Lecture 2++

Henry Lau (2020)

M2 ROBOCON STUDIO

Topics

Semiconductor

Basic Diodes formulas

Fuse

Types of diodes

Usage

Circuit analysis

Lecture 1.1

Extra notes about how capacitor and inductor store charge

https://www.electronics-tutorials.ws/inductor/lr-circuits.html
https://www.electronics-tutorials.ws/rc/rc_1.html

Notice how time constant is calculated, and how the charging is affected by the time constant

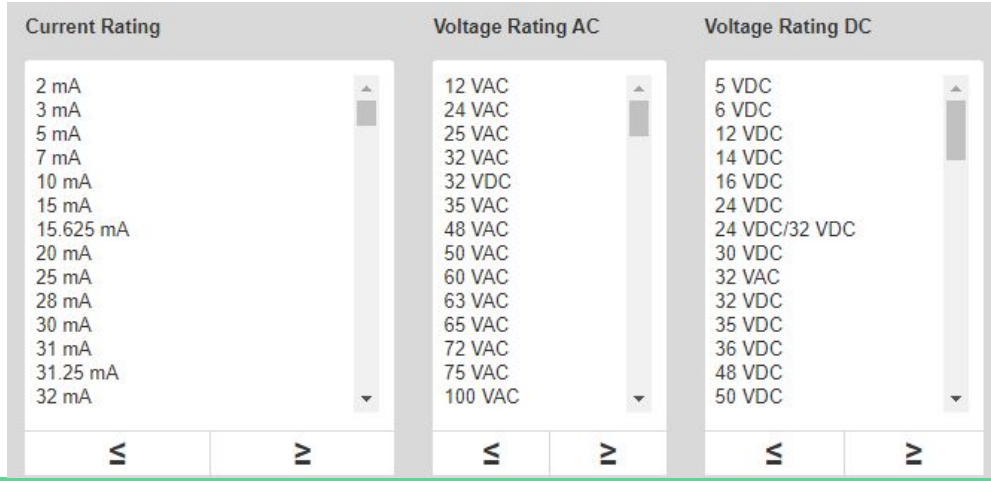
Fuse (Protection)

Fuse

Fuse is a device used for overcurrent protection to a circuit / PCB

Have resettable fuse and one off fuse

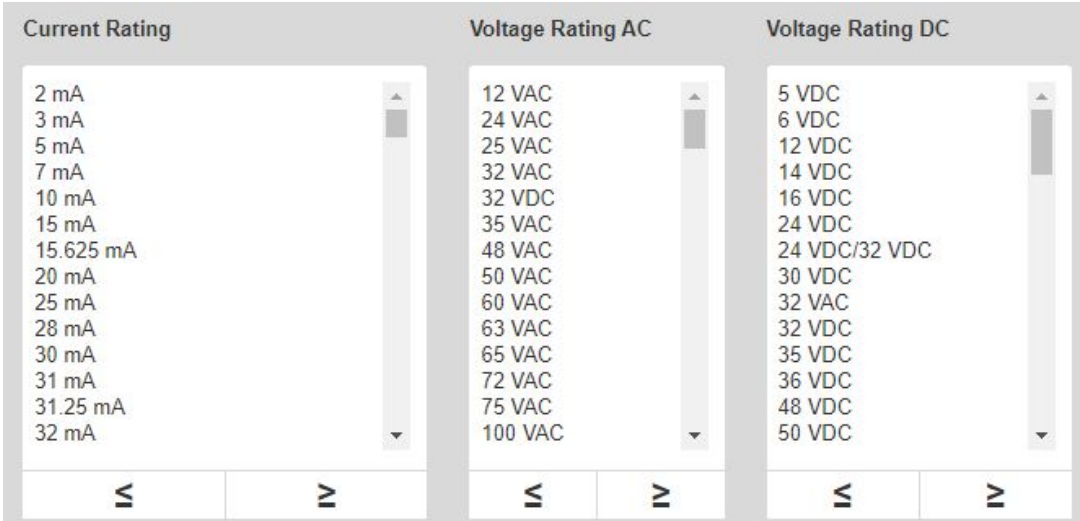
For one off fuse you could choose between fast/slow reaction time



Value

Current rating
=> the current it will allow to pass through without opening

Voltage rating
=> the isolation voltage of the fuse



Type

One-off fuse
=> needed to be replaced after being tripped

Resettable fuse (PPTC)
=> it will form open circuit when the temperature rises up
=> close when the it cools
=> even though the fuse is resettable, its resistance will be higher before it burnt

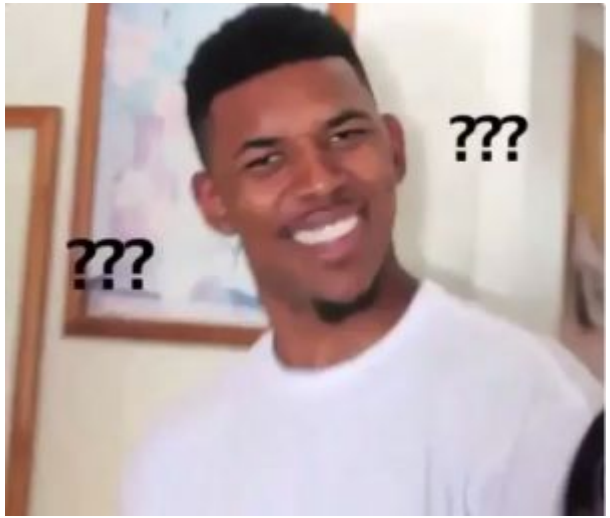
Semiconductor

Semiconductor

Conductors: Material that can conduct electricity (copper, graphite, gold etc)

Insulators: Material that won’t conduct electricity (wood, paper, plastic).

