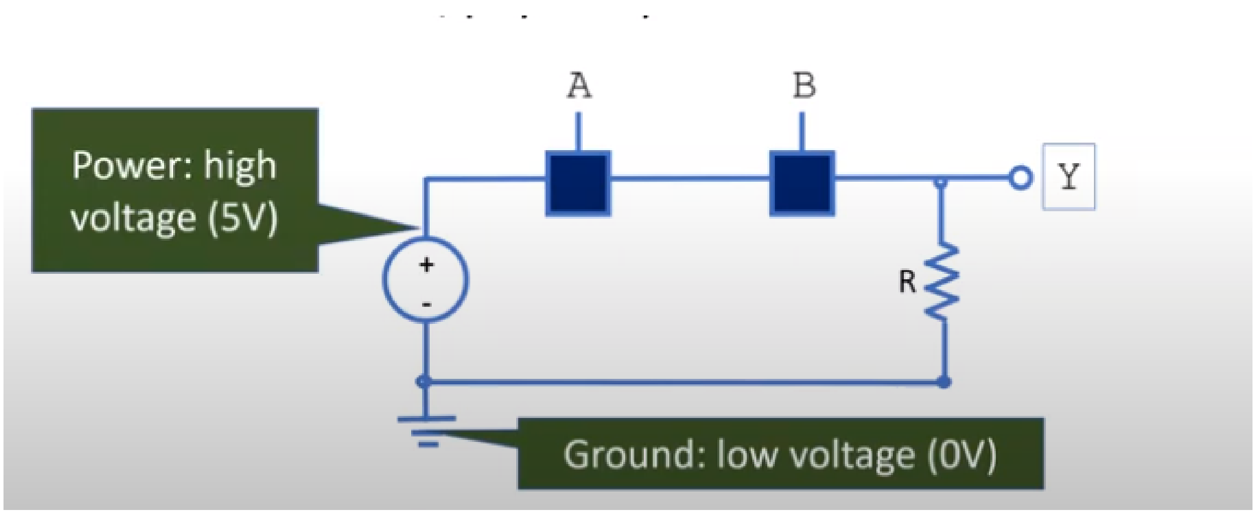


Lastly the `BUFFER` Gate simply outputs the stored value as is, this may seem silly but will come in handy later on.

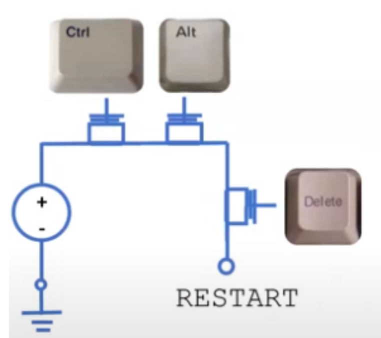


On the Inside

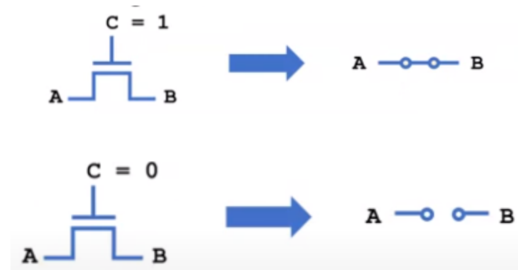
How do these gates work physically? Essentially we have something like the figure below, we can think of each input `A` and `B` as switches, we see that `Y` does not get powered unless both `A` and `B` are switched on, thus representing logical `AND` .



