Vacuume tubes

Vacuum tube

A **vacuum tube**, an **electron tube**, or valve (British usage) or, colloquially, a **tube** (North America), is a glass or metal enclosure in which electrons move through the vacuum or gas from one metal electrode to another.

The vacuum tube is often used to amplify weak currents or act as a one-way valve (rectifier) for electric current.

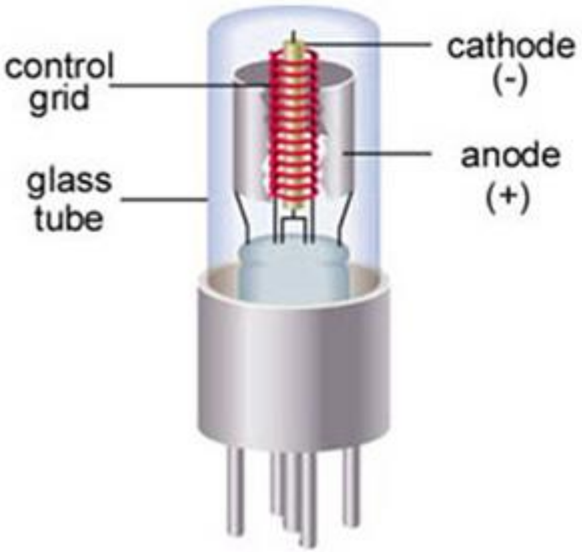
The simplest kind of electron tube is the diode, which was invented in 1904 by John A. Fleming. In Greek, “di” means “two,” and it was called a diode since it only had two electrodes inside—the negative electrode or “cathode” and the positive electrode or “anode.”

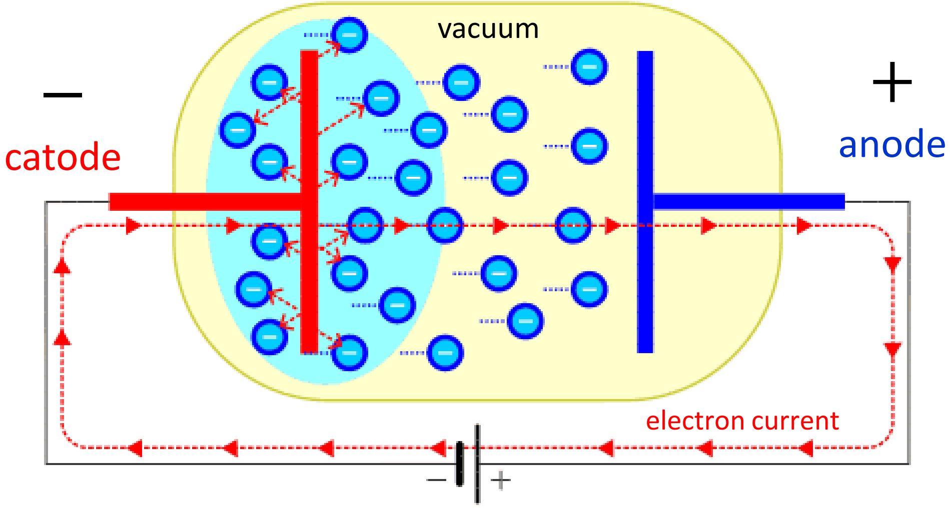
double
diode

double
triode

https://ethw.org/Electron_(or_Vacuum)_Tubes

Vacuum tubes
diode

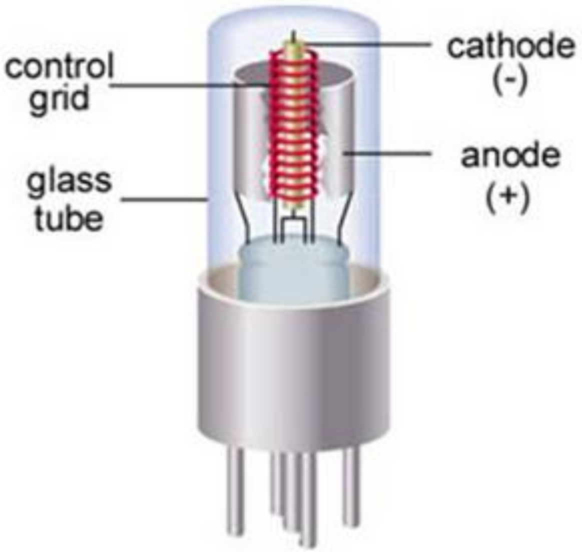


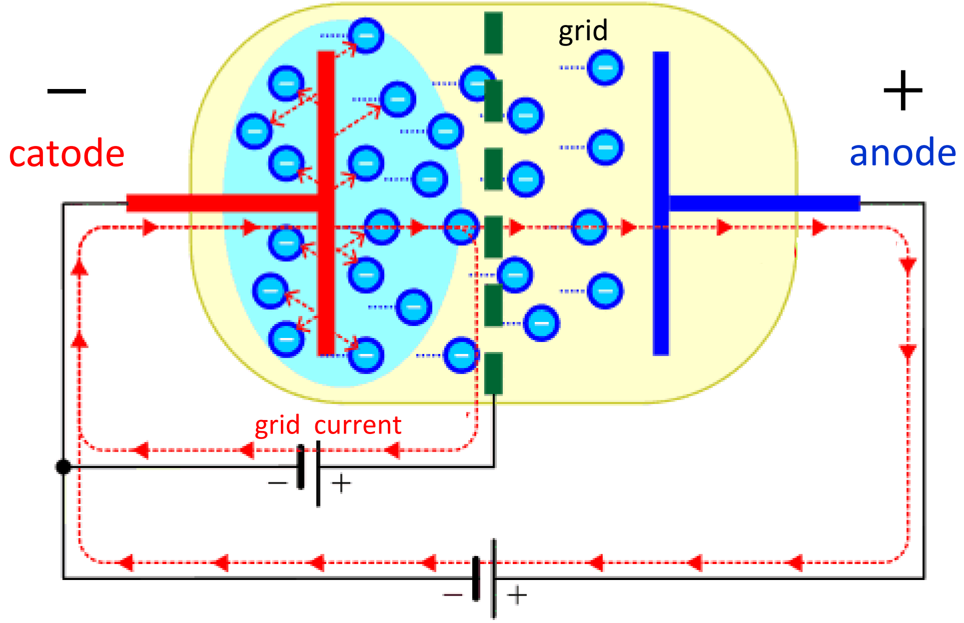


https://www.extremetech.com/

https://eduinf.waw.pl/inf/prg/009_kurs_avr/1040.php

Vacuum tubes
triode





https://www.extremetech.com/

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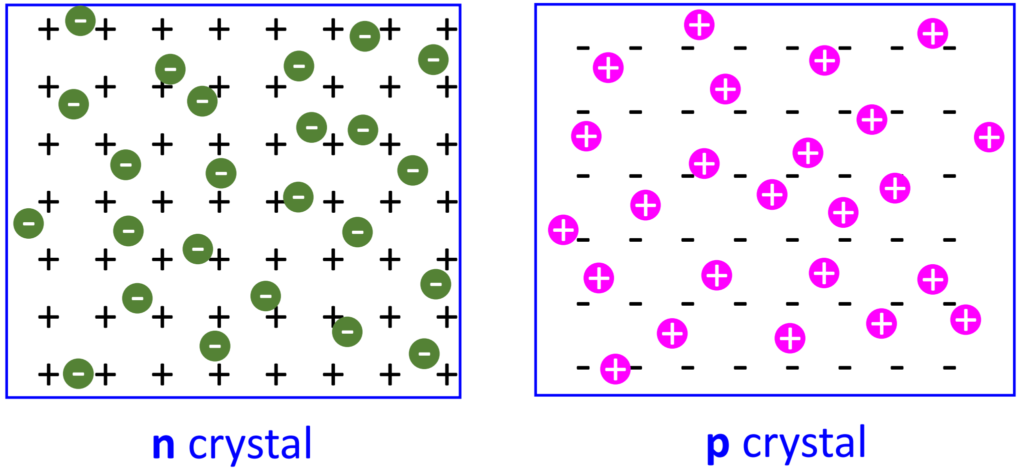
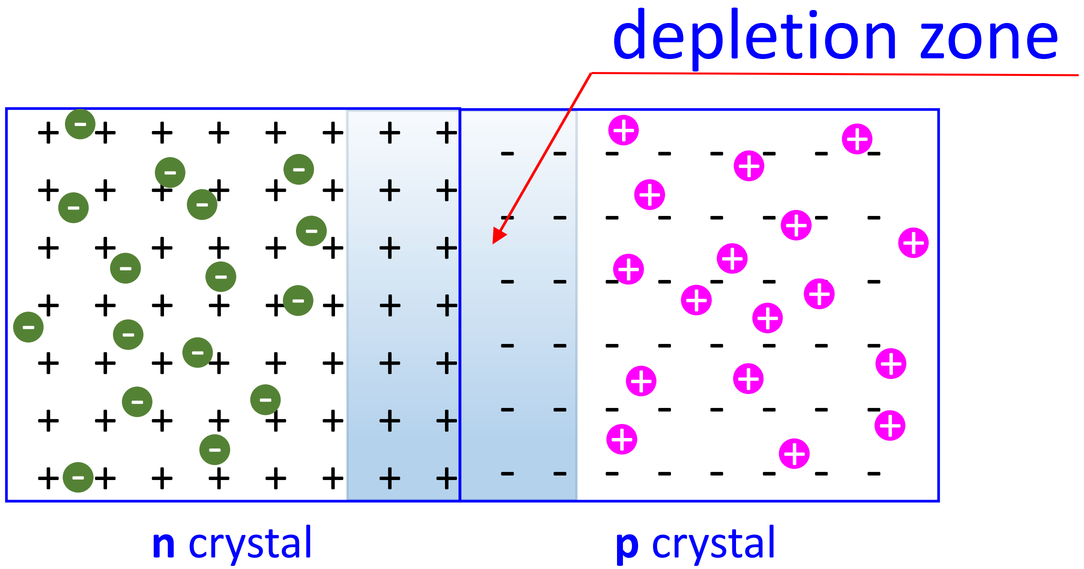
Semiconductor Devices and Circuits

The *p-n* junction without an external applied voltage

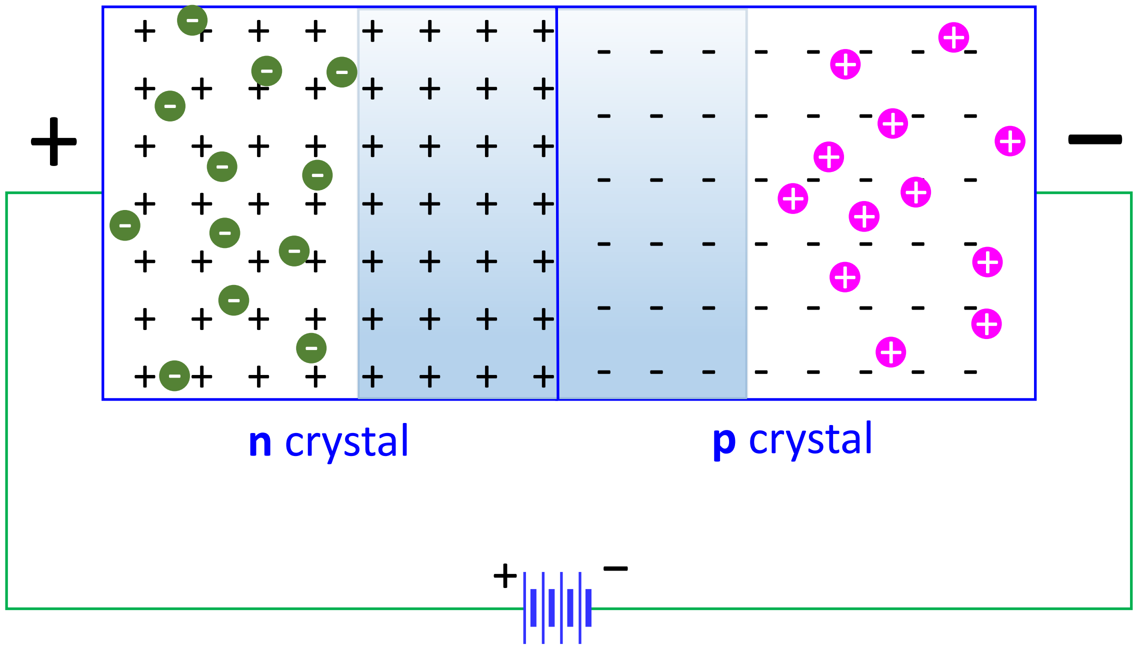




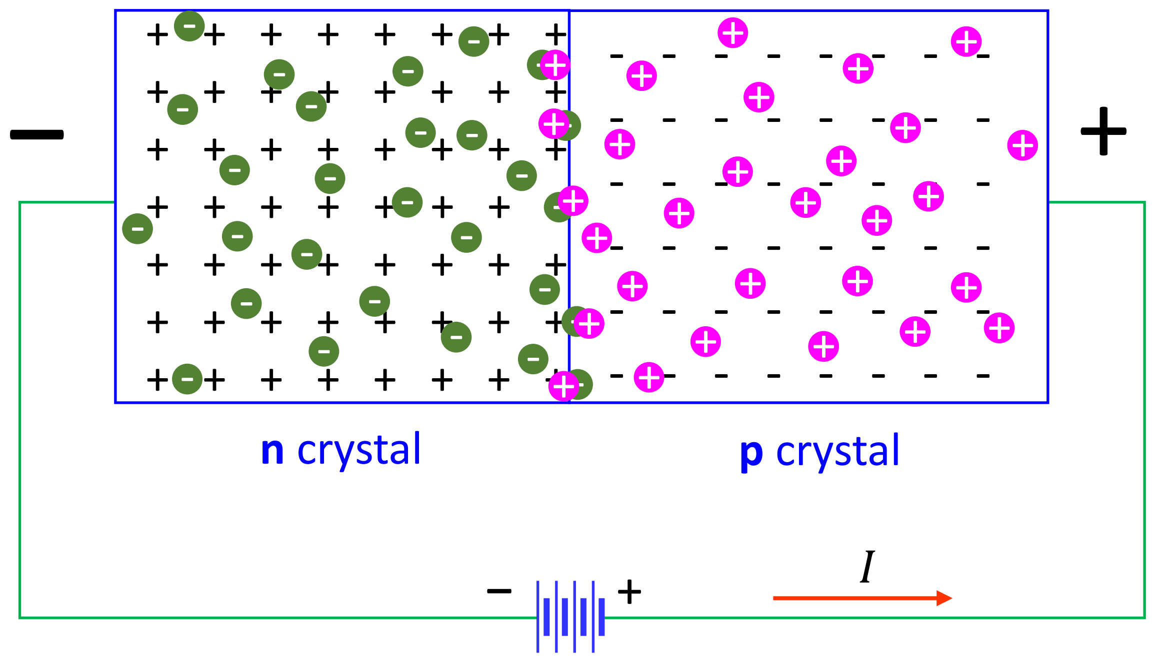
depletion zone

- The **area** where holes and electrons become **depleted** is generally known by the term **depletion region**. It is an **area** where there is lack of majority current carriers. Normally, a **depletion region** is developed when P-N junction is formed.
- The **depletion region** is also called as **depletion zone**, **depletion** layer, space charge **region**, or space charge layer. The **depletion region** acts like a wall between p-type and n-type semiconductor and prevents further flow of free electrons and holes.