Semiconductors:????



Semiconductor

Materials that will only conduct electricity under certain situation, and will insulate electricity under other conditions.

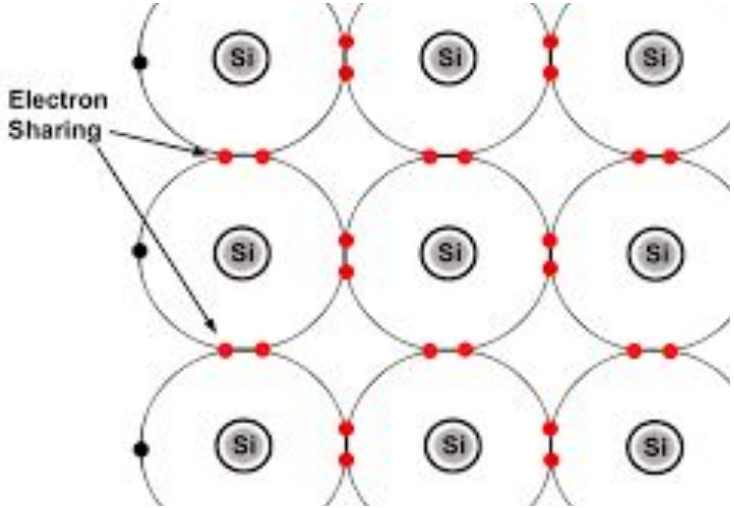
This unique property makes it a good material in controlling electrical signal.

Silicon is one of the most common semiconductors.

Semiconductor

Silicon is a chemical element with an electron arrangement of 2,8,4. The most outer shell has 4 electrons. Usually they form covalent bond with other atoms in order to get 8 outermost shell electrons. (This is inside the syllabus of DSE Chemistry, if you have any problem understanding this part, please use google.)

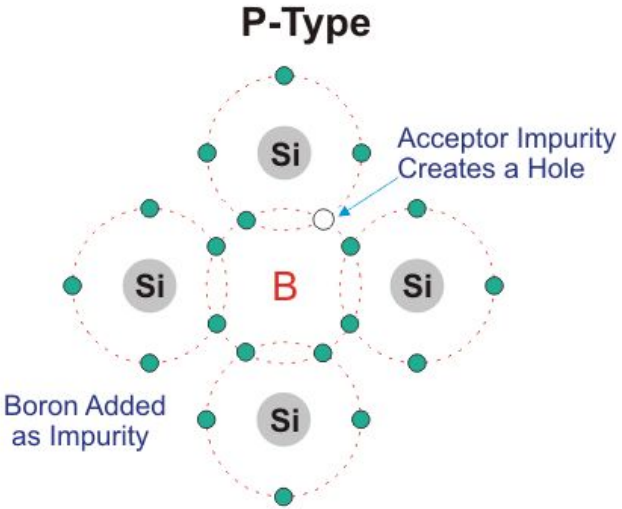
At this state it acts like an insulator.



P-type semiconductors

P-type semiconductors are created by injecting impurity with only 3 outermost electron into silicon. This will create a vacancy called “electron hole” which “carries” positive charge and forms a P-type semiconductor, with the “P” standing for positive .

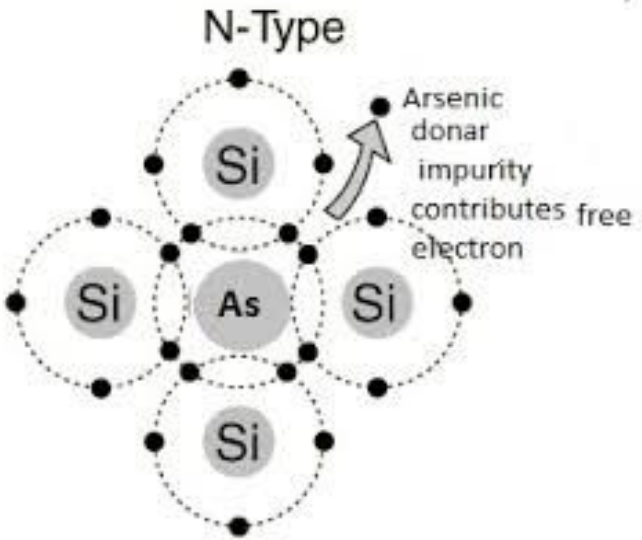
P-Type will accept electrons to fill the electron hole



N-type semiconductor

By injecting impurity with 5 outermost electron, like arsenic, the extra electron will become free electron which will induce negative charge. The free electron is mobile and could flow to other electronics. The “N” stands for negative.