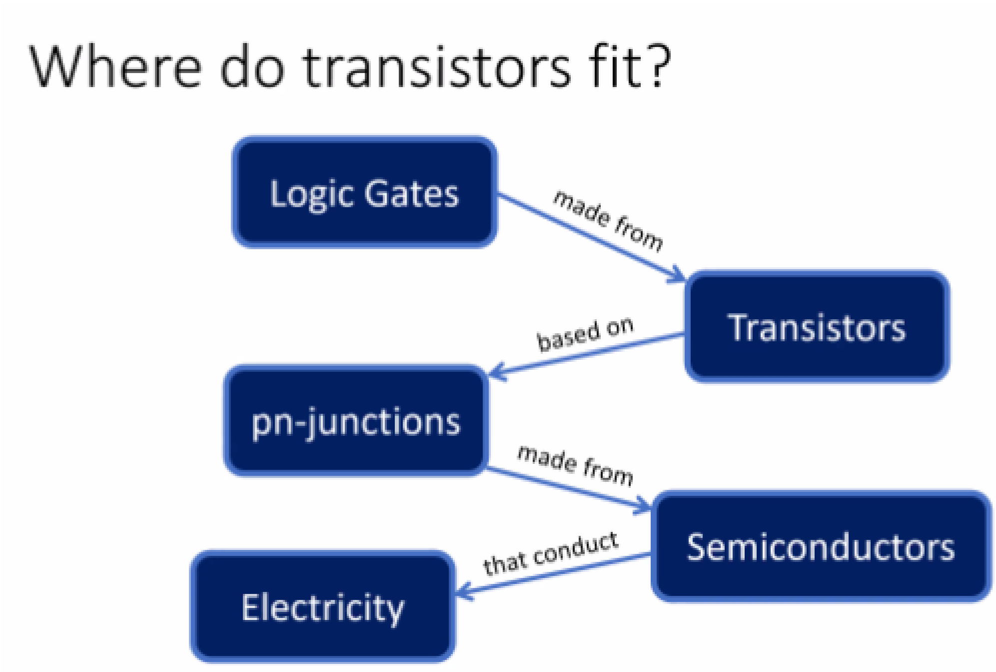
We can use the `CTRL-ALT-DELETE` hotkey as an example, where it restarts your PC, here all three must be pressed this we can think of this as `CTRL & ALT & DELETE` , with the corresponding circuit



Transistors



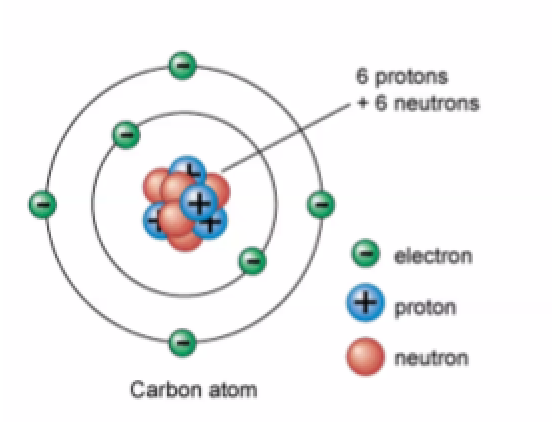
A transistor connects Point A to Point B, based on the value at Point C. If the value of Point C is high enough, A & B are connected. Otherwise, A & B are not connected. This is done through electricity. Note that transistors can also amplify the signal.



Basics of Electricity: Everything is Made Out of Atoms

`Protons` are big (hardly move) and are positively charged.
`Electorons` are small (easily move) and negatively charged.
`Neutron` are big and neutrally charged.

`Electricity` is the flow of electrons, they try to flow from regions of high electrical potential (many electrons) to regions of low electrical potential.



This potential is referred to as `voltage` (V)

The rate of this flow is called `current` (I)

`Resistance` is like how narrow a waterpipe is, and it's defined by `R = V/I`

The `Direction` at which electricity flows is the `opposite` to the direction of the electron itself, since electrons are negatively charged

Although the current is caused by electrons flowing through the material, the convention is to measure the current as the `movement of positive charges` note that since protons don't actually move, when electrons move from `A` to `B` , `A` becomes more positive and `B` becomes more negative. We view current in terms of the creation of positive charge in a material.

Resistance

Electrical resistance indicate how well a material allows electricity to flow through it:

- High resistance don't conduct electricity (insulators)
- Low resistance conduct electricity (conductors, used for wires)

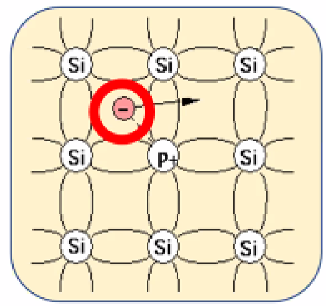
Semiconductors

Semiconductor materials (`silicon` and `germanium`) straddle the boundary between `conductors` and `insulators`, behaving like one or the other depending on external factors such as temperature and purity. This makes them very important in usage in computer chips.

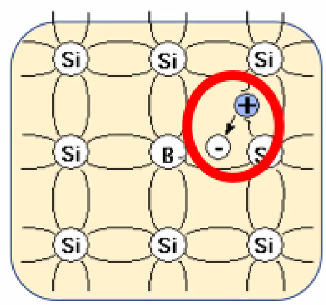
Consider silicon atoms with 4 valence electrons, forming bonds with other bonds, this structure is very stable. At room temperatore, this is more or less an insulator.