The *p-n* junction with an external applied voltage

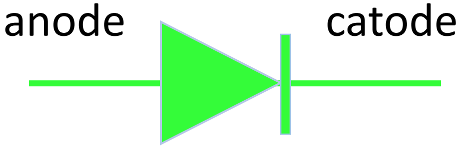


The *p-n* junction with an external applied voltage



Semiconductor Diode

A p-n junction diode is two-terminal or two-electrode semiconductor device, which allows the electric current in only one direction while blocks the electric current in opposite or reverse direction. If the diode is forward biased, it allows the electric current flow. On the other hand, if the diode is reverse biased, it blocks the electric current flow. P-N junction semiconductor diode is also called as p-n junction semiconductor device.



The basic symbol of p-n junction diode

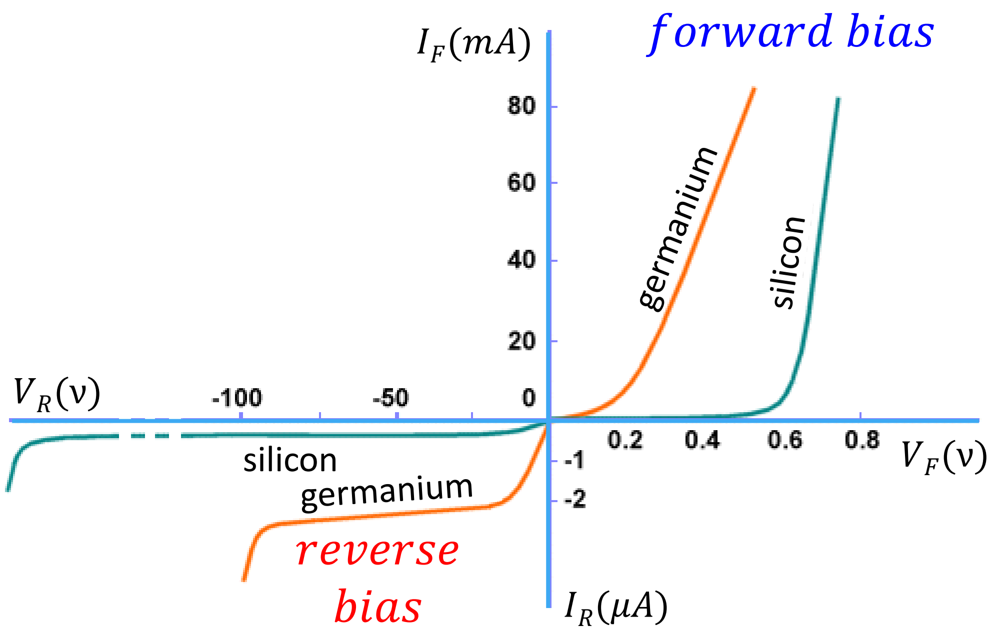
https://www.digikey.es/product-detail/es/vishay-semiconductor-diodes-division/1N5408-E3-54/1N5408-E3-54GICT-ND/190152

Typical voltages for a diode

- The voltage dropped across a conducting, forward-biased diode is called the *forward voltage*. Forward voltage for a diode varies only slightly for changes in forward current and temperature, and is fixed by the chemical composition of the P-N junction.
- Silicon diodes have a forward voltage of approximately 0.7 volts.
- Germanium diodes have a forward voltage of approximately 0.3 volts.
- The maximum reverse-bias voltage that a diode can withstand without “breaking down” is called the *Peak Inverse Voltage*, or *PIV* rating.

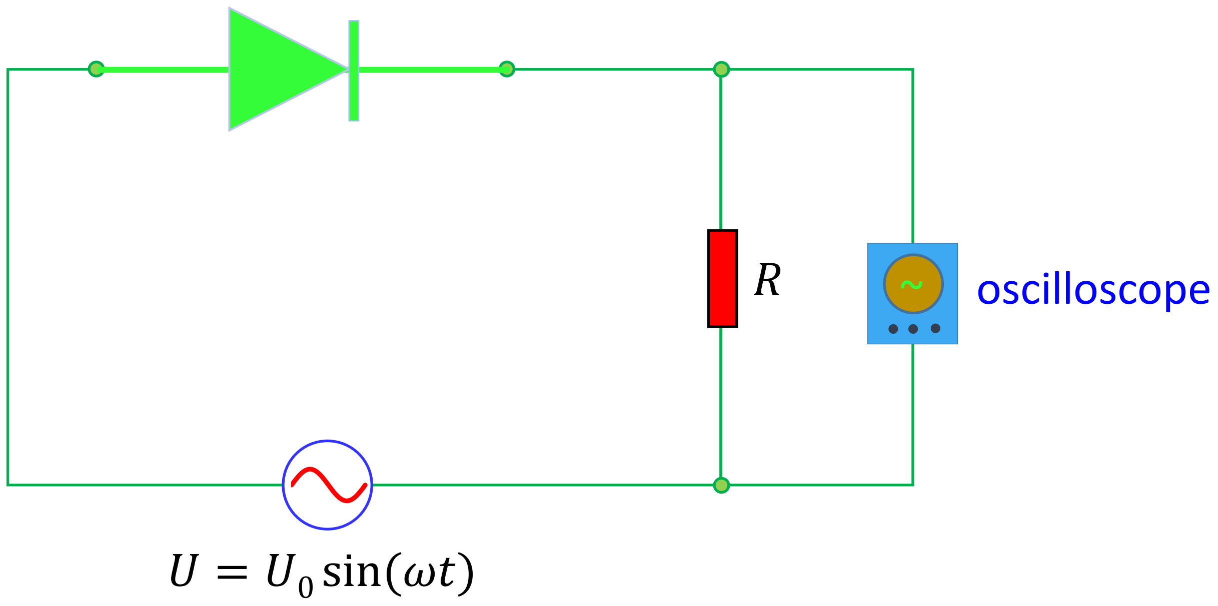
https://www.allaboutcircuits.com/textbook/semiconductors/chpt-3/introduction-to-diodes-and-rectifiers/

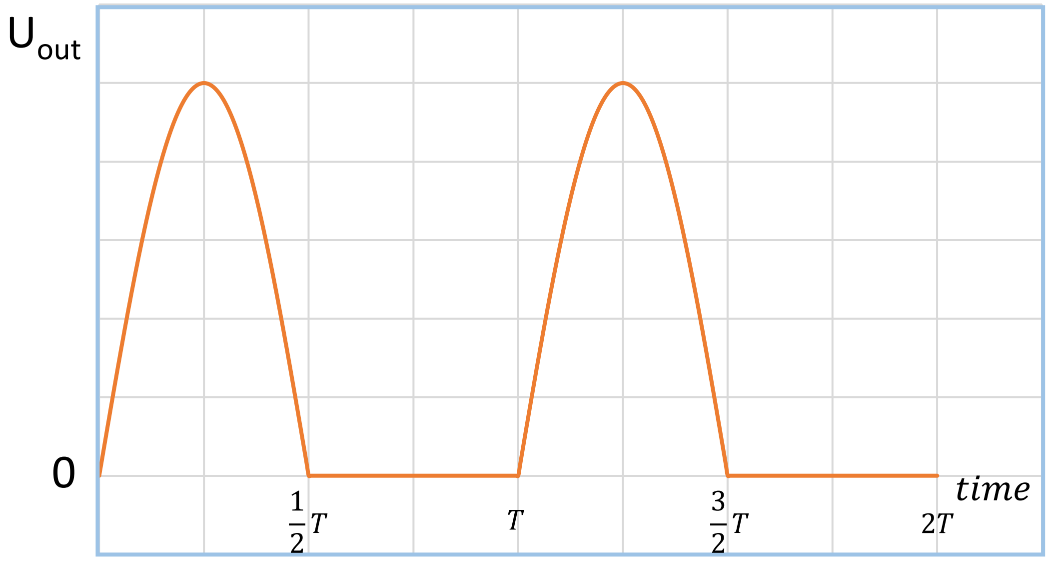
Characteristic curves for silicon and germanium diodes



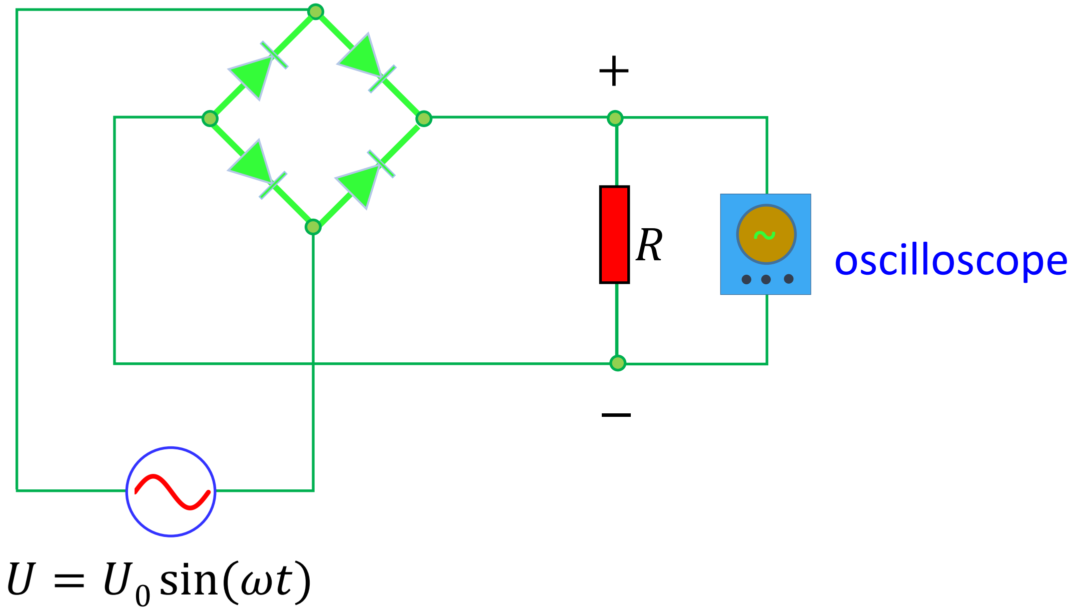
http://www.technologyuk.net/physics/electrical-principles/the-diode.shtml