The N-type readily donates its free electron.

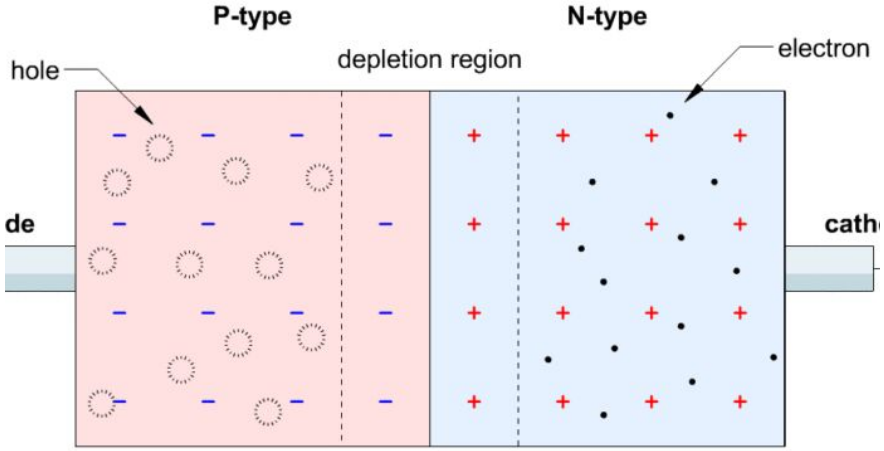


Semiconductors

N-type has free electrons which could flow away according to external electric field. P-type has electron holes that will be shifted around according to the external electric field.

When they are used alone, they are like normal conductors with slightly higher resistance.

Pairing them up will form a p-n junction.



Diode

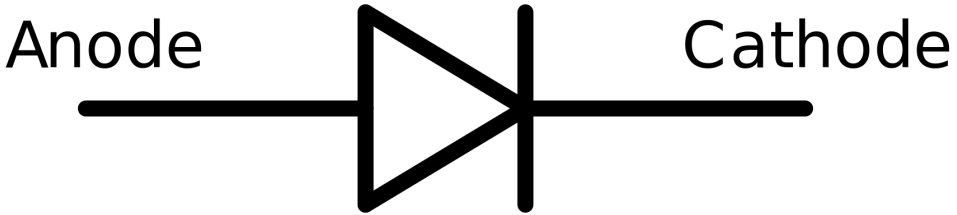
Diode

Diode is an electronic device which contains one P-N junction.

By using several PN junctions in different configurations, you can make other electronic devices.

The P side is called anode, the N side is called cathode.

There are 2 operating modes for diode, forward bias mode and reverse bias mode.

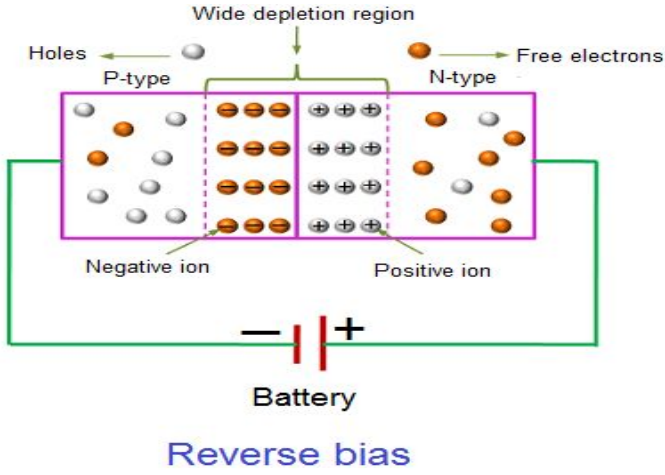


Reverse Bias Mode

In reverse bias mode, the voltage of cathode is higher than the voltage at anode.

The potential difference will pull the free electrons and electron hole away from each other and formed a depletion layer. The higher the potential difference is, the wider the depletion layer will be.

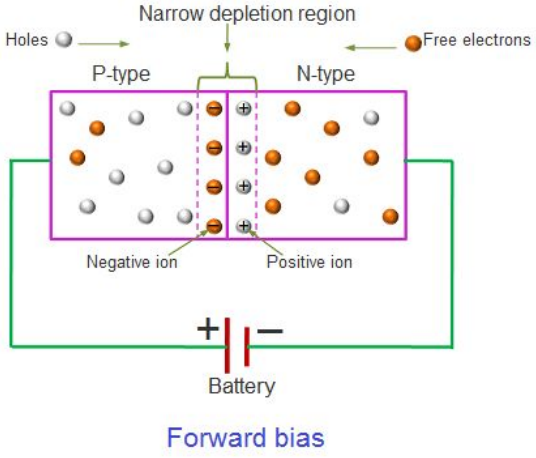
In this mode, the diode does not conducts current.



Forward Bias Mode

In forward bias mode, the voltage at cathode is lower than the voltage at anode.

