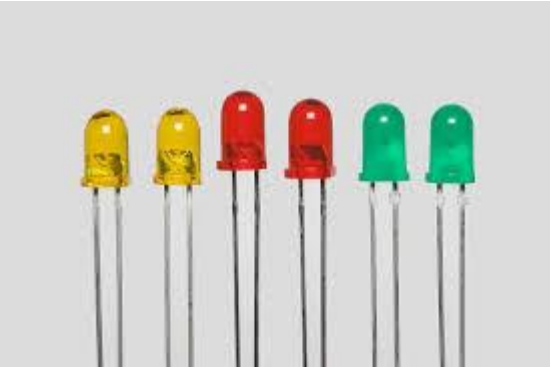
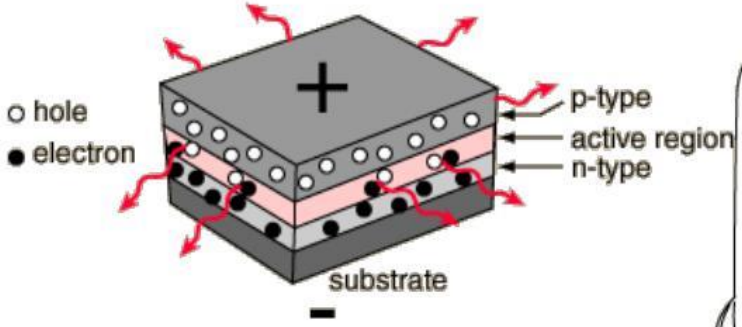
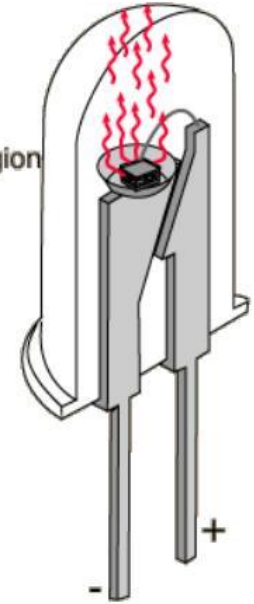
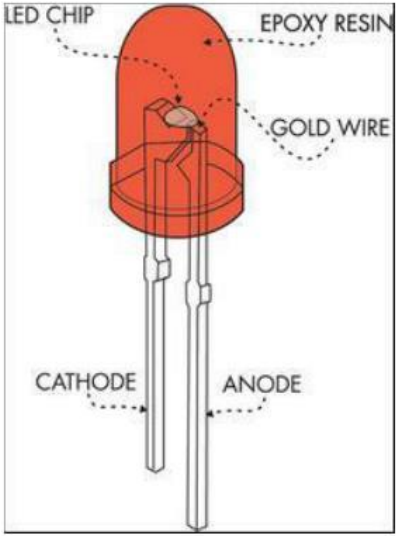
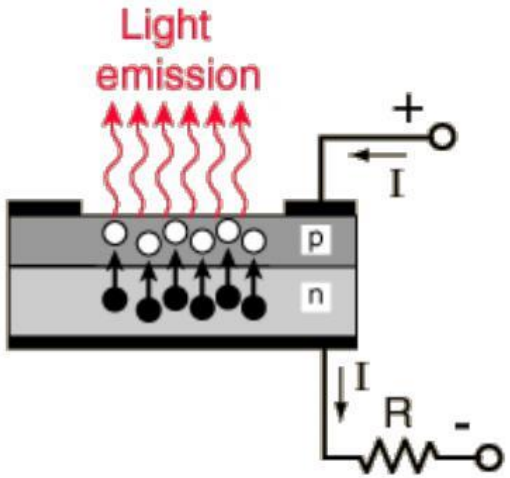