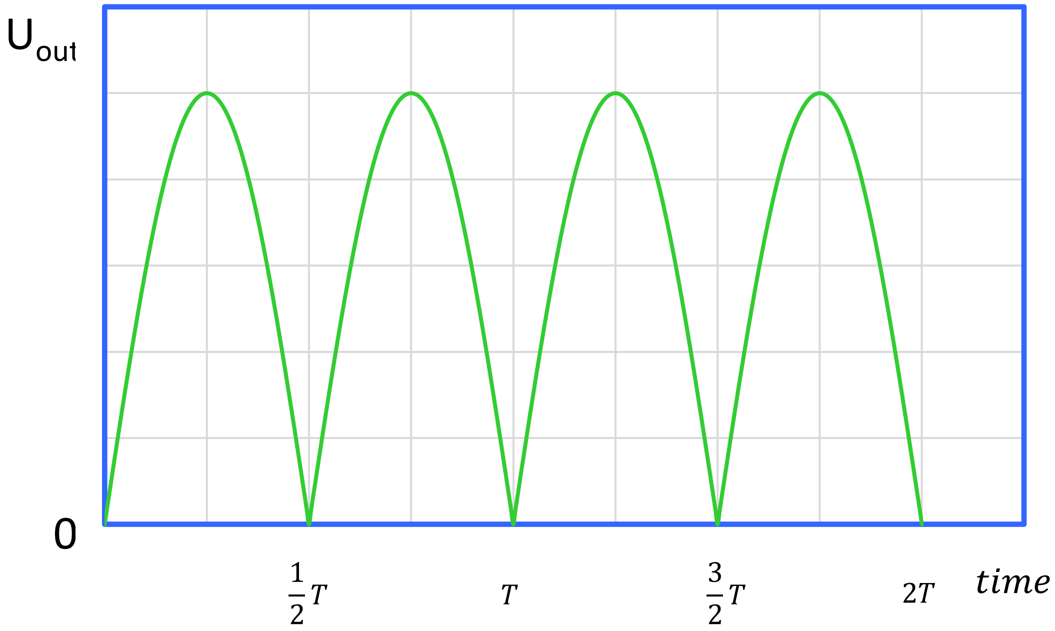
Diode rectifier



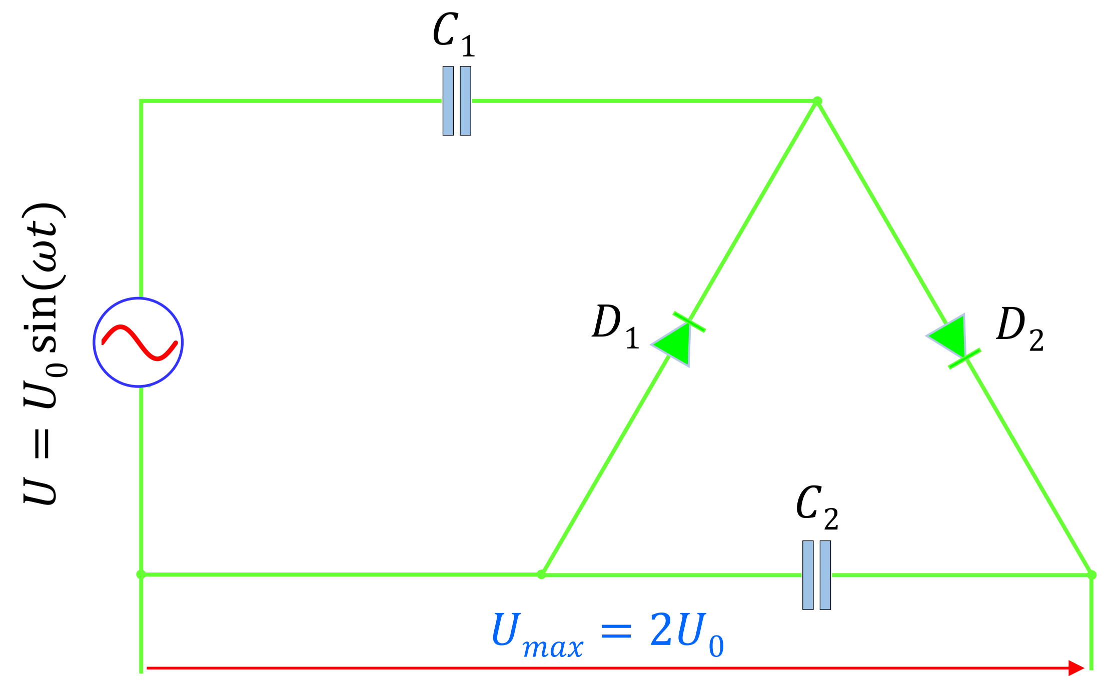


The Diode Bridge (Graetz Bridge) Rectifier



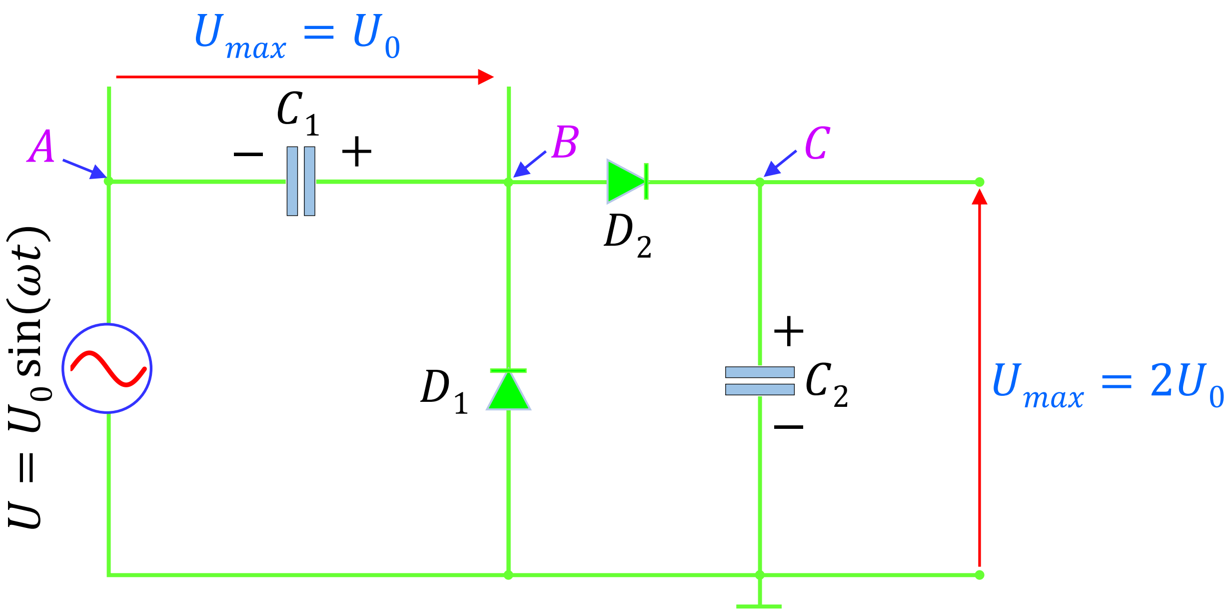


DC Half-Wave Voltage Doubler diagram



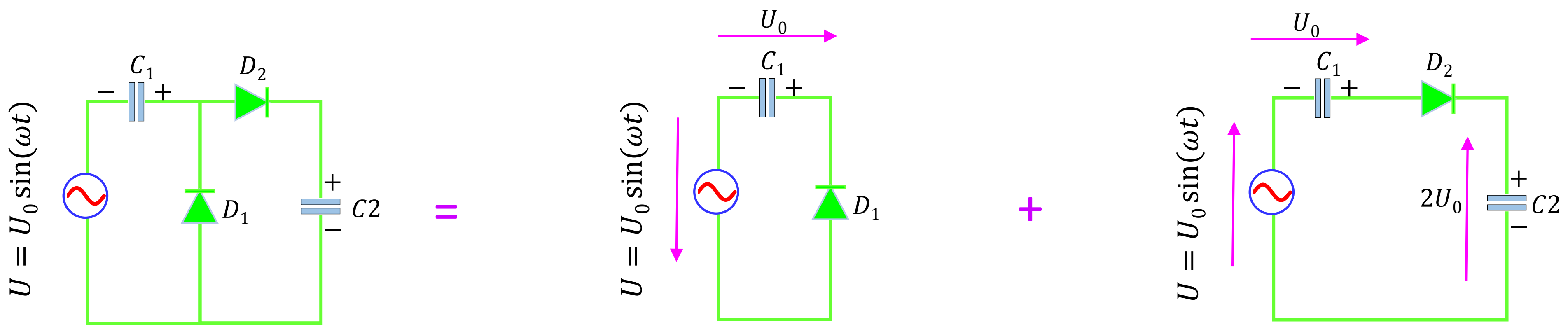
https://www.nutsvolts.com/magazine/article/dc-voltage-converter-circuits

DC Half-Wave Voltage Doubler diagram



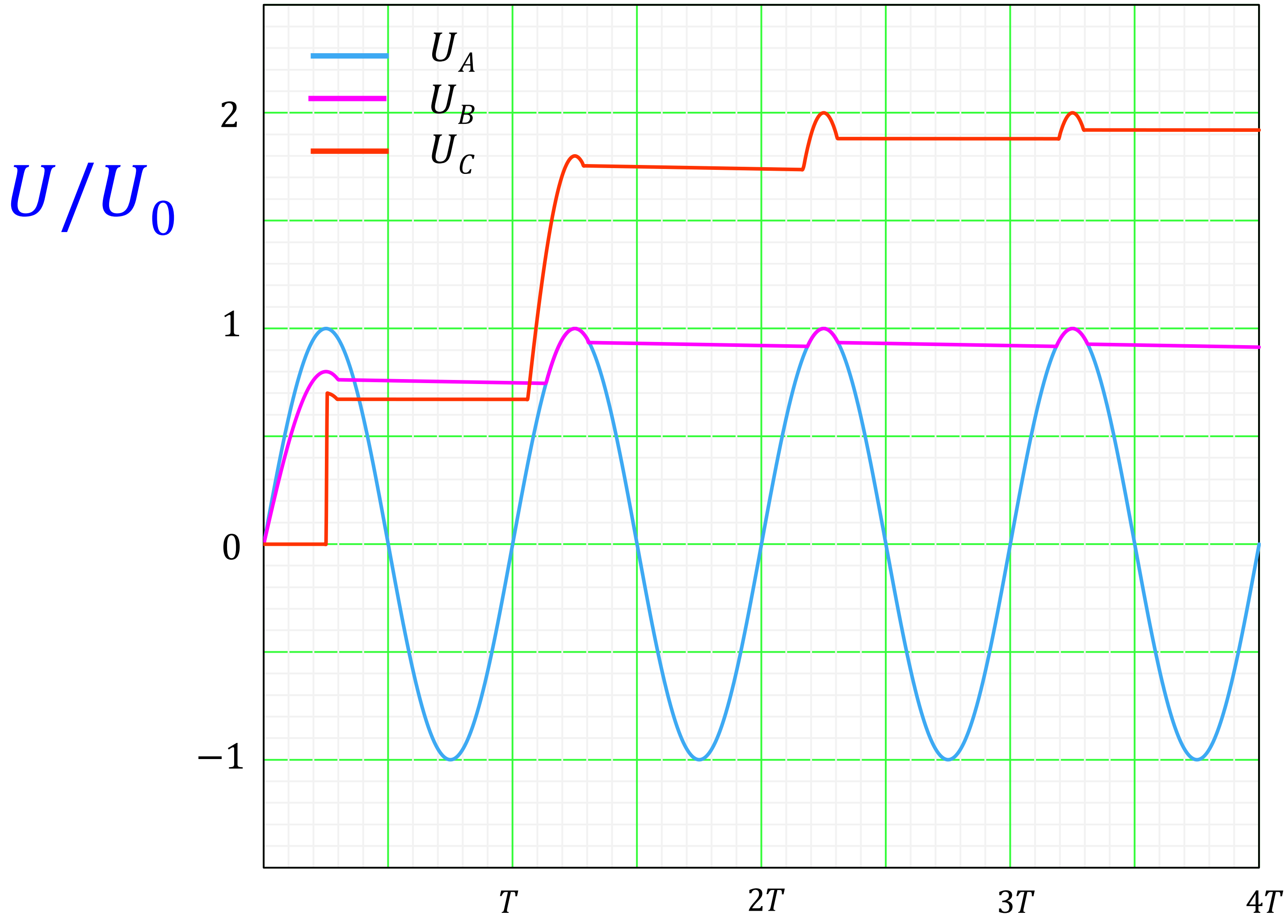
https://www.allaboutcircuits.com/textbook/semiconductors/chpt-3/voltage-multipliers/

DC Half-Wave Voltage Doubler diagram

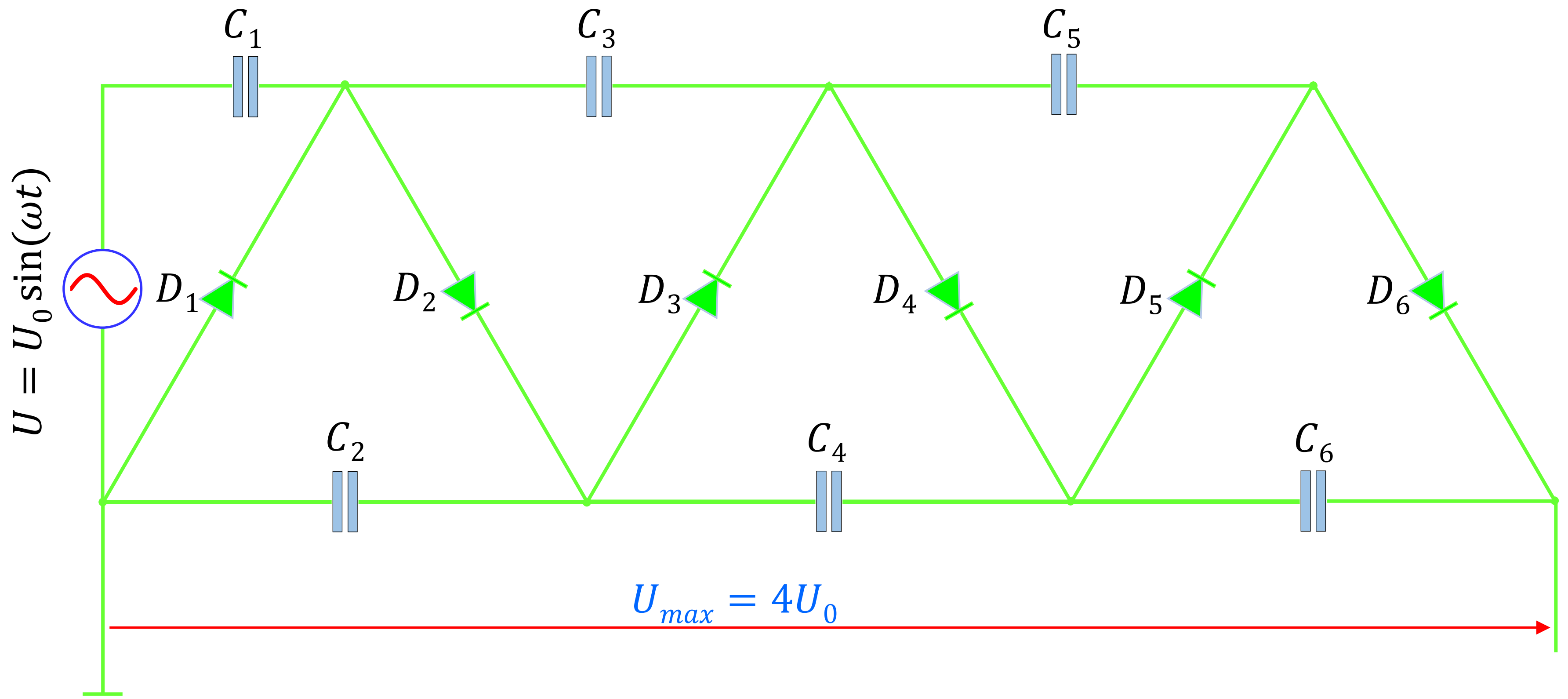


https://techwritingcareer.com/liechtml/Semi/SEMI_3.html

DC Half-Wave Voltage Doubler diagram



DC voltage quadrupler diagram



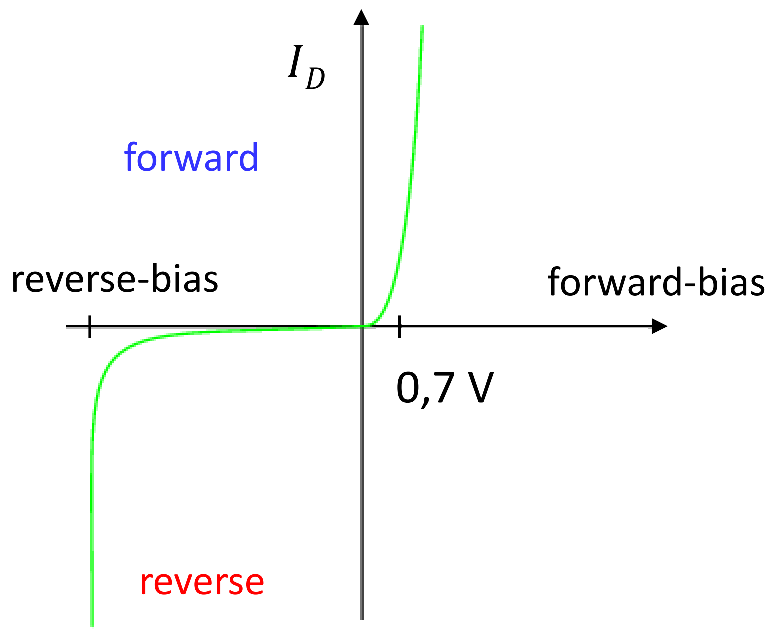
https://www.nutsvolts.com/magazine/article/dc-voltage-converter-circuits