We can encourage semiconductors conductivity by the following ways:

N-type (`Negative-type`): Add a few atoms with 5 valence electrons, such as phosphorus. Since electrons carry a negative charge, this causes the overall material to hold a negative charge.



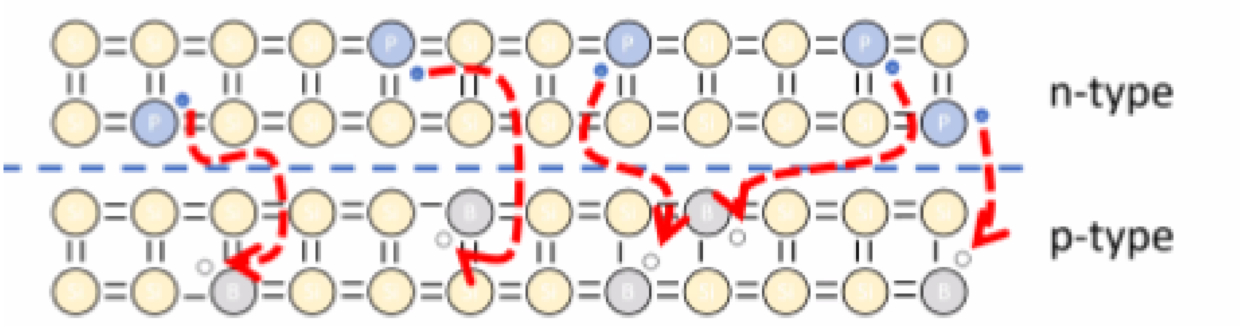
P-type (`Positive-type`): Add some atoms with 3 valence electrons, such as Boron, this creates a `hole` because it attracts electrons to compensate for its lacking valence electron.



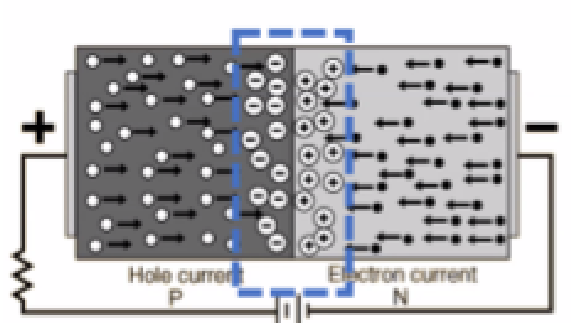
Here, the extra electrons and holes are called `charge carriers` , they move freely through the material

PN Junction

If we bring p-type and n-type together, the electrons at the surface of the n-type material are `drawn` to the `holes` in the p-type.



This is called a PN Junction, when left alone, the electron from the n section will be attracted to the holes of the p section, cancelling eachother and creating a section with no free carriers called the `depletion` layer. Highlighted in the blue, and once it becomes wide enough, a electrical field is created.