The external electric field will push the electron holes in P and free electrons in N towards each other. When the electron holes and free electrons combines with each other, there will be electron flow => diode conducts current in this mode



V-I curve of a diode

$$I_D = I_S \left(e^{qV_D/NkT} - 1\right)$$

Where,

I_D = Diode current in amps

I_S = Saturation current in amps (typically 1 x 10^{-12} amps)

e = Euler's constant (~ 2.718281828)

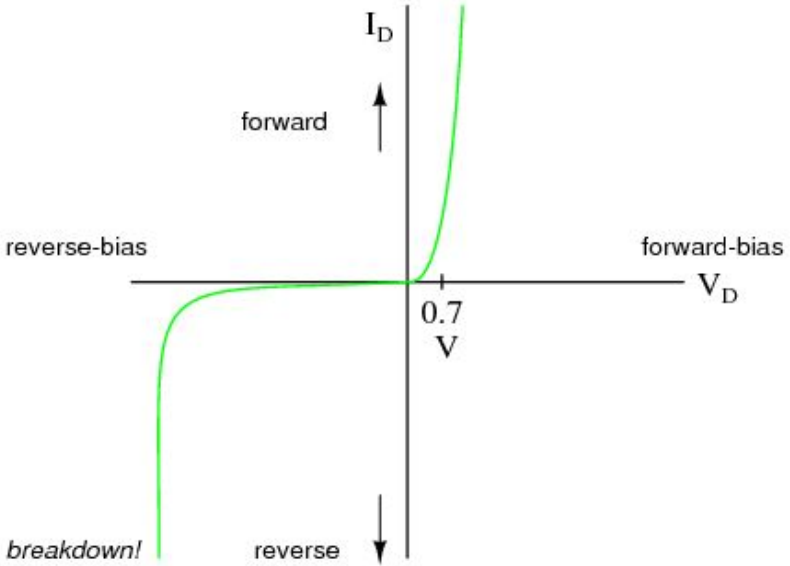
q = charge of electron (1.6 x 10^{-19} coulombs)

V_D = Voltage applied across diode in volts

N = "Nonideality" or "emission" coefficient (typically between 1 and 2)

k = Boltzmann's constant (1.38 x 10^{-23})

T = Junction temperature in Kelvins



V-I curve of a diode

Saturation is the leakage current of the diode in reverse bias mode.

The power consumption of a diode is the current passing through times voltage difference across it.

Ideally a diode could conduct infinite current.

In reality every diode has a power rating, exceeding it will damage the diode.

Assumptions (DONT DO IN EXAMS!!!!!!)

The resistance is not constant, as the slope of the curve is not constant.

Can take approximations on voltage drop across diode.

When the current is small (in tens of milliampere), we will treat diodes with around 0.1-0.2V voltage drop.

When they are conducting higher current(in hundreds of milliampere or higher), we will treat them with around 0.7V voltage drop.

Those are just general rule of thumb, in real life, each diode has varying performance.

Types of diodes

Types of diodes

Schottky diode

Zener diode

LED

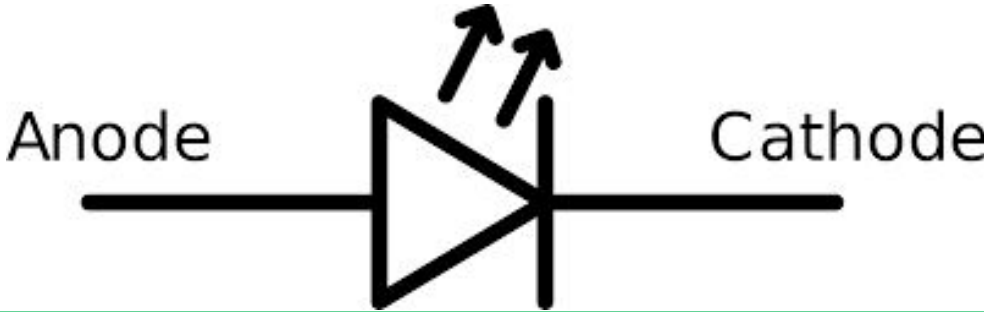
LED

LED stands for light emitting diode. As its name shows, it is a kind of diode that could turn electrical energy into light energy.

Tutorial questions in Diode (I) should have covered LED already.

LED with different color has different V-I curve.

Very commonly used in PCB as status indicator or as lighting

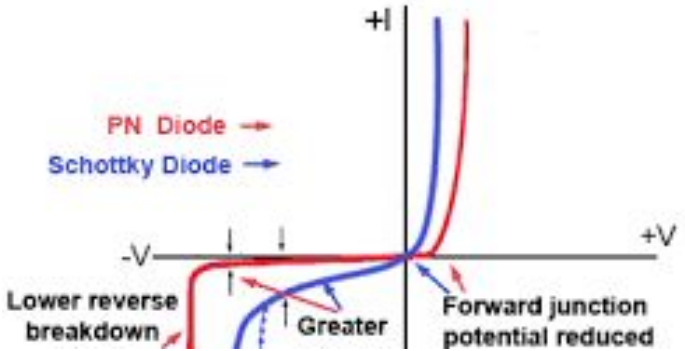


Schottky

Schottky diode has similar V-I curve with normal diode

Schottky diode is a diode designed with low dropout voltage. The reduced in voltage drop means less power power loss. (Approximate at 0.3V)

Higher leakage current, although it is insignificant in most cases



Schottky diode selection from mouser

https://www.mouser.hk/Search/Refine?N=18337915

Keywords:

Forward voltage, Vrrm, Forward current

Usually this 3 factor will usually affect the decision made

Common schottky diode used in M2: SS24

Usage

Rectifying: the AC voltage is being rectified into a DC voltage. (not relevant in M2)

OR-ing application: Allows user to using more than 1 power source safely at the same time.