Zener Diode

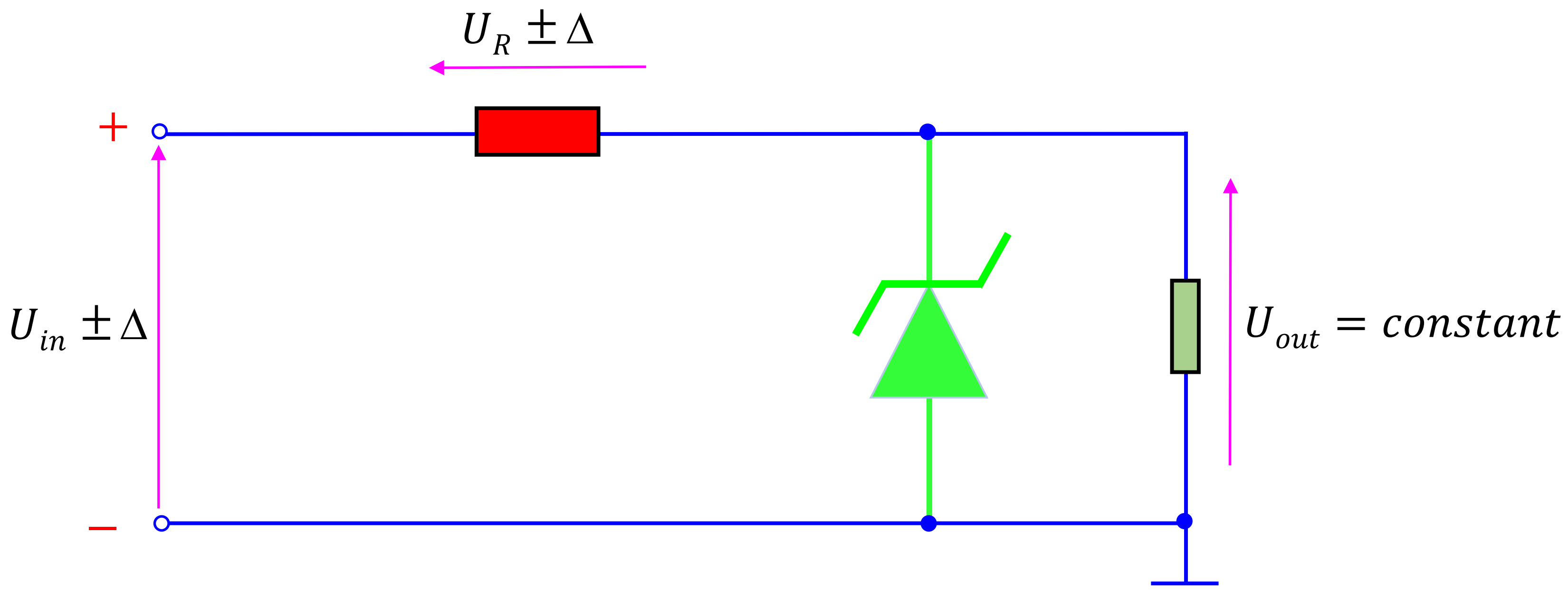
- Zener diodes are normal P-N junction diodes operating in a reverse biased condition. Working of the Zener diode is similar to a P-N junction diode in forward biased condition, but the uniqueness lies in the fact that it can also conduct when it is connected in reverse bias above its threshold/breakdown voltage.
- When a normal diode is biased such that a negative voltage is applied to the n side and positive voltage to the p side, the diode is said to be in forward biasing condition. This applied voltage tends to decrease the potential barrier after it goes beyond the threshold voltage. At this point and afterwards, the majority carriers cross the potential barrier and the device starts conducting with flow of current through it.
- When the diode is biased in reverse condition to above, the applied voltage is such that it adds to the potential barrier and hinders the flow of majority carriers. However it does allow the flow of minority carriers (holes in *n* type and electrons in *p* type). As this reverse bias voltage increases, the reverse current tends to increase gradually.
- At a certain point, this voltage is such that it causes breakdown of the depletion region, causing a massive increase in the flow of current. This is where the Zener diode working comes into play.

Zener Diode

Zener diode breakdown voltages can range from 2 to 200 V.

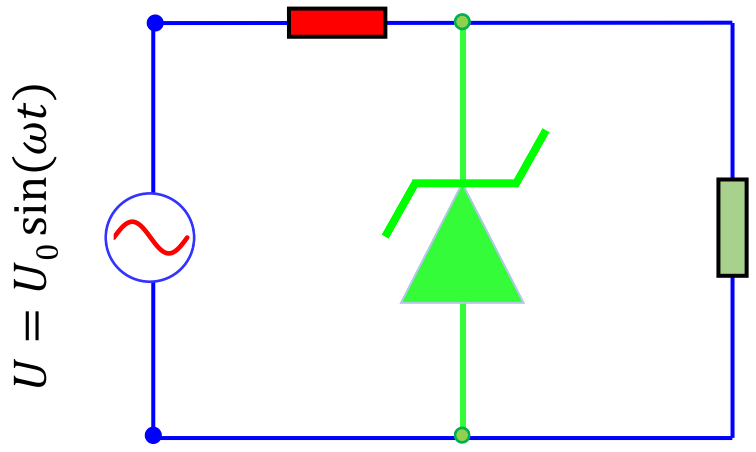


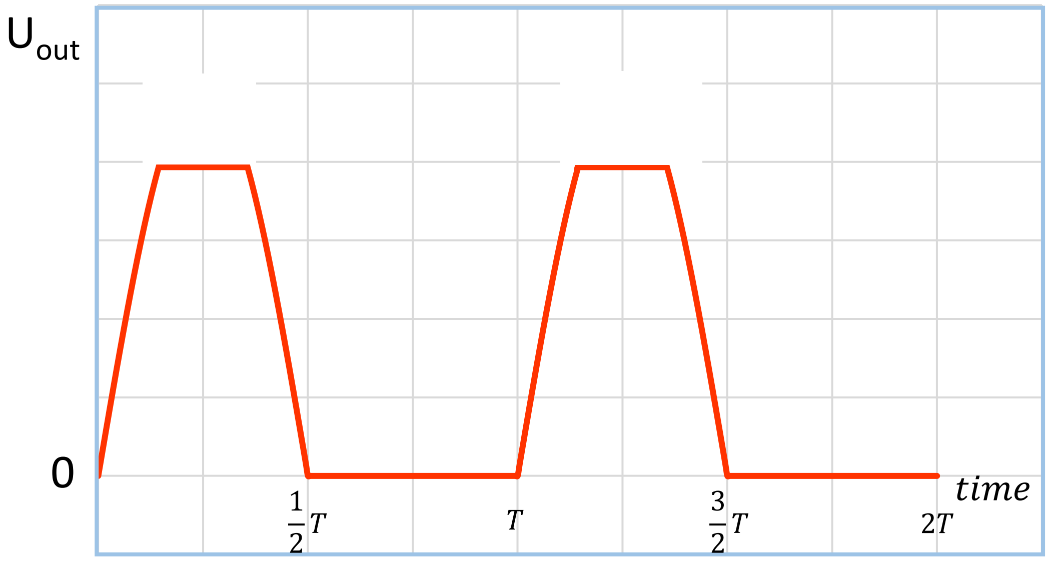
Zener diode functions
Voltage regulator



https://www.digikey.com/en/maker/blogs/zener-diode-basic-operation-and-applications/

Zener diode functions
diode clipping





Zener diodes are used to modify or shape AC waveform clipping circuits. The clipping circuit limits or clips off parts of one or both of the half cycles of an AC waveform to shape the waveform or provide protection.

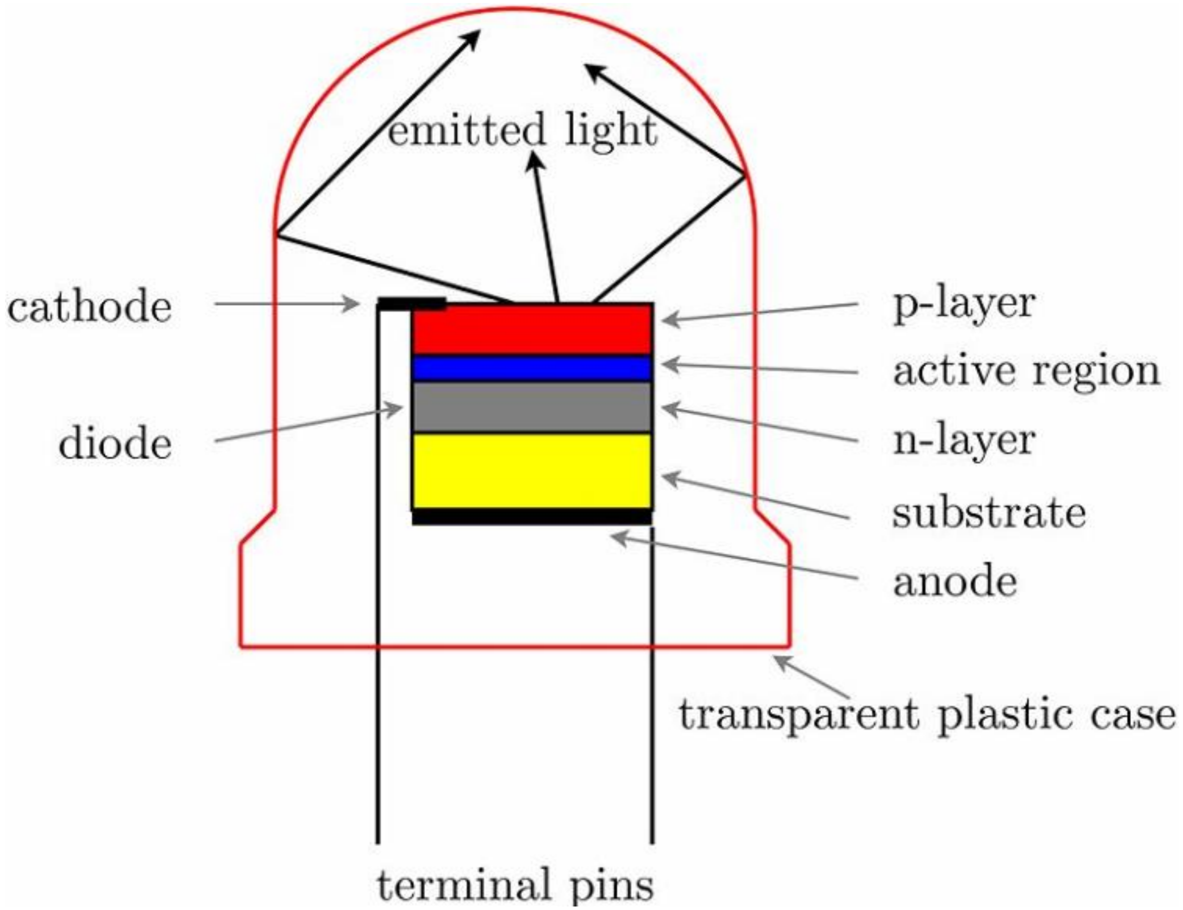
https://www.digikey.com/en/maker/blogs/zener-diode-basic-operation-and-applications/

Light Emitting Diode

- The Light Emitting Diode (LED), is basically just a specialised type of diode as they have very similar electrical characteristics to a P-N junction diode. This means that an LED will pass current in its forward direction but block the flow of current in the reverse direction.
- Light emitting diodes are made from a very thin layer of fairly heavily doped semiconductor material and depending on the semiconductor material used and the amount of doping, when forward biased an LED will emit a coloured light at a particular spectral wavelength.
- When the diode is forward biased, electrons from the semiconductors conduction band recombine with holes from the valence band releasing sufficient energy to produce photons which emit a monochromatic (single colour) of light. Because of this thin layer a reasonable number of these photons can leave the junction and radiate away producing a coloured light output.
- The output from an LED can range from red (at a wavelength of approximately 700 nanometers) to blue-violet (about 400 nanometers). Some LEDs emit infrared (IR) energy (830 nanometers or longer); such a device is known as an infrared-emitting diode (IRED).

https://www.electronics-tutorials.ws/diode/diode_8.html

Light Emitting Diode



https://www.myledlightingguide.com/blog-what-is-an-led

Light Emitting Diode

https://kaushikscienceprojects.com/product/led-round-shape-packet-qty-15/
http://www.elektroonline.pl/news/1435,W-Polsce-powstala-unikatowa-dioda-LED

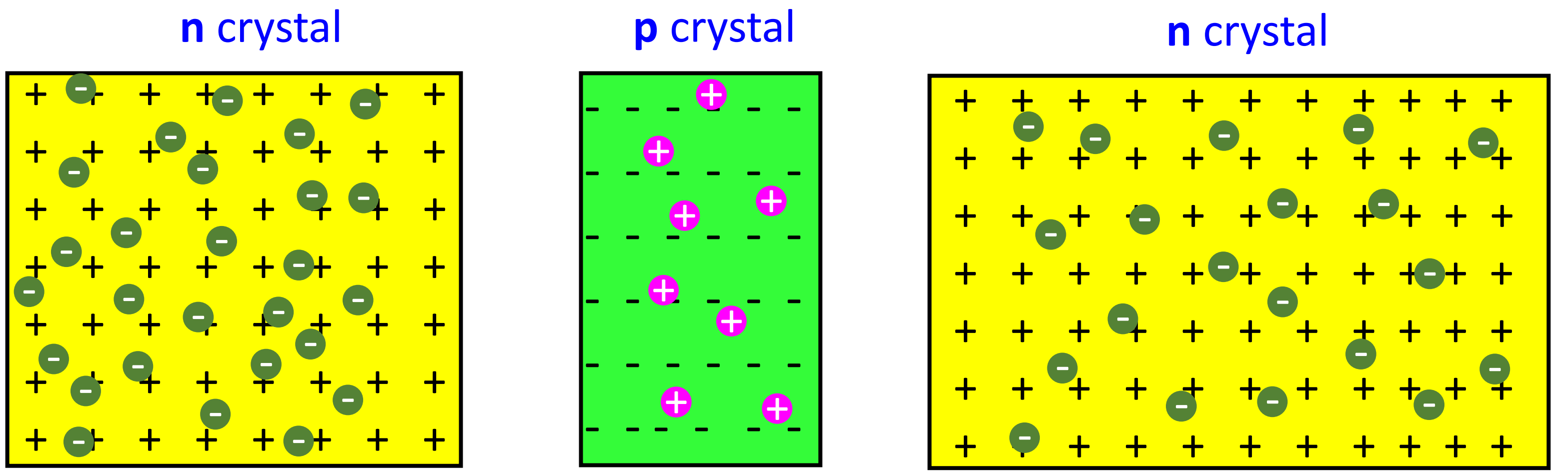
transistor

Transistor is a semiconductor device that can both conduct and insulate. A transistor can act as a switch and an amplifier.