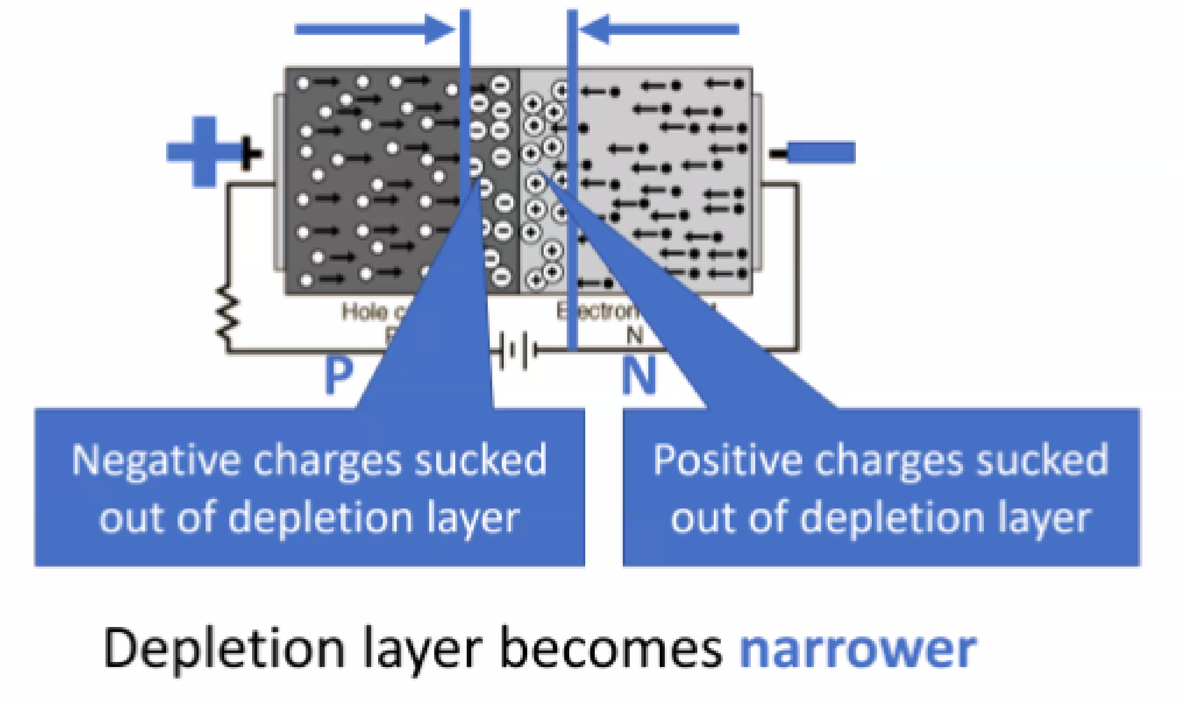


This actually creates an electrical field, when the electrons initially move from the `n-type` material to the `p-type` material (attracted by `holes`), we call that `Diffusion` then when the `Electrons` move back drawn by the electric field, we call that `Drift` . The depletion layer grows up to a certain level and becomes stable.