Reverse polarity protection

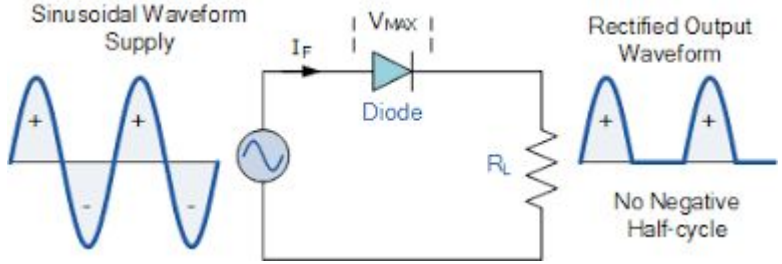
Remember AC stands for alternating current, which means the current flow in the wire is switching polarity. DC stands for Direct current.

Rectifier

2 types of rectifying, half bridge and full bridge.

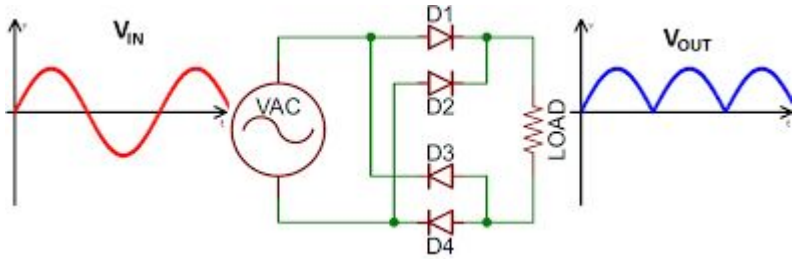
Half bridge:

Uses 1 diode



Full bridge :

Uses 4 diode

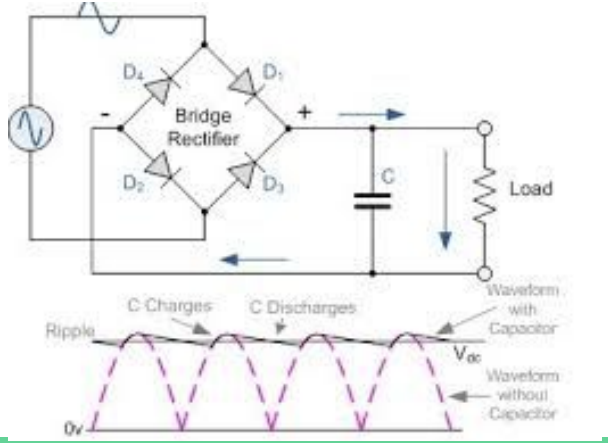


Rectifier

Half bridge uses less diodes, but is much less efficient.

The rectified voltage are not very stable, usually a capacitor is uses on the output side to store electric charge and stabilize the voltage.

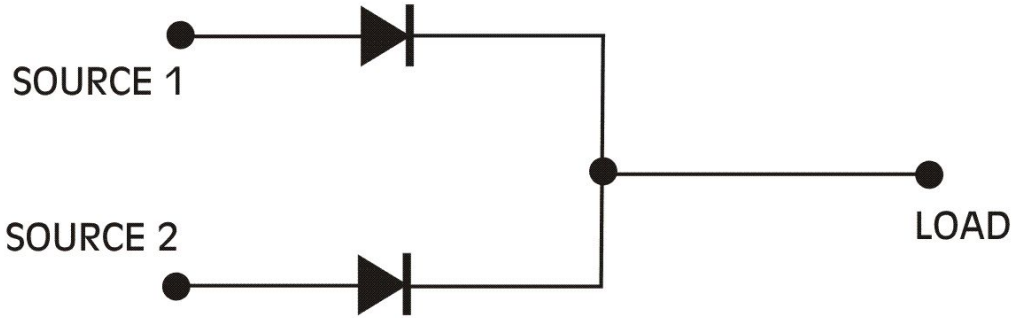
Since our competition doesn’t allow us to use AC power source, we won’t have to use such circuits in M2’s PCB.



ORing Diode

Sometimes we want to use 2 power source for 1 load. As power source are designed for sourcing current instead of sinking current, we need some measures to prevent the output current of a power to be negative.(flowing back into the power supply)

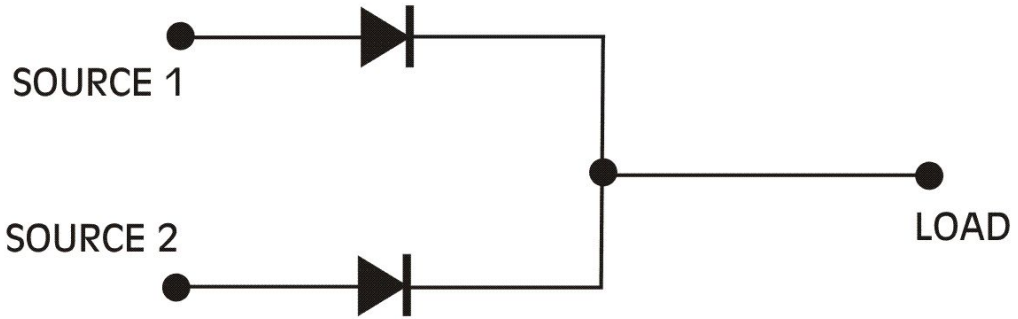
By using diode, preferably with diodes with the same model number we can ensure the current will not flow back to the power supply.