# LED - Light Emitting Diodes



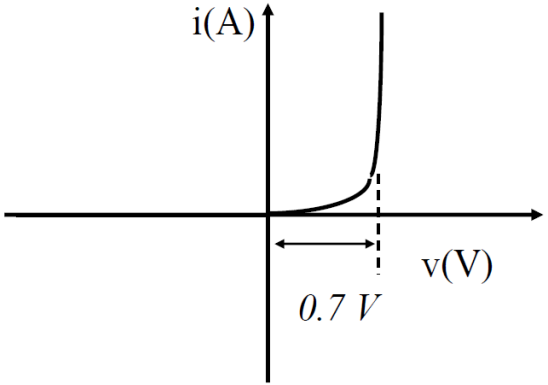



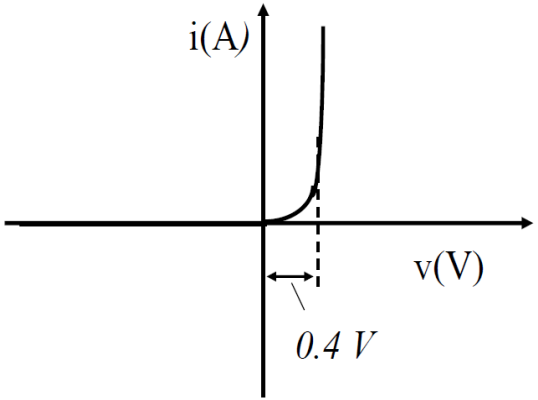

UV – AlGaN
Blue – GaN, InGaN
Red, green – GaP
Red, yellow – GaAsP
IR- GaAs

# Current-voltage characteristic of a *real* diode

*A Silicon (Si) Diode*



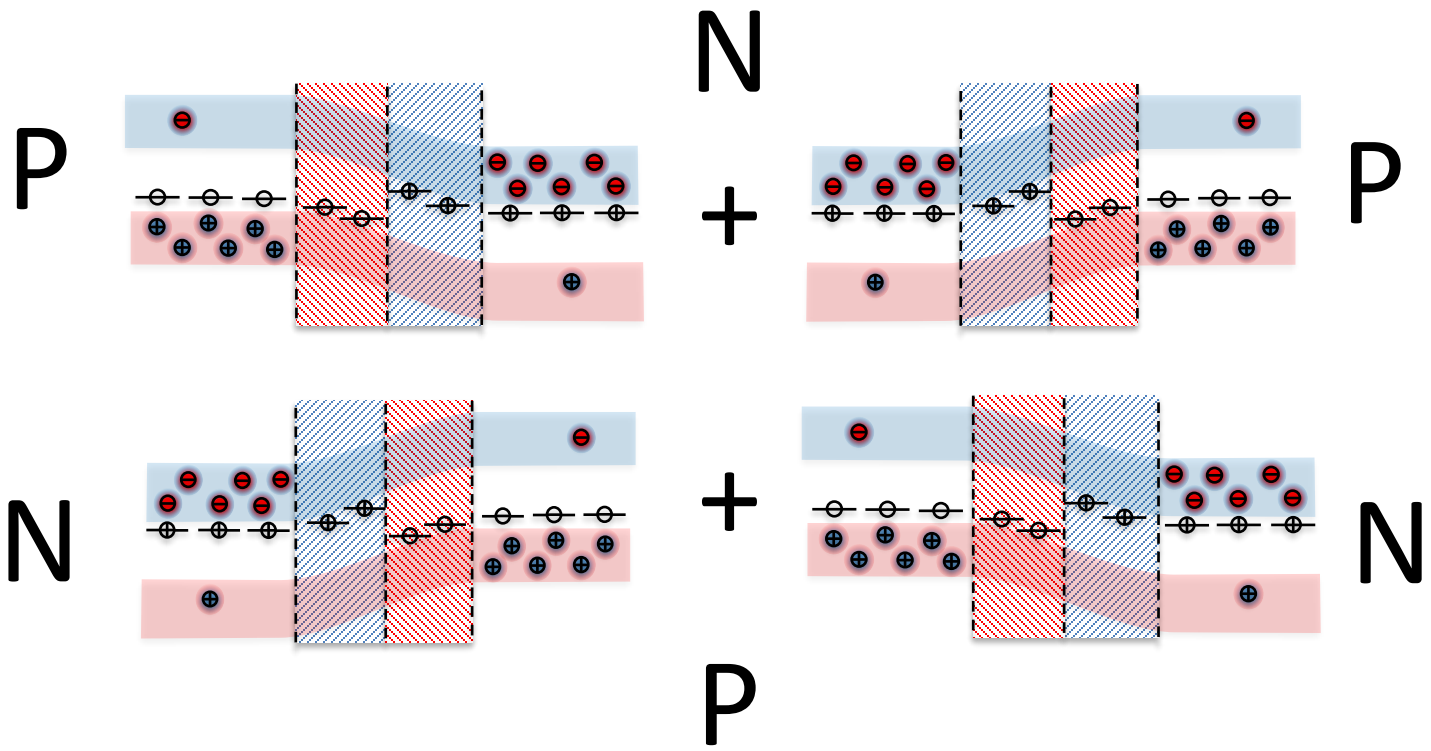

*A Germanium (Ge) Diode*




- The *typical* voltage drop across a *Si* diode at forward bias is 0.7V

# Operation principles of the Bipolar Junction Transistor (BJT)

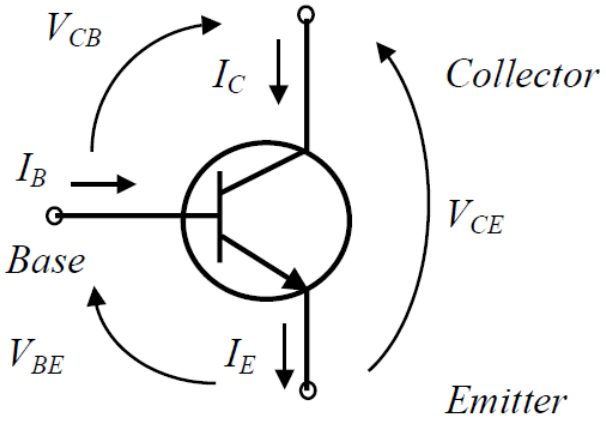
Bipolar Junction Transistor (BJT) is based on a semiconductor crystal comprising 3 areas: p-type, n-type, p-type (PNP transistor) or n-type, p-type, n-type (NPN transistor).



# BJT symbolic representation

BJT has 3 terminals, each one is in contact with one of the areas. The central area of the crystal is called “base”. One of the side areas marked by the arrow is called “emitter”. This area typically has the highest dopant concentration. The third area is called “collector”