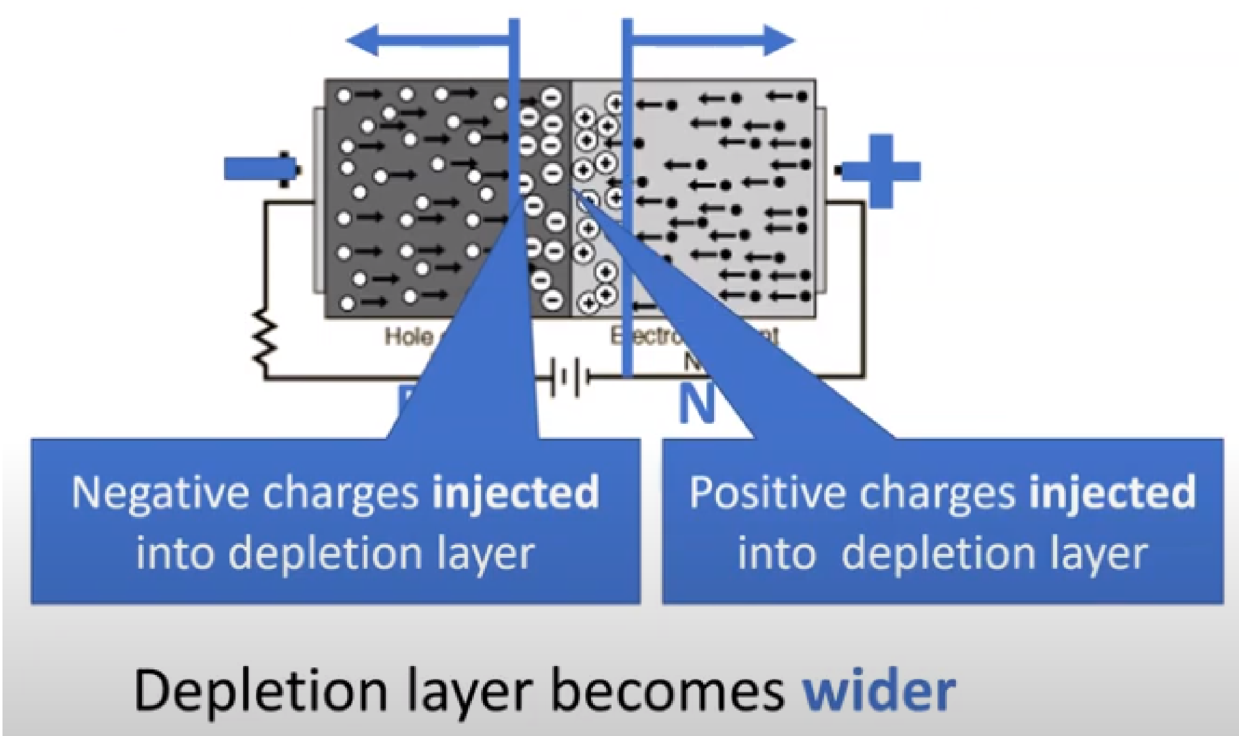
Applying voltage to a PN Junction

Because of the PN Junction is unstable, we can apply charges to the sides

- `Forward Bias` (Positive voltage to P), sucks electrons out of the depletion layer causing the depletion layer to shrink. This means that it becomes easier to travel through and thus has better conductivity, as if a switch was connected.



- `Reverse Bias` (Positive Voltage to N), pushes electrons into the depletion layer causing the depletion layer to grow, harder to travel through because of worse conductivity, as if a switch was disconnected.



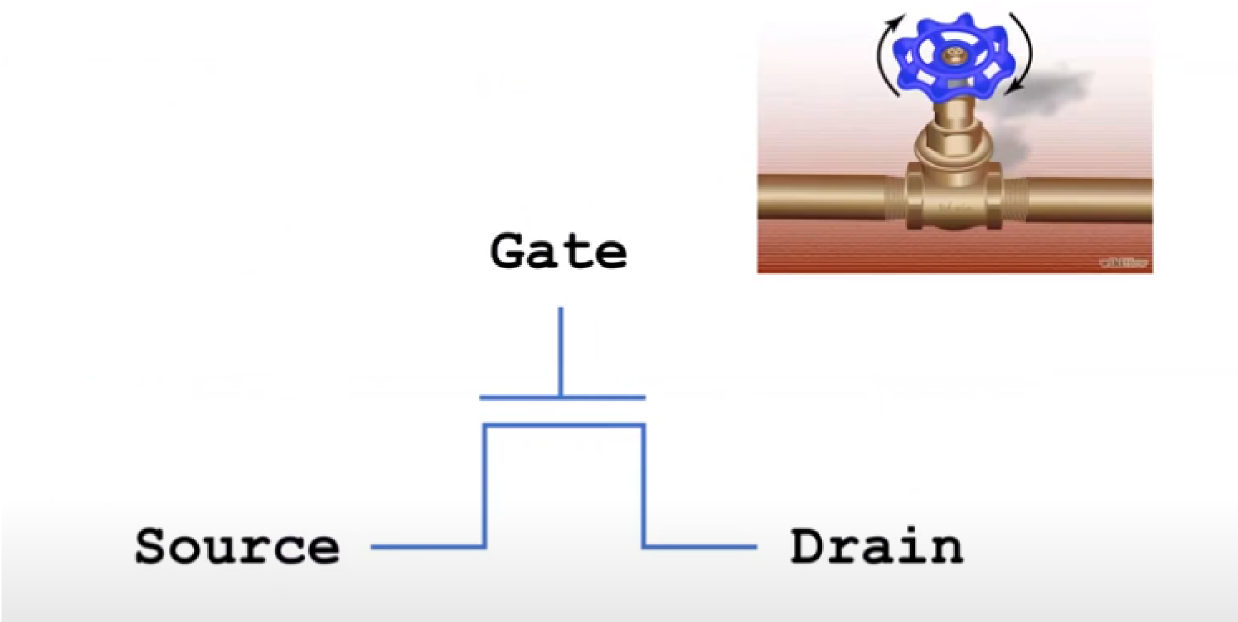
And this is essentially how transistors work