ORing Diode

There are 2 types of mode, either voltage at source 1 > source 2, or source 2 > source 1.

If source 1 > source 2, the load gets current from source 1. The diode at source 2 is being reversed bias and it won't conduct electricity. The situation will just be reversed when source 2 > source 1.



ORing Diode

Application in robocon

Sometimes you do not want to turn off some devices (like PC or raspberry PI)

Some sensors required warm up time before usage (SICK distance sensors)

Using ORing operation could allow next to infinite up time for those devices

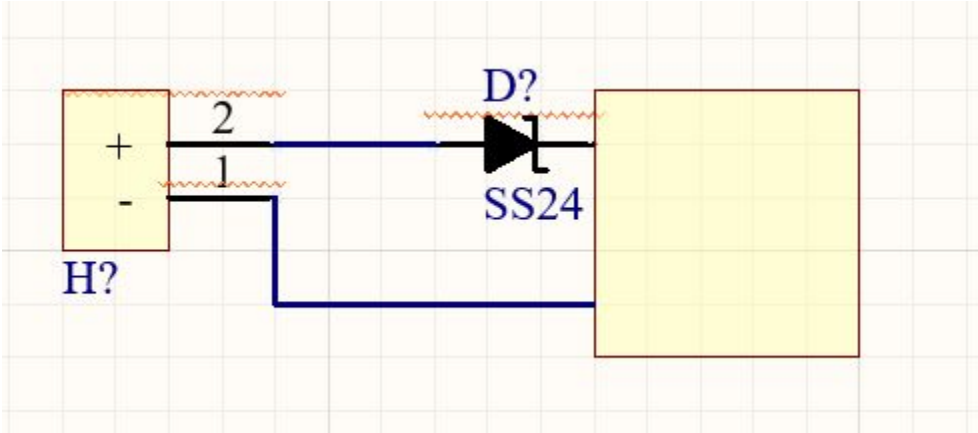
(Extra) ORing Diode vs ORing MOSFET

The advantage of using ORing diode is that it is easy to implement when compared to ORing MOSFET. ORing diode doesn’t require extra control circuits, while you need other PMIC (power management IC) to control MOSFET in ORing application.

The bad side is that it has higher power lost (average 0.3V to 0.5V drop , P=VI) when compared to ORing MOSFET settings (usually in millivolt range).

Reverse Polarity Protection

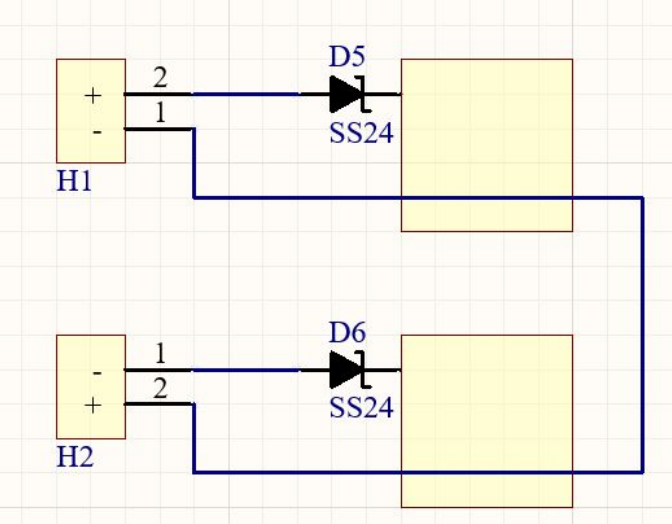
Since diode only allows current to flow in one direction, it could prevent current from flowing in reversed direction, protecting the circuit when power is connected in reverse



Reverse Voltage Protection

Only protects the circuit when it is not connected to other parts of the system

When the ground is connected to other boards (signal communication). The current could still flow through the incorrectly connected board (bottom one)

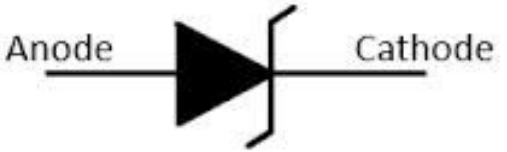


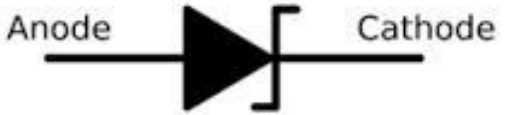
Zener diode

When the voltage at anode is higher than cathode, it will conduct current just like normal diode.

But when the voltage at cathode is higher than anode at a certain threshold, it will conducts current from . (Zener effect)

The level is named “Zener voltage”.