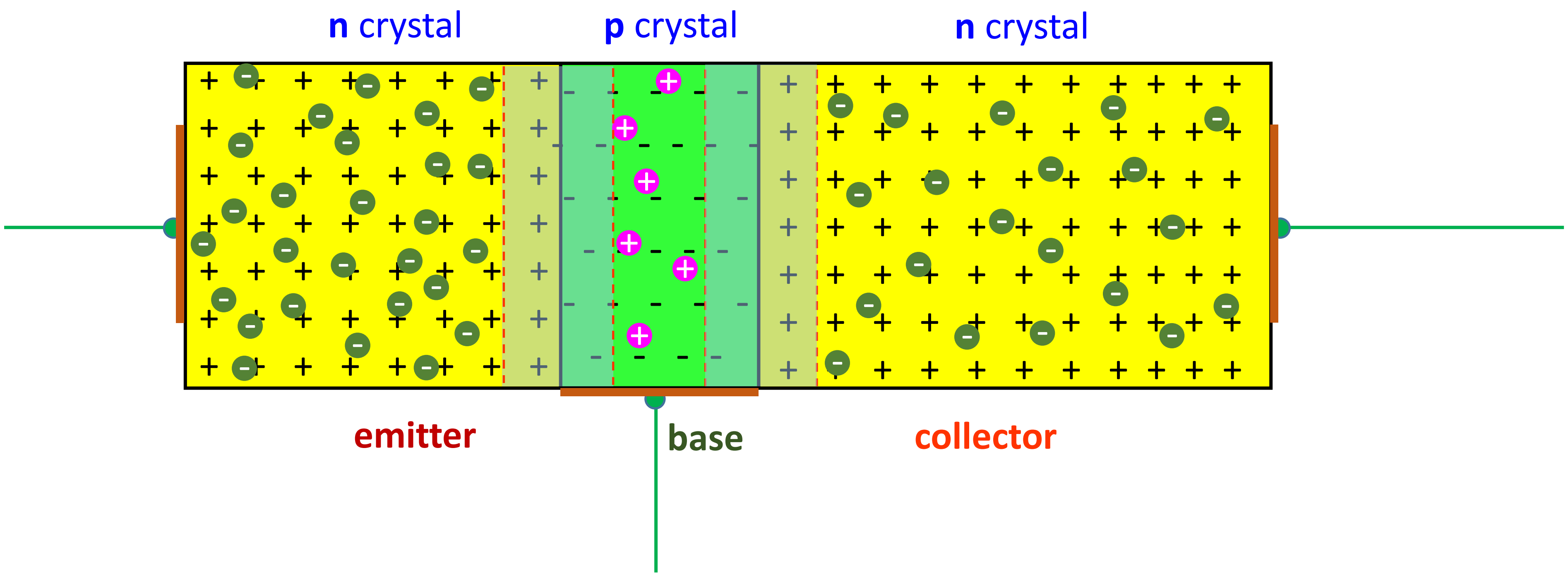
Transistors were invented at Bell Laboratories in New Jersey in 1947 by three brilliant US physicists: **John Bardeen** (1908–1991), **Walter Brattain** (1902–1987), and **William Shockley** (1910–1989).

The first transistor was fabricated with germanium.

Bipolar Junction Transistor (BJT)

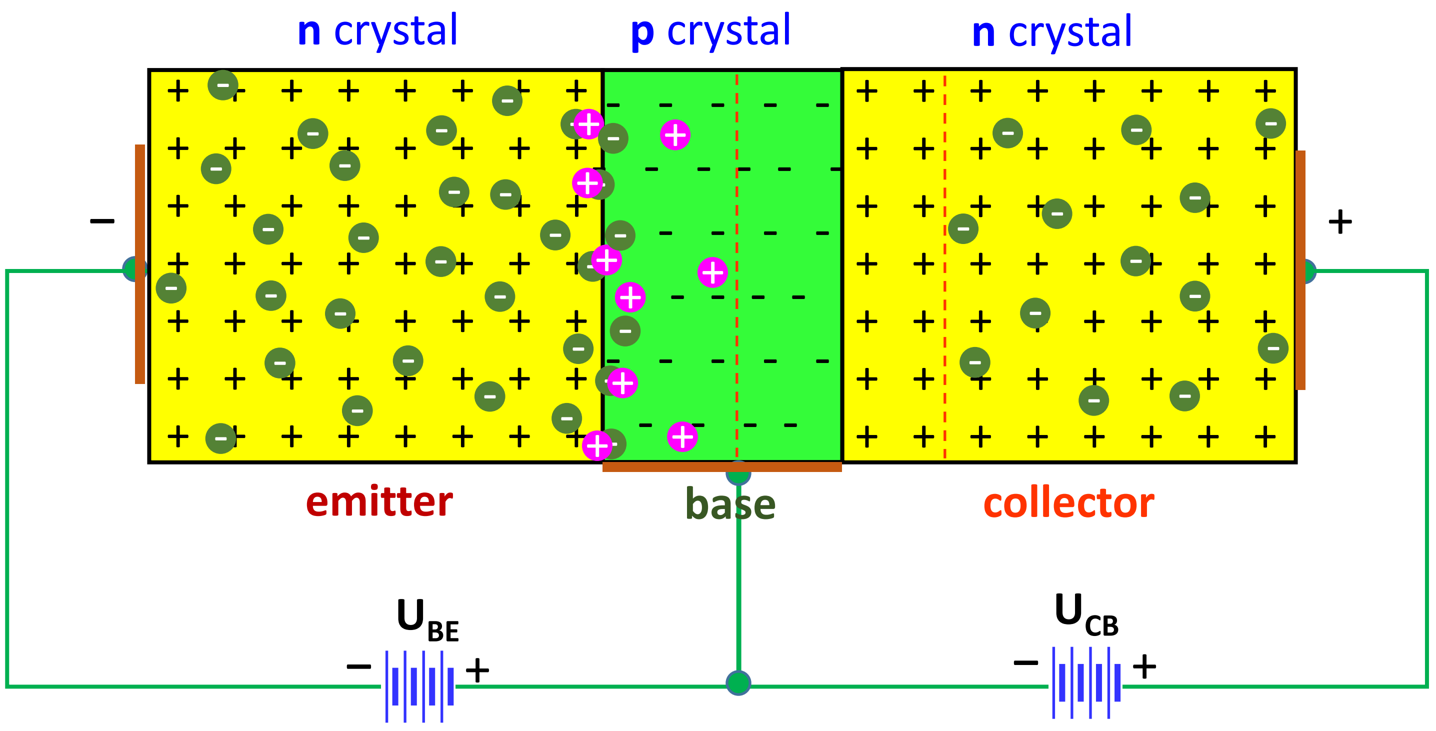


Bipolar Junction Transistor (BJT)



- **Emitter** is moderately wide and highly doped
- **Base** is very narrow and lightly doped
- **Collector** is very wide and moderately doped

Bipolar Junction Transistor (BJT)

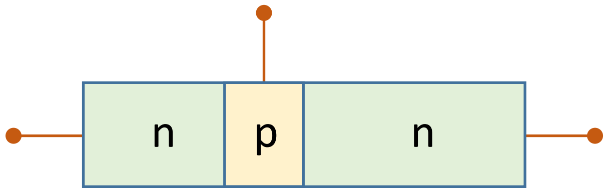


base-emitter junction is forward biased

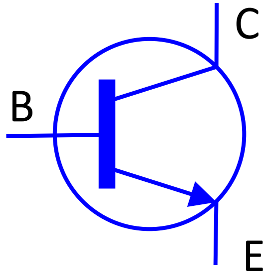
base-collector junction is reverse biased

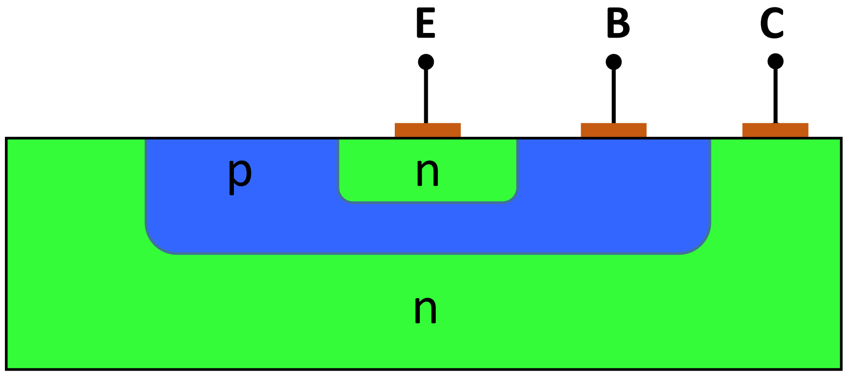
- **Emitter** is moderately wide and highly doped
- **Base** is very narrow and lightly doped
- **Collector** is very wide and moderately doped

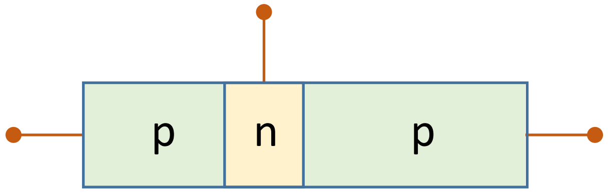
Bipolar Junction Transistor (BJT)



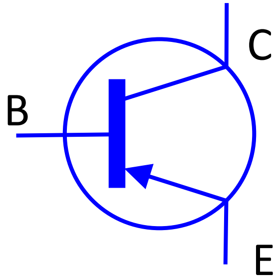
negative-positive-negative

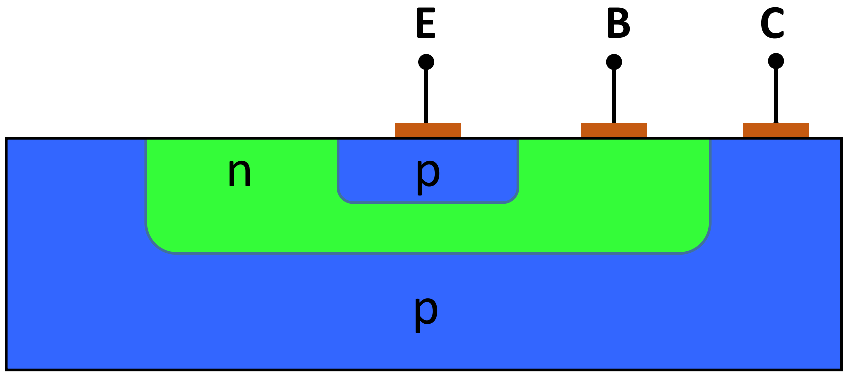






positive-negative-positive



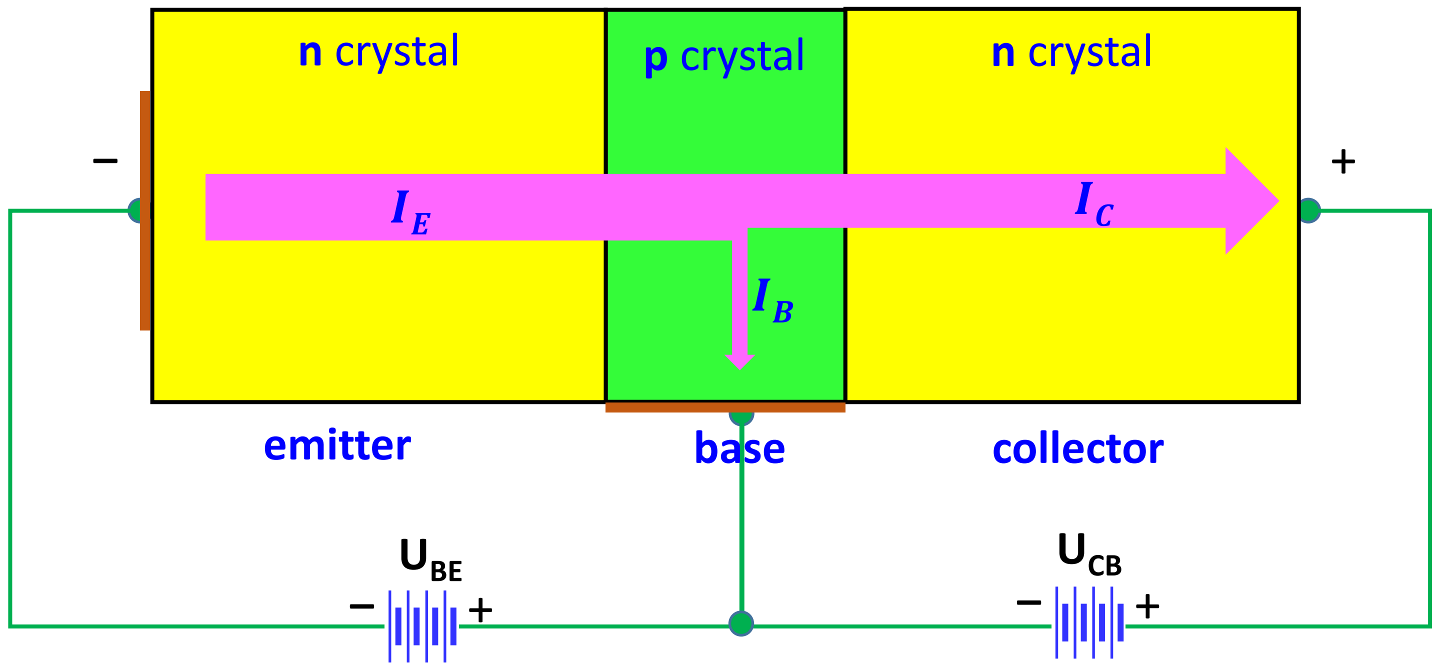


collector (C), **base** (B), and **emitter** (E)

How does the transistor work?

- Magnitude of forward biased U_{BE} controls the number of carriers entering the base-emiter junction.
- Magnitude of reverse biased U_{CB} has a little control over the number of carriers entering the base-collector junction.

How does the transistor work?



base-emitter junction is forward biased

base-collector junction is reverse biased

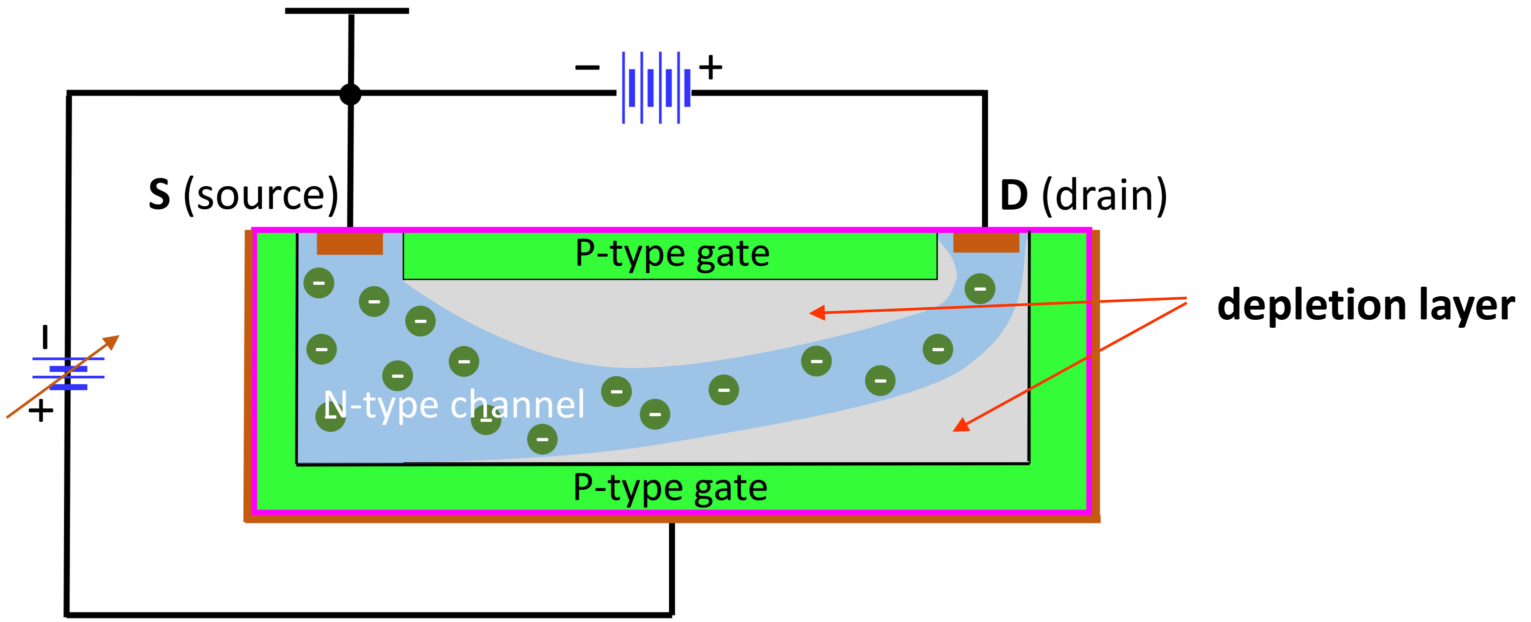
$$I_E = I_B + I_C$$

Junction field effect transistors (JFET)