Creating transistors

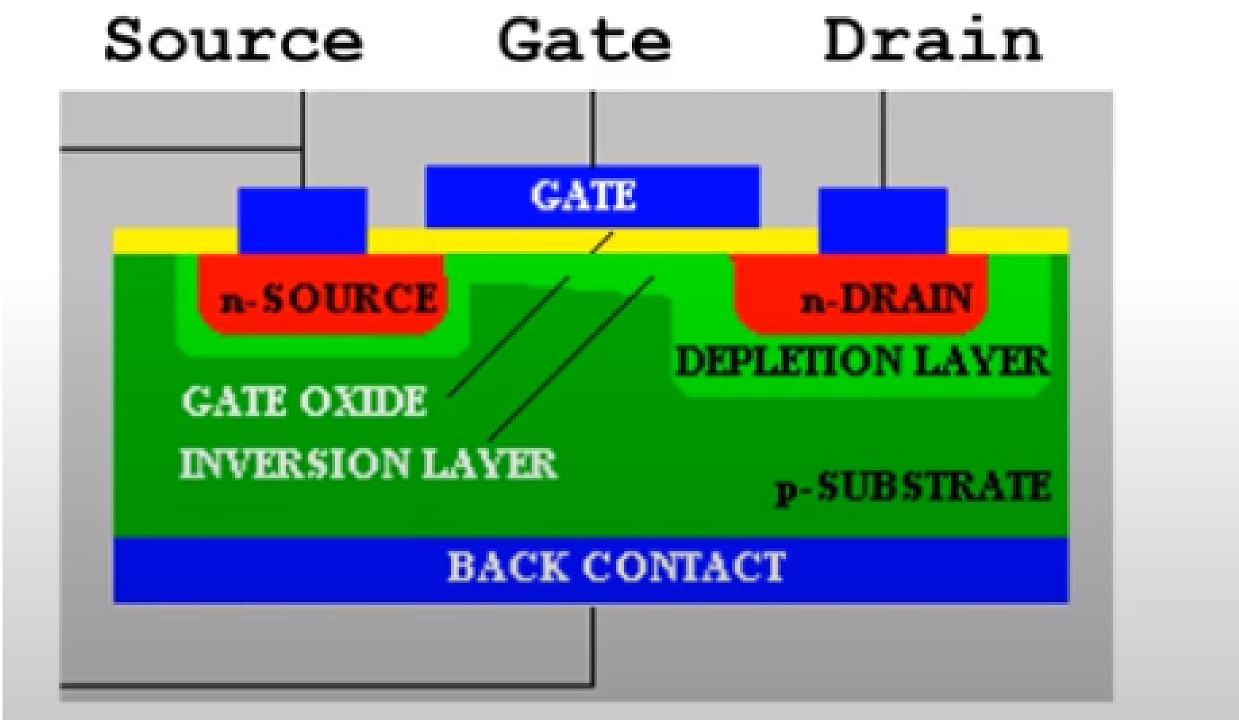
Transistors use the characteristics of PN Junctions to create more interesting behaviour. The main principle is attributed to the PN Junction, and the main type of transistor used today is called `MOSFET` - Metal Oxide Semiconductor Field Effect Transistor.

MOSFET

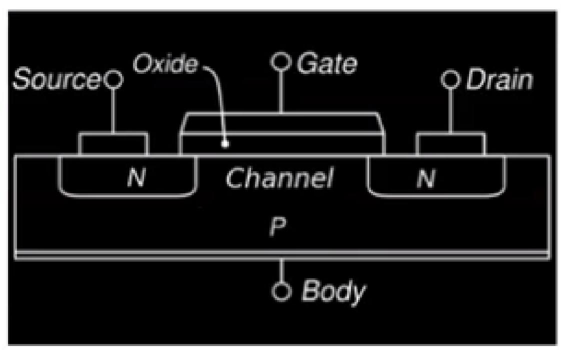
Recall that a transistor is essentially a drain, where you can control how much goes through.

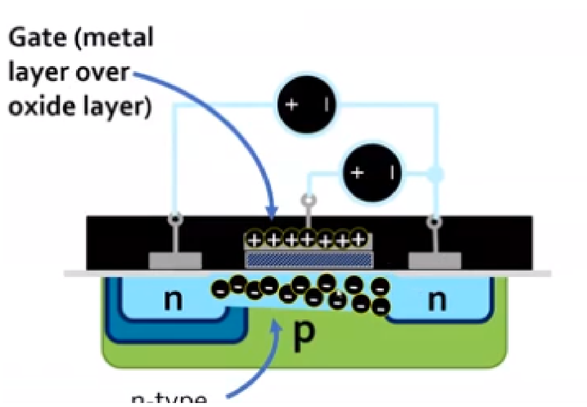


So here, Oxide is an insulator, where as Metal is a conductor. The Metal Layer is also referred to as the `Gate`



So we can apply a charge to the `Gate` which is connected to the `Oxide` material. The source and drain is simply made of two `N-Type` materials that are surrounded by `P-Type` materials. No current can pass through because they are very stable.





By creating a charge to the metal, we essentially are creating a `reverse bias` since