*Symbolic representation of* BJT *in circuits*

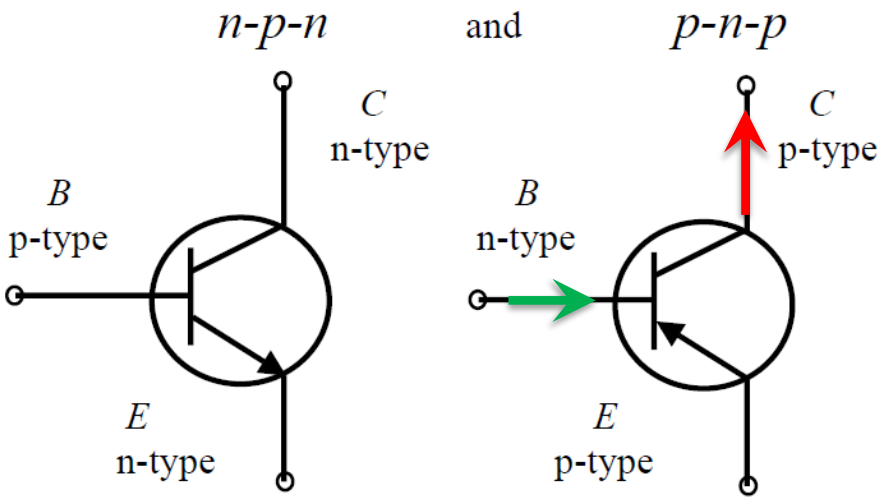


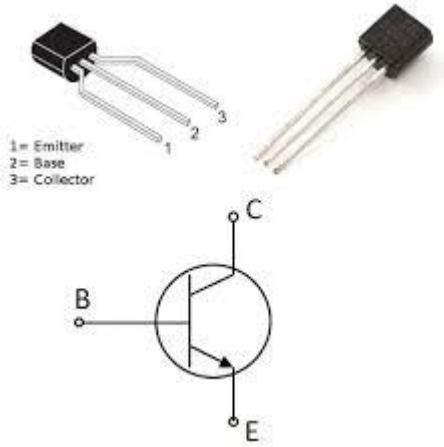

- BJT is *a three-terminal* device
- The “arrow” shows the direction of current in an *emitter*
- Only *two* voltages and *two* currents are independent