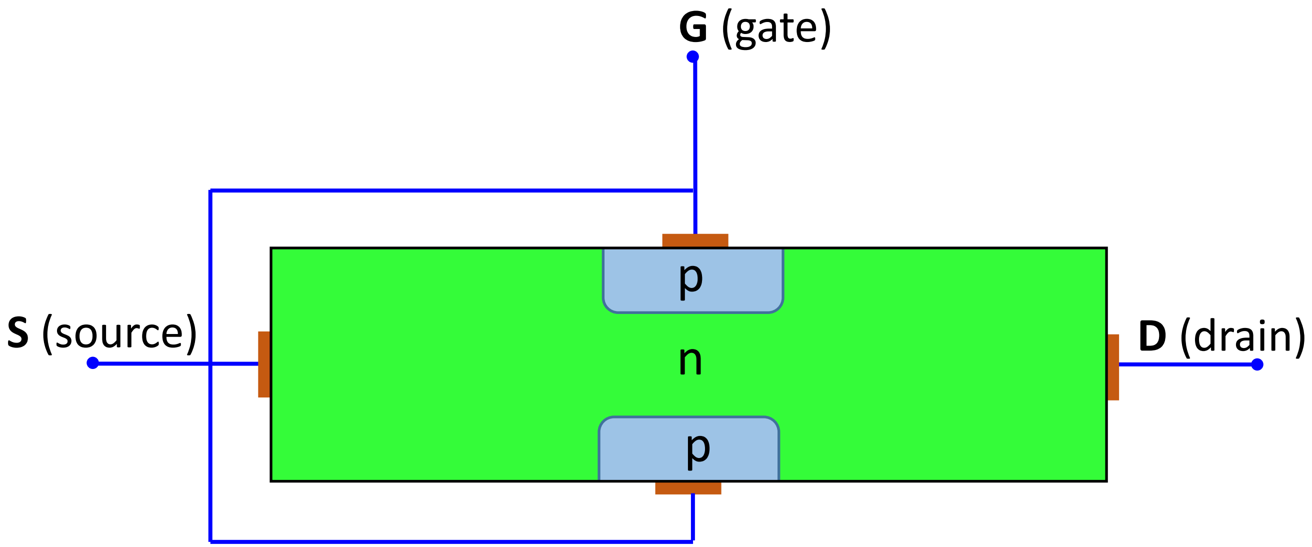
- The field effect transistor is a three terminal device that is constructed with no PN-junctions within the main current carrying path between the **Drain** and the **Source** terminals. These terminals correspond in function to the Collector and the Emitter respectively of the bipolar transistor. The current path between these two terminals is called the “channel” which may be made of either a P-type or an N-type semiconductor material.
- The control of current flowing in this channel is achieved by varying the voltage applied to the **Gate**.

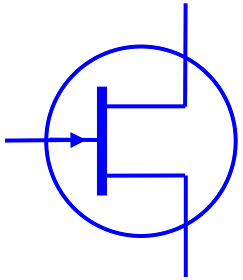
https://www.electronics-tutorials.ws/transistor/tran_5.html

Junction field effect transistors (JFET)

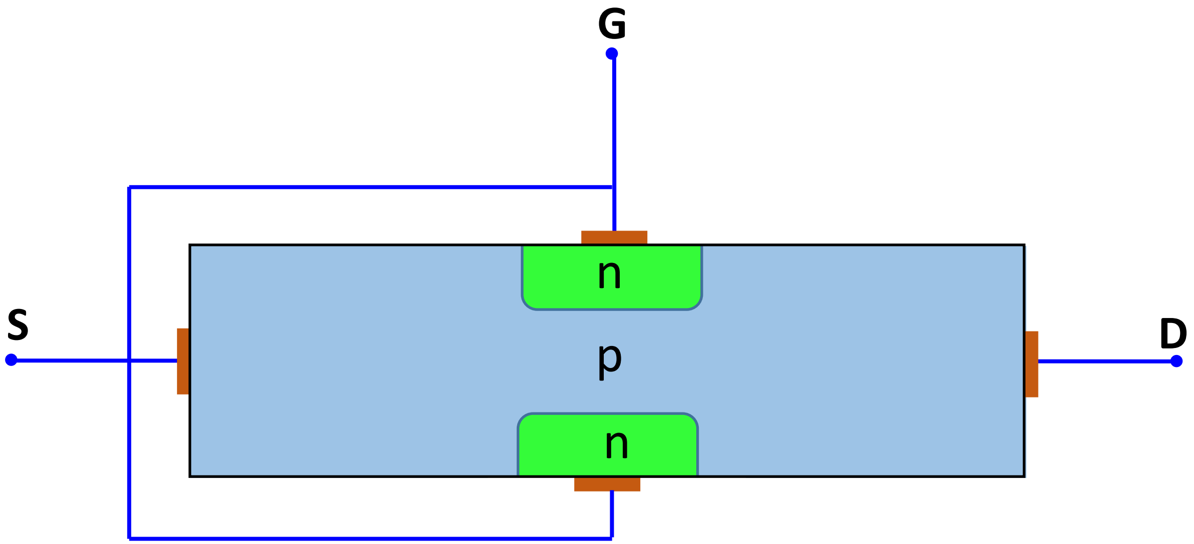


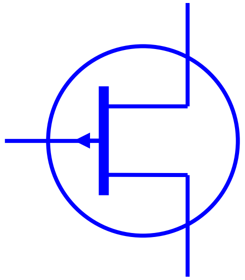
Junction field effect transistors (JFET)





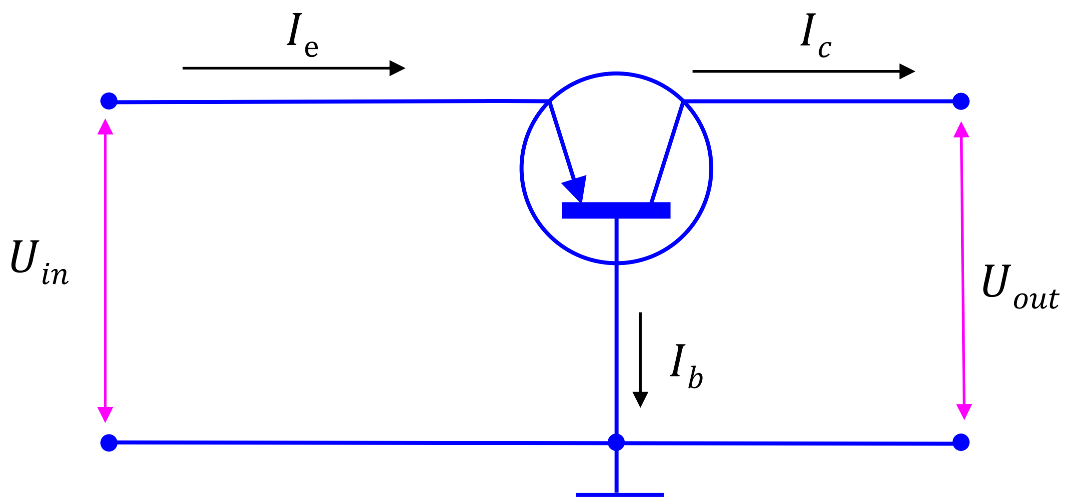
N-Channel JFET





P-Channel JFET

Transistor parameters



$$I_e = I_c + I_b$$

$$\beta = \frac{I_c}{I_b}$$

$$\alpha = \frac{I_c}{I_e}$$

$$\beta = \frac{\alpha}{\alpha - 1}$$

$$\alpha = \frac{\beta}{\beta + 1}$$

α is less than 1 (i.e. 0.993)

β has a value between 20 and 200 for most general purpose transistors.

https://www.pitt.edu/~qiw4/Academic/ME2082/Transistor%20Basics.pdf

Typical voltages for a transistor

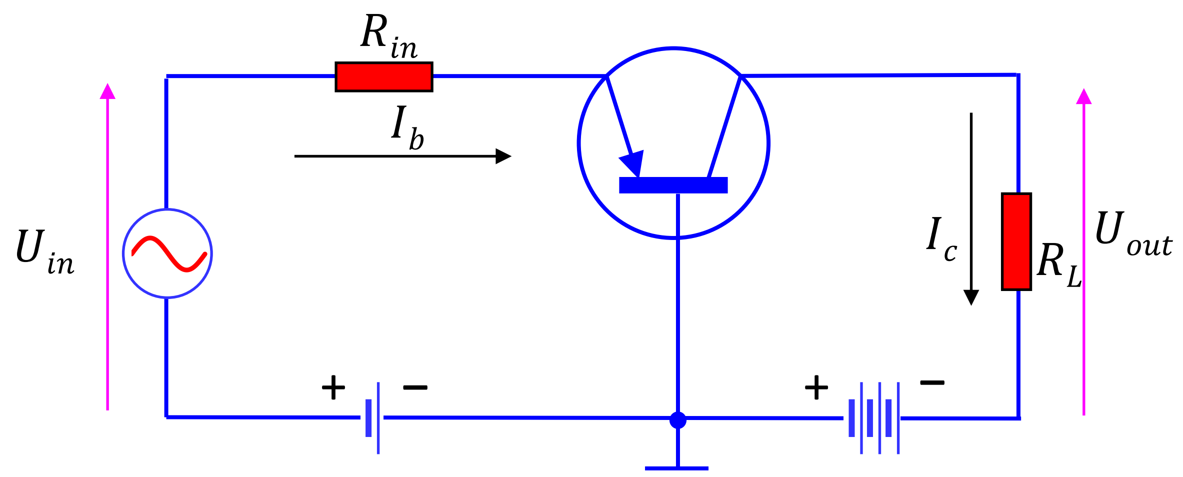
The transistor is normally operated in the active region for amplifying the electric current. In active region, the emitter junction (I_e) is forward biased and the collector junction (I_c) is reverse biased.
The typical base-emitter voltages (U_{be}) for both *n-p-n* and *p-n-p* transistors are as follows:

- If the transistor is made up of a silicon material, U_{be} will be **0.7 V**.
- If the transistor is made up of a germanium material, U_{be} will be **0.3 V**.

The typical collector-base voltages (U_{cb}) for both *n-p-n* and *p-n-p* transistors will be anywhere between **3 V** to **20 V**.

https://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/transistors/bipolarjunctiontransistor/transistorterminalvoltages.html

The Common Base Transistor Circuit

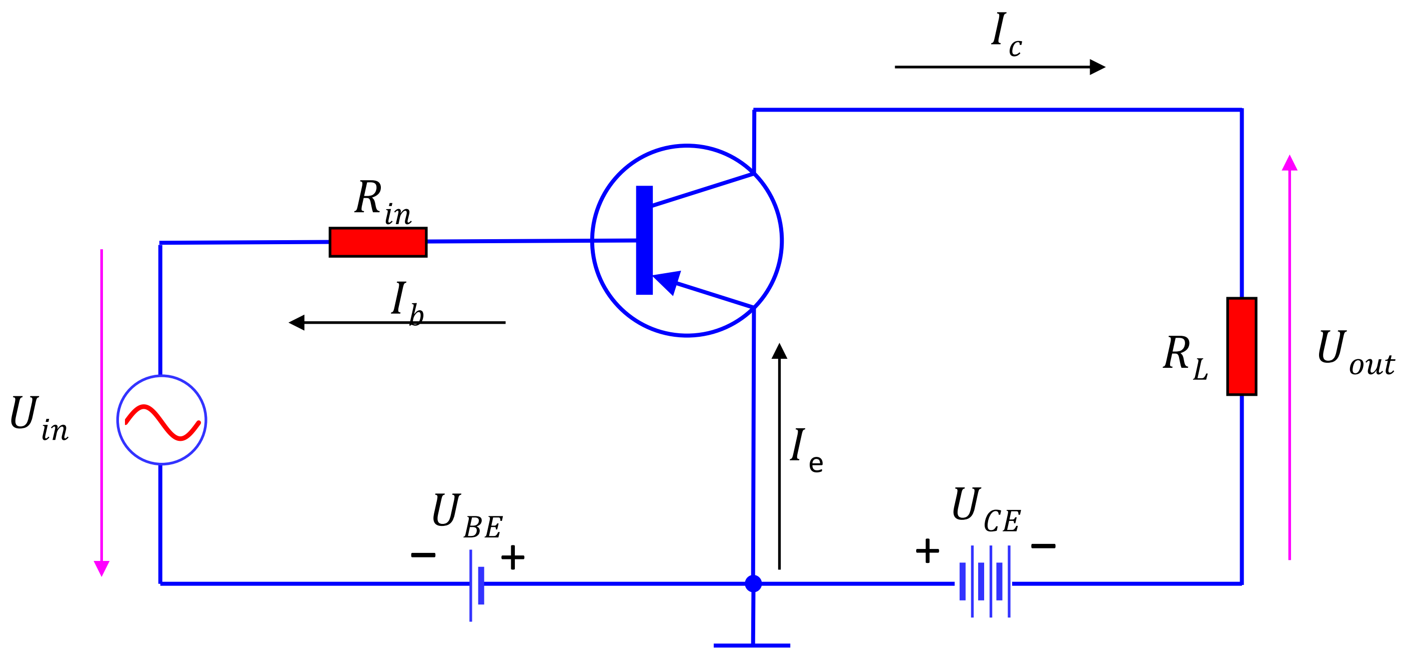


A - amplification

$$A = \frac{U_{out}}{U_{in}} = \frac{R_L\, I_c}{R_{in}\, I_e} = \alpha\, \frac{R_L}{R_{in}}$$

The common base circuit is generally only used in single stage amplifier circuits such as microphone pre-amplifier or radio frequency (RF) amplifiers due to its very good high frequency response.