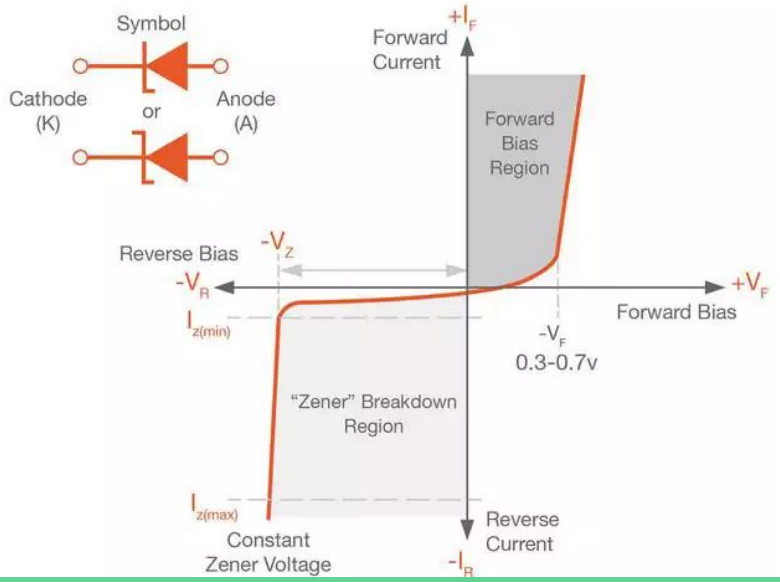


Zener diode

Zener effect: when the reverse voltage has reached its zener voltage, it will conduct current. While other types diode will be damaged permanently, zener diode could be recovered from breakdown.

The Zener voltage is constant.

Power loss = zener voltage * current.



Zener Diode Selection

https://www.mouser.hk/Search/Refine?N=18337913&orgKeyword=zener+diode

Keywords: Zener voltage, Power dissipation, uni/bidirectional

Usage

Voltage regulator (for very low current usage)

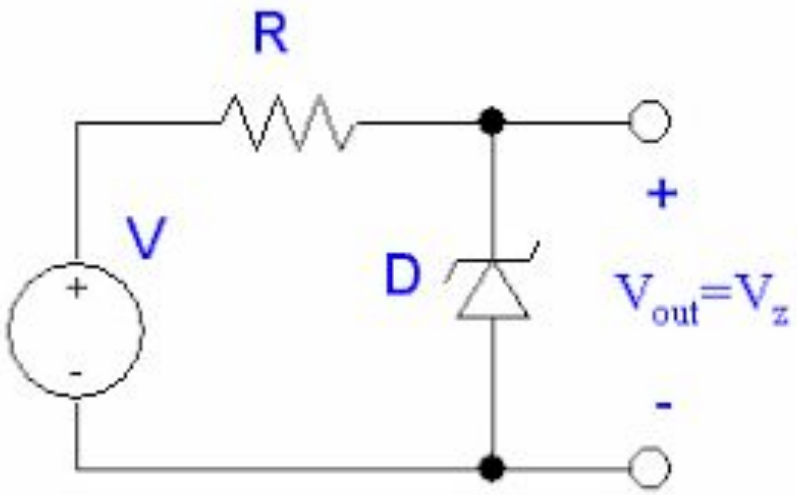
Voltage reference (could use dedicated voltage reference IC for higher accuracy)

Voltage regulator

The regulated voltage is equal to the zener voltage.

It could be only used in small current operation, and it is not an efficient way to regulate voltage.

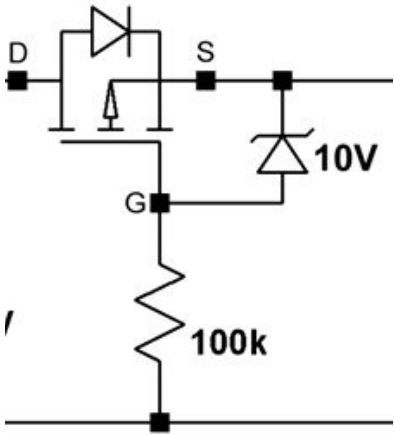
Not commonly used in robocon.



Voltage reference.

As the zener voltage is constant, it can be used as voltage reference for different kinds of applications.

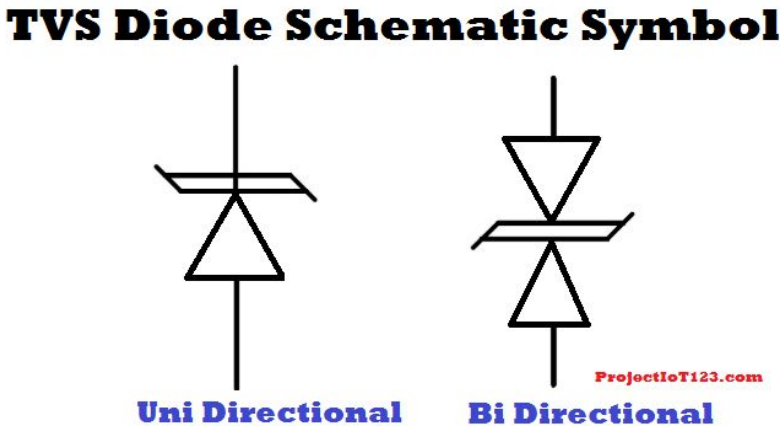
For example, we could use a zener diode to control the the voltage difference between gate and source pin of MOSFET. As the DC resistance of MOSFET is dependent to the voltage across its gate and source pins.