$$V_{CE} = V_{BE} + V_{CB}$$

$$I_E = I_B + I_C$$

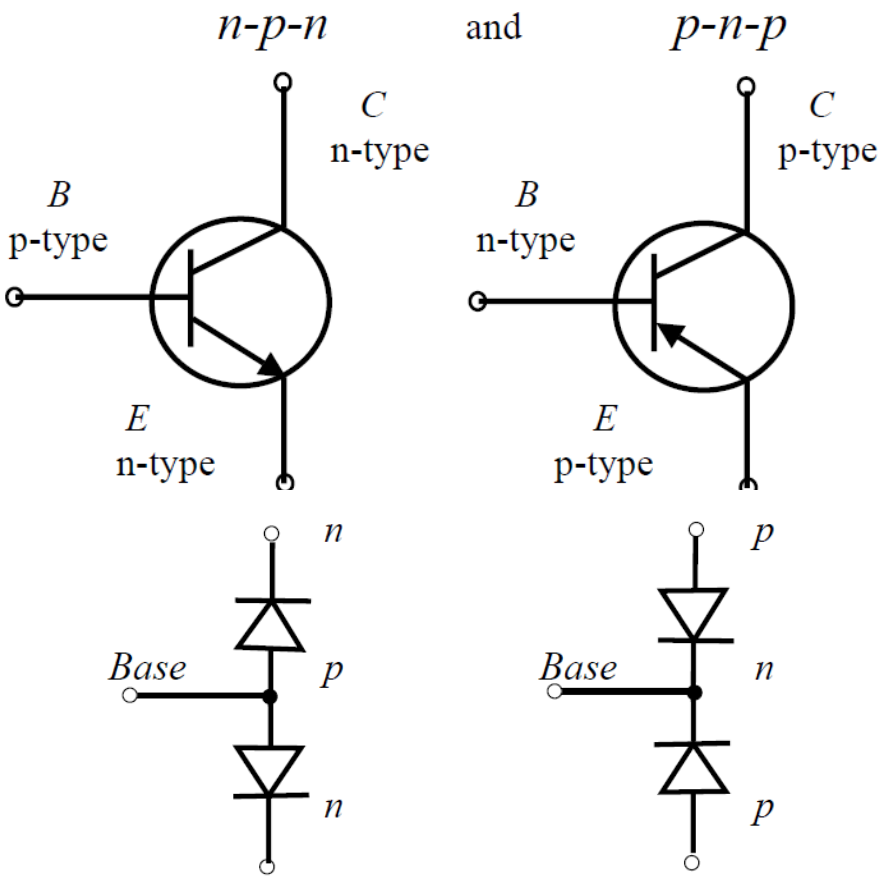
# Current controlled current source



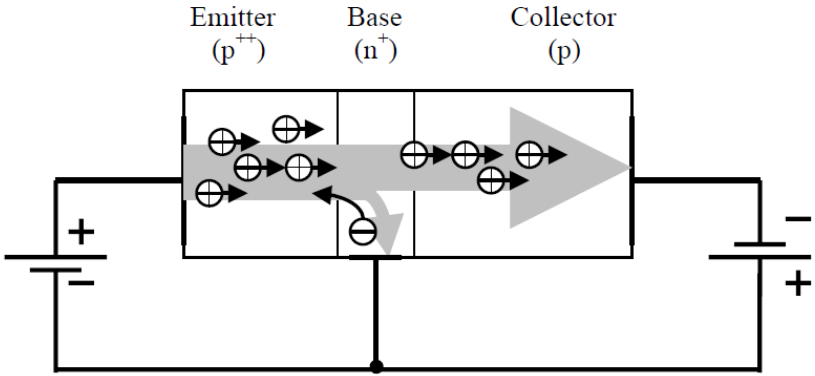

The main function of BJT is “current controlled current source”. It means that the high current in the emitter-collector circuit (red arrow) can be controlled by a low current flowing in the base (green arrow).

# Types of BJT




- There are two basic types of BJT
- This notation comes from the type and sequence of the semoconductor layers
- Direction of the “arrow” specifies the type of BJT in circuit diagrams

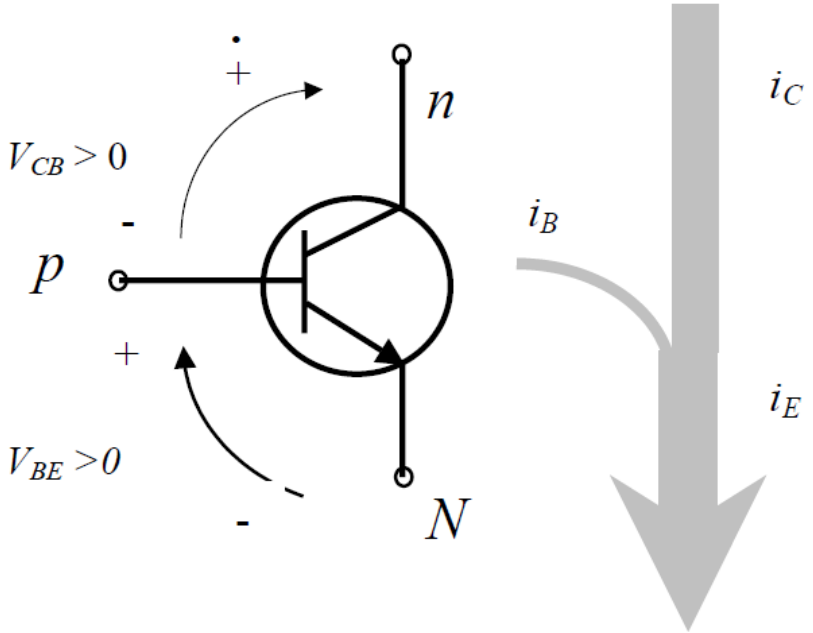
# BJT design




- *Typical doping concentrations of the emitter, base and collector are $10^{19}$, $10^{17}$, $10^{15}$ $cm^{-3}$.*
- *The base is narrow, typically $w_b \sim 5x10^{-7}m$.*