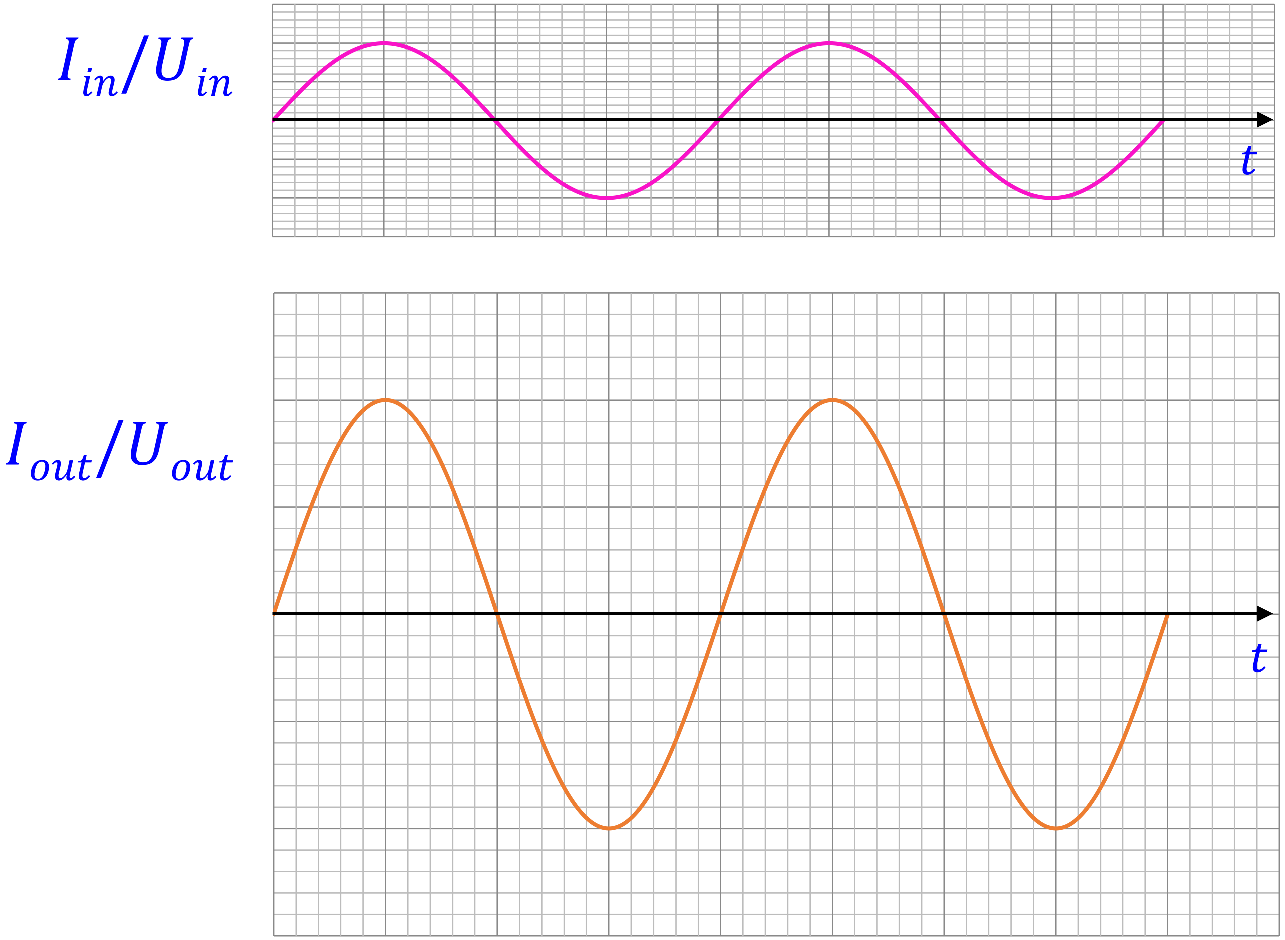
The Common Emitter Amplifier Circuit



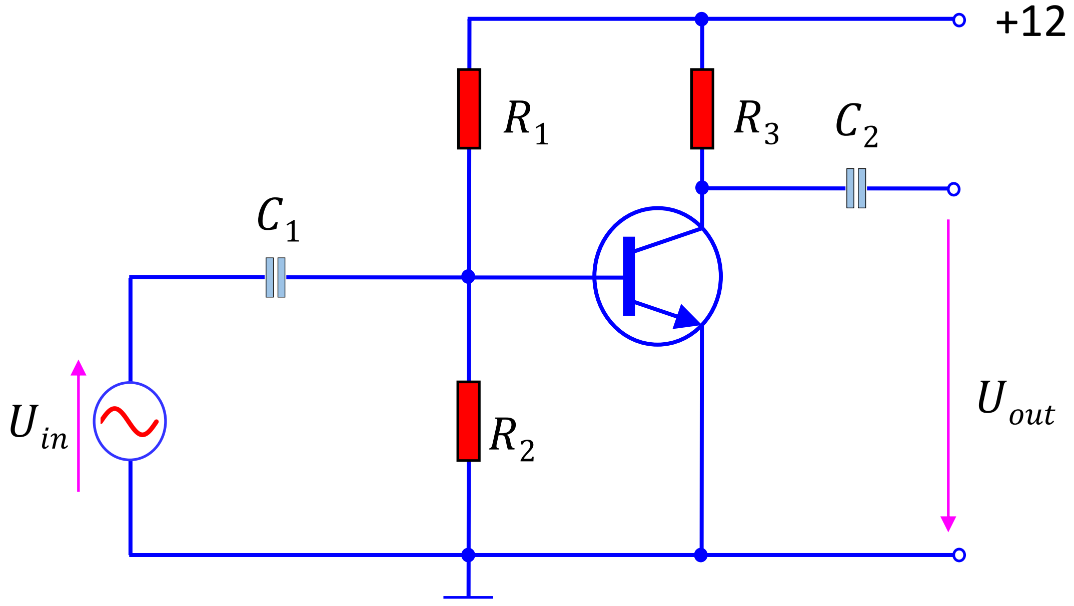
$$A = \frac{U_{out}}{U_{in}} = \frac{R_L\, I_c}{R_{in}\, I_b} = \frac{R_L}{R_{in}}\, \beta$$

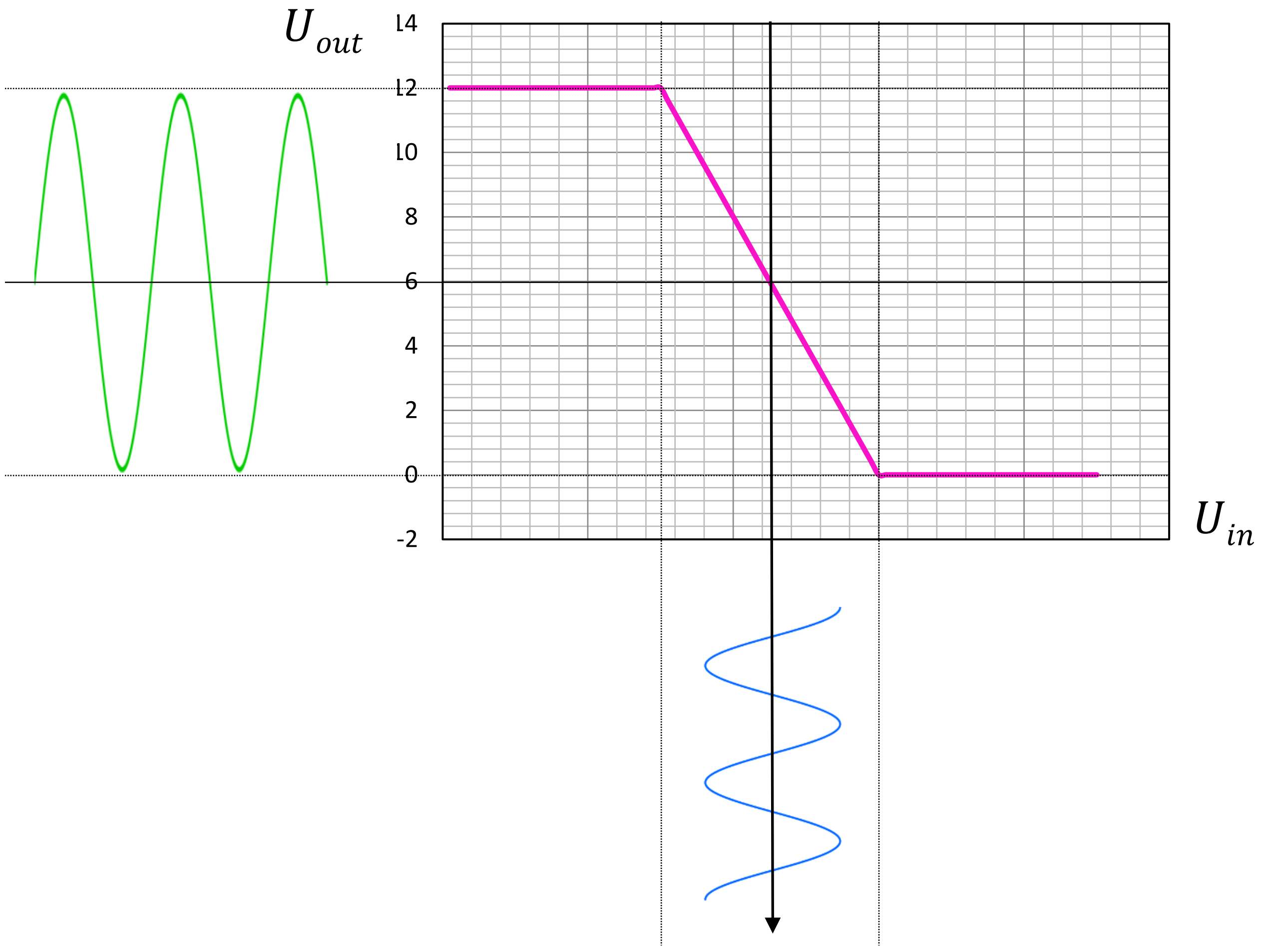
The common emitter (CE) amplifiers are used when large power gain is needed.