TVS Diode

Protect components from voltage spike

Uni / bi-directional



TVS diode selection

TVS diode used in HKU Robocon

https://www.mouser.hk/datasheet/2/240/Littelfuse_TVS_Diode_SMBJ_Datasheet.pdf-1108540.pdf

Could be added in front of power circuitry to protect it from voltage surge transient current (regenerative braking from motor)

Altium Lab Section

Design a power input part of a PCB, with the following specifications

Schottky Diode for reverse polarity protection
TVS diode for transient protection
Bulk Capacitor
Suitable power connector as input

Prerequisite: Altium Introduction (I) and (II)

Extra notes

DC and AC circuit analysis

DC analysis => open all capacitor, short all inductors

AC analysis => short all capacitor, open all inductors

Thevenin and Norton

Circuit analysis for calculating equivalent resistance and reactance.

Useful when deciding multistage circuits

Google for the methods.

Soldering profile

Most electronic devices are heat sensitive. Their soldering profile should be read before soldering them.

If the component is soldered for extensive time, the component could be permanently damaged.

https://www.mouser.hk/datasheet/2/408/TLP291-4-1209261.pdf

Common problem in soldering

Solder doesn’t stick to the pad/component

- Ensure the soldering iron is in contact with the pad and component, use flux

Solder doesn’t spread across the pad

- Use hot air gun on the surrounding area (instead of increasing temp of iron)

Solder doesn’t flow into the core of multi core wire

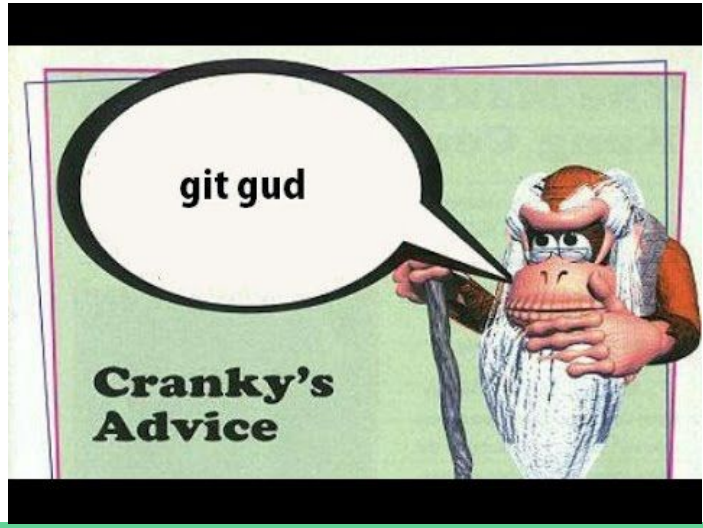
- Dip the wire into flux

Can’t solder parts that are too small

- Design PCB that you could solder

Remember to clean the PCB after soldering it

JUST GET GOOD LOL



SMD package standards for resistor and capacitor

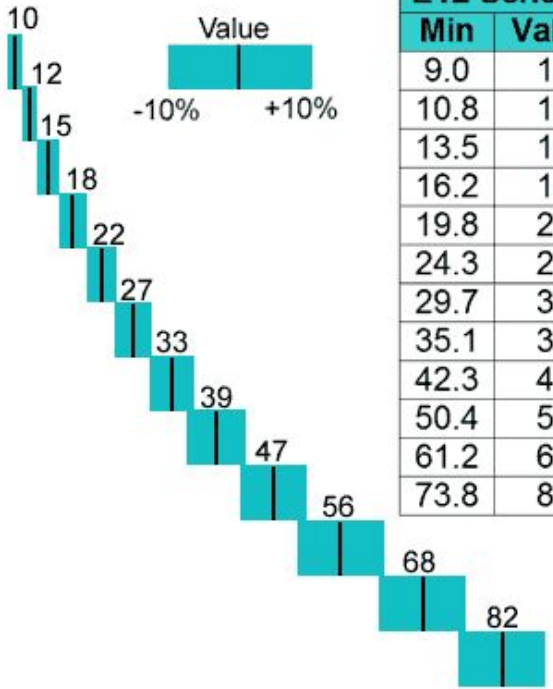
https://electronics.stackexchange.com/questions/375637/difference-between-1206-0805-and-0603-smd-resistor

Standard Value

You could purchase and use standard value components along the E series of preferred components

E3, E6, E12, E24 etc

Reduce pressure in logistics and purchase



E12 Series +/- 10%		
Min	Value	Max
9.0	10	11.0
10.8	12	13.2
13.5	15	16.5
16.2	18	19.8
19.8	22	24.2
24.3	27	29.7
29.7	33	36.3
35.1	39	42.9
42.3	47	51.7
50.4	56	61.6
61.2	68	74.8
73.8	82	90.2