amplification

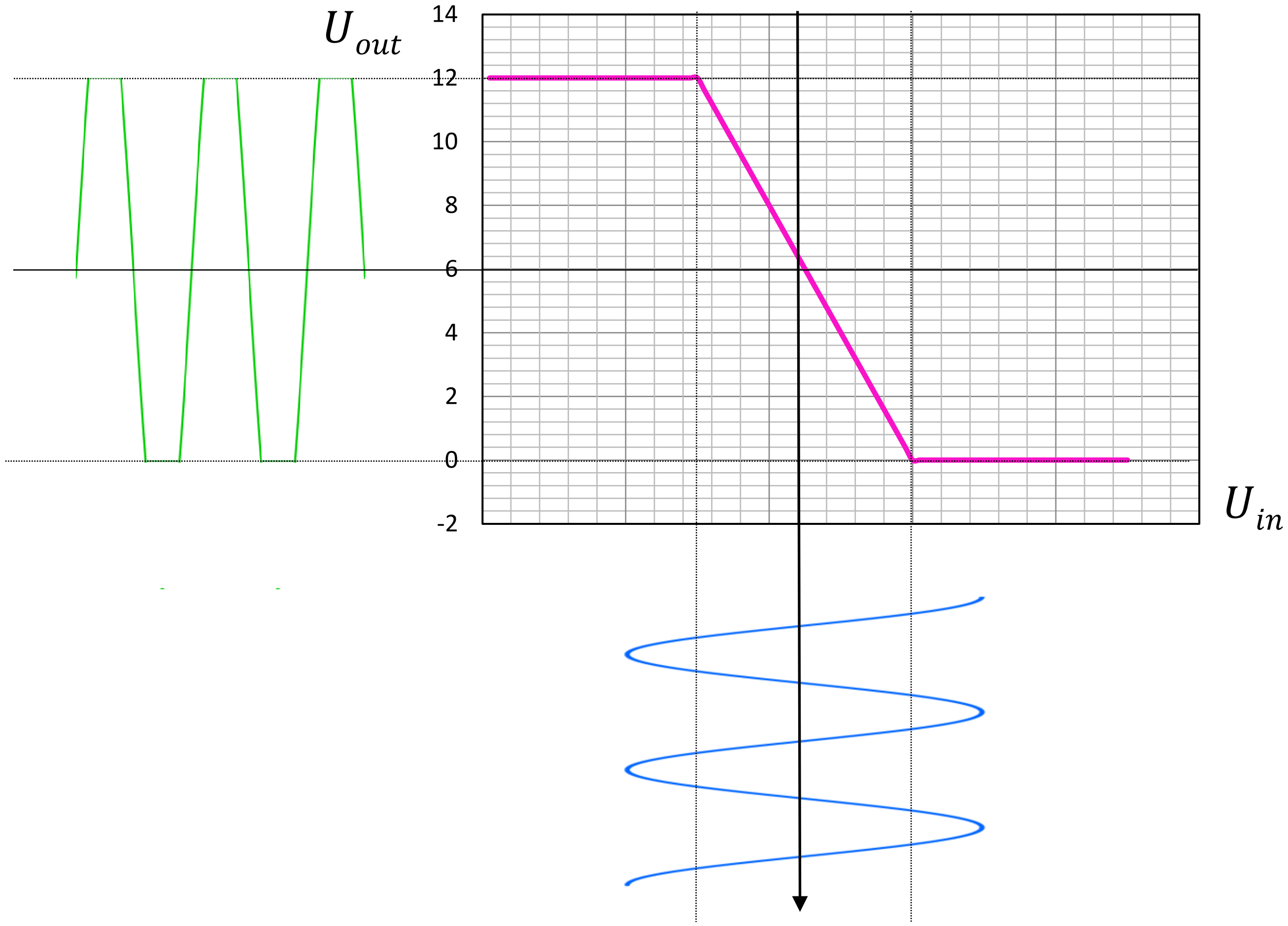


common emitter transistor amplifier

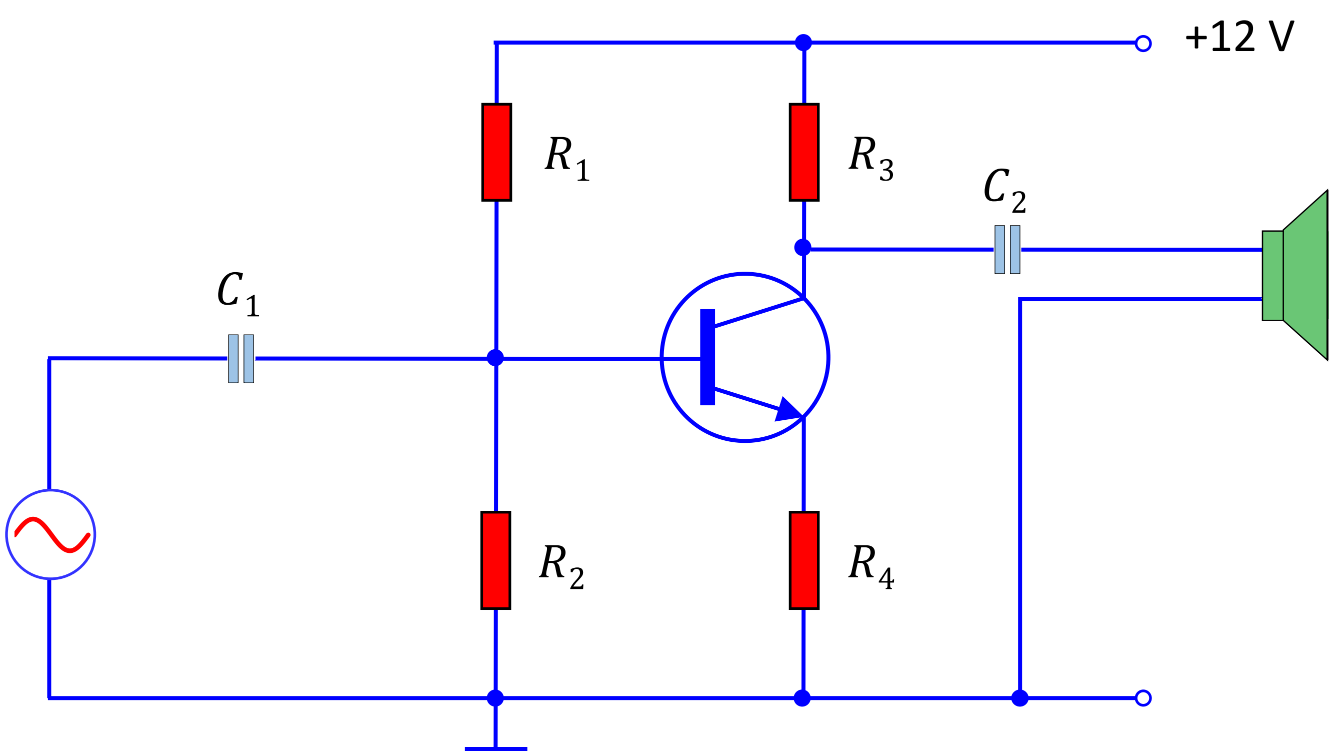




overdriven amplifier

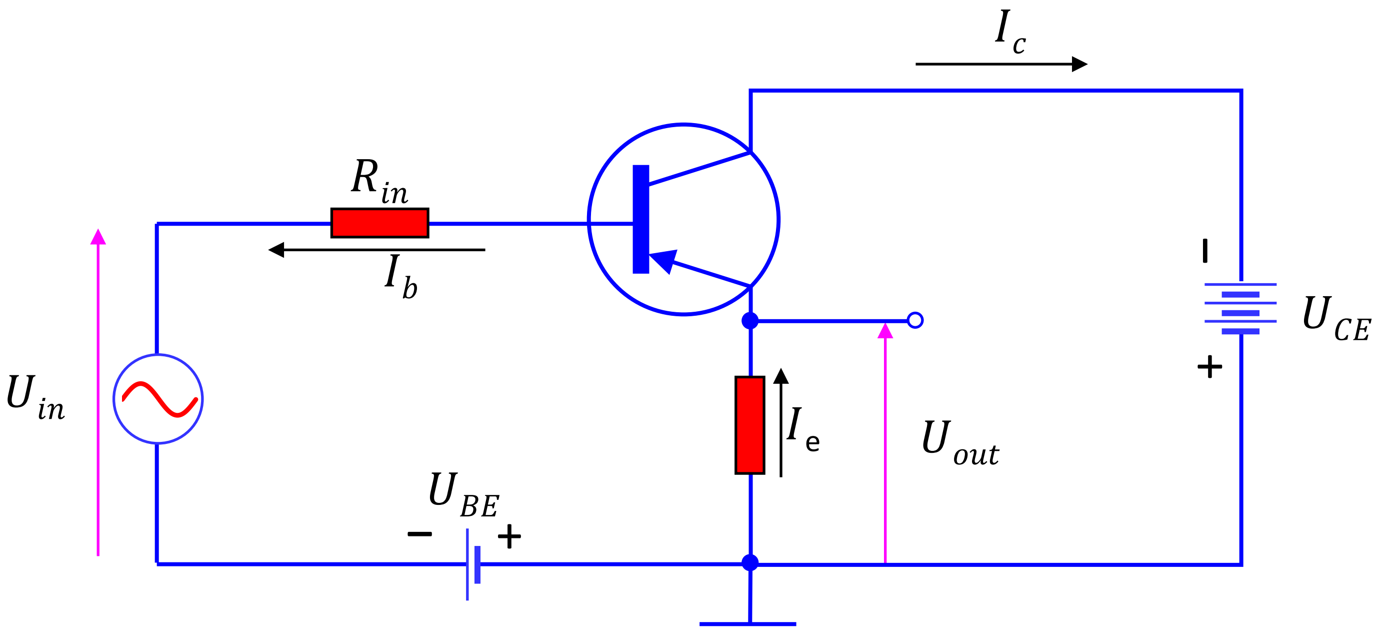


common emitter transistor amplifier



$R_1 = 100k\Omega$
$R_2 = 10k\Omega$
$R_3 = 10k\Omega$
$R_4 = 1k\Omega$
$C_1 = 1\mu F$
$C_2 = 1\mu F$

The Common Collector Transistor Circuit

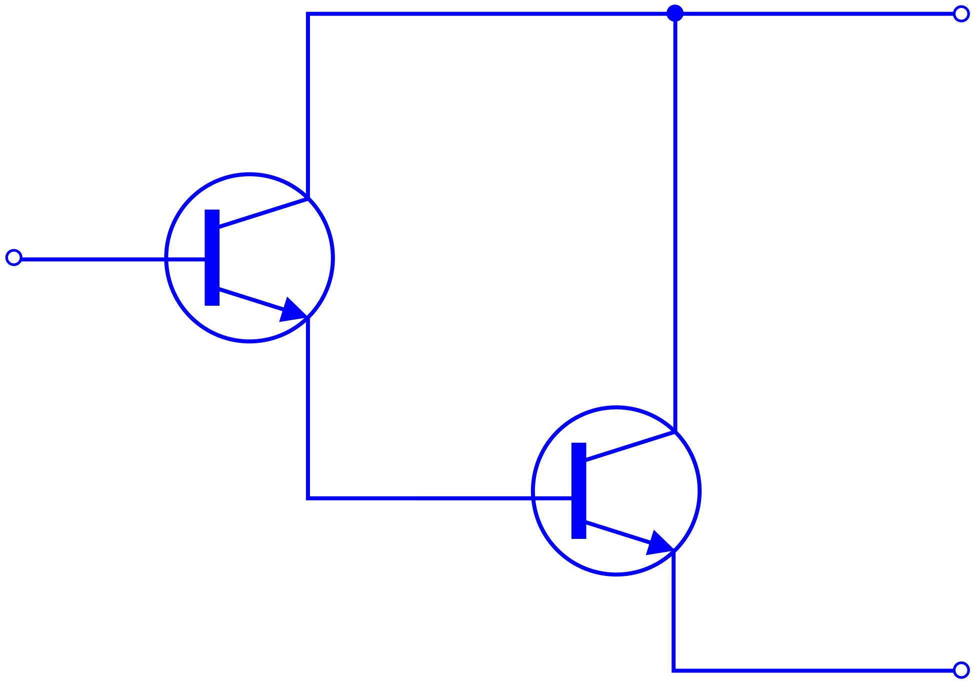


$$A_i = \frac{I_e}{I_b}$$

$$A_i = \beta + 1$$

Sometimes common collector configuration is also referred to as emitter follower, voltage follower.
This configuration is mostly used as a voltage buffer.
It has high input impedance and low output impedance. It has low voltage gain and high current gain.

Darlington pair



A Darlington pair is two transistors that act as a single transistor but with a much higher current gain. This mean that a tiny amount of current from a sensor, micro-controller or similar can be used to drive a larger load.
The overall current gain of the Darlington pair is the product of the two individual transistors.

Voltage Source vs. Current Source

Voltage Source

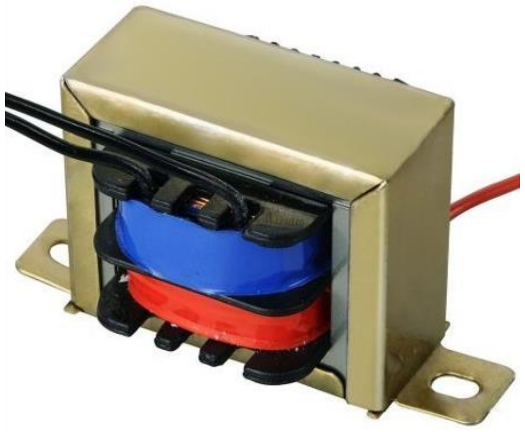
A voltage source is a two-terminal device whose voltage at any instant of time is constant and is independent of the current drawn from it. Such a voltage source is called an Ideal Voltage Source and have zero internal resistance.

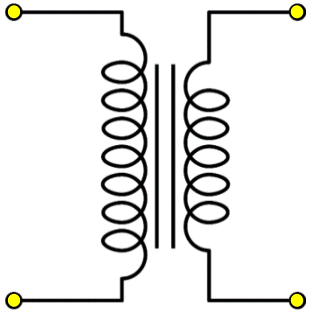
Sources having some amount of internal resistances are known as Practical Voltage Source.due to this internal resistance; voltage drop takes place, and it causes the terminal voltage to reduce. The smaller is the internal resistance (r) of a voltage source, the more closer it is to an Ideal Source.

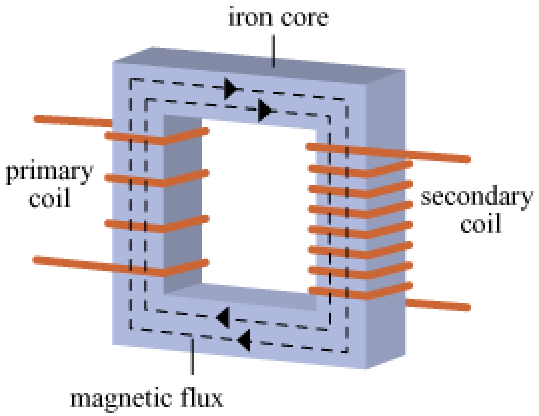
Current Source

- The current sources are further categorised as Ideal and Practical current source.
- An **Ideal current source** is a two-terminal circuit element which supplies the same current to any load resistance connected across its terminals. It is important to keep in mind that the current supplied by the current source is independent of the voltage of source terminals. It has infinite resistance.
- A **practical current source** is represented as an ideal current source connected with the resistance in parallel.

electrical transformer



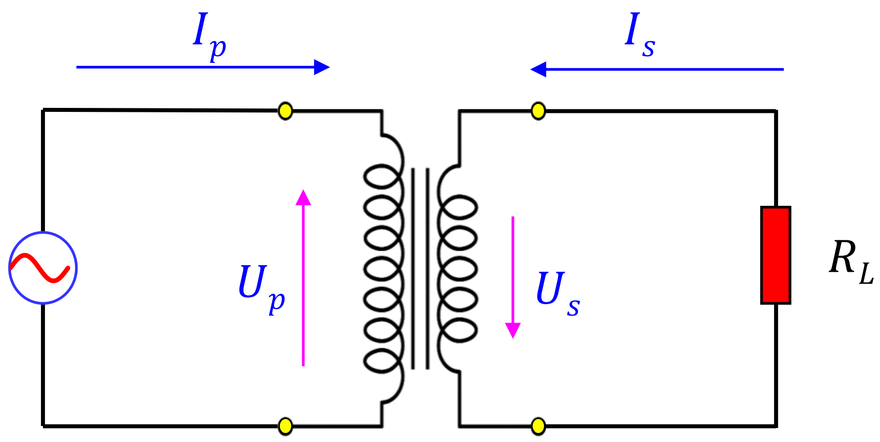




https://kaushikscienceprojects.com/product/transformer/

http://www.hk-phy.org/energy/power/transmit_phy05_e.html

Electrical transformer



$$P_p = P_s$$

$$I_p U_p = I_s U_s$$

$$n = \frac{N_p}{N_s} = \frac{U_p}{U_s} = \frac{I_s}{I_p}$$

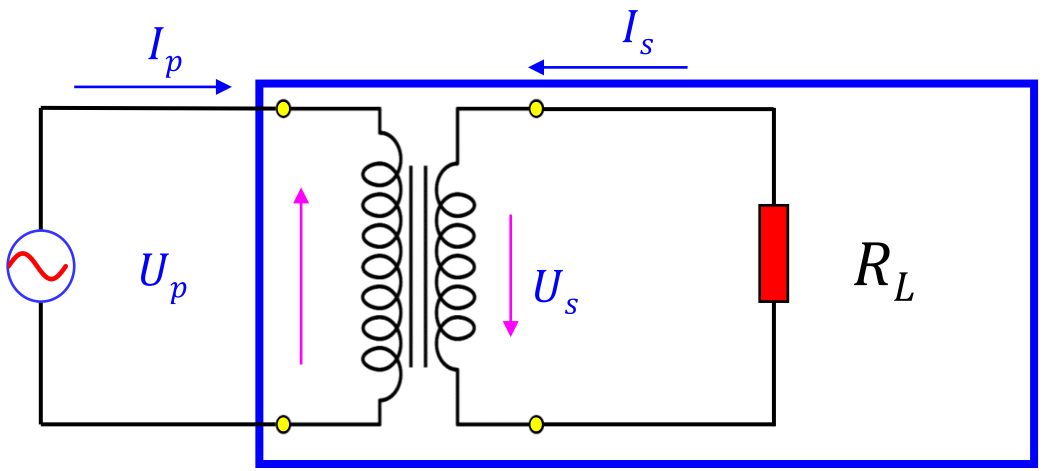
$$I_s = \frac{U_s}{R_L} = n * Ip$$

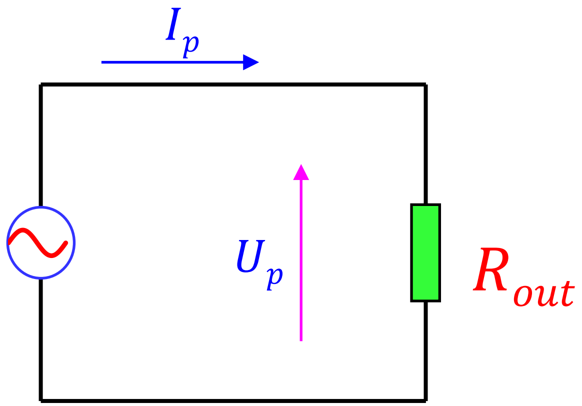
n – turns ratio
U_p – primary voltage
U_s – secondary voltage
N_p – number of primary winding
N_s – number of secondary winding
P – power

$$R_{out} = \frac{U_p}{I_p} = n * U_s \frac{n}{I_s} = n^2 \frac{U_s}{I_s}$$

$$R_{out} = n^2 R_L$$

impedance matching





$$R_{out} = n^2 * R_L$$