# BJT: current relationships

- *Forward active*




*According to Kirchhoff current law:*

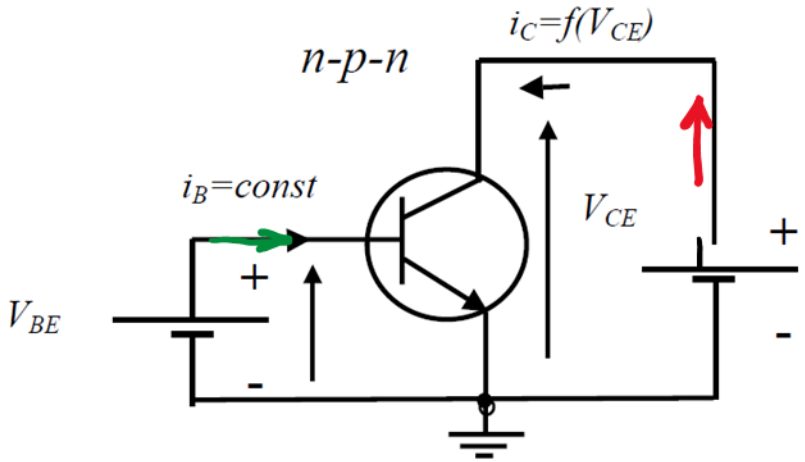
$$I_C = \beta \cdot I_B$$

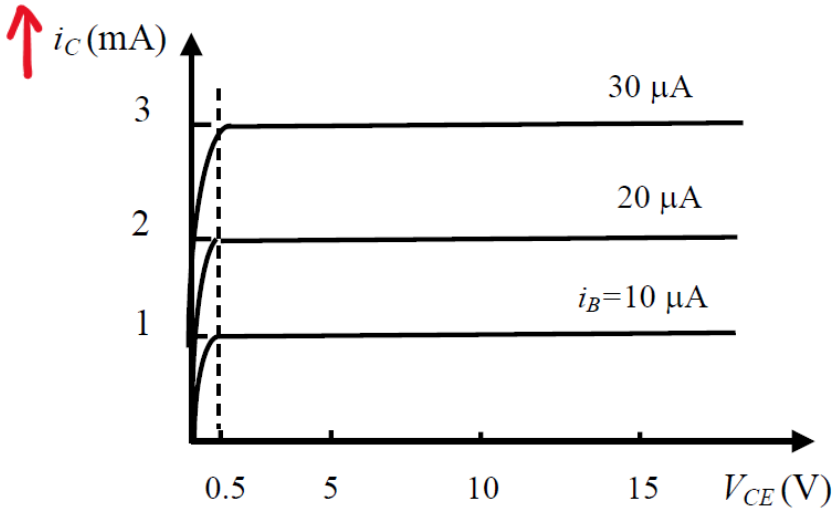
$$I_C = \alpha \cdot I_E,$$

$$\alpha = \frac{\beta}{1+\beta} \quad \text{or} \quad \beta = \frac{\alpha}{1-\alpha}$$

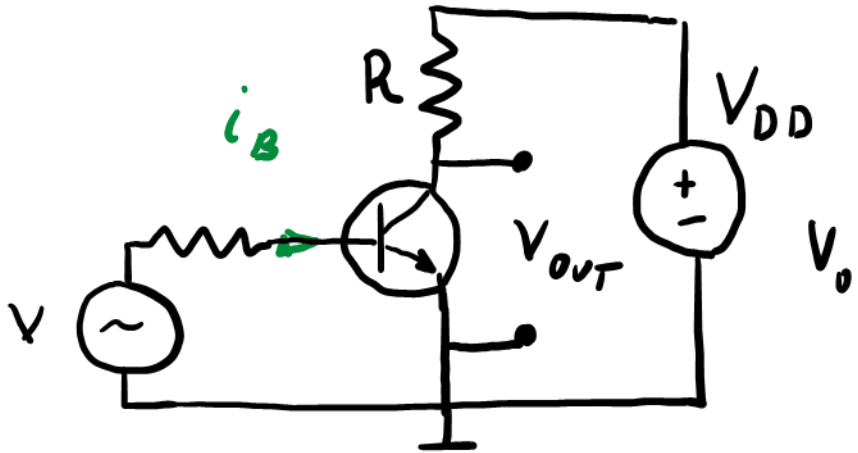
The parameters α and β characterize the BJT operation. α is, typically, around one, β is between 50 and 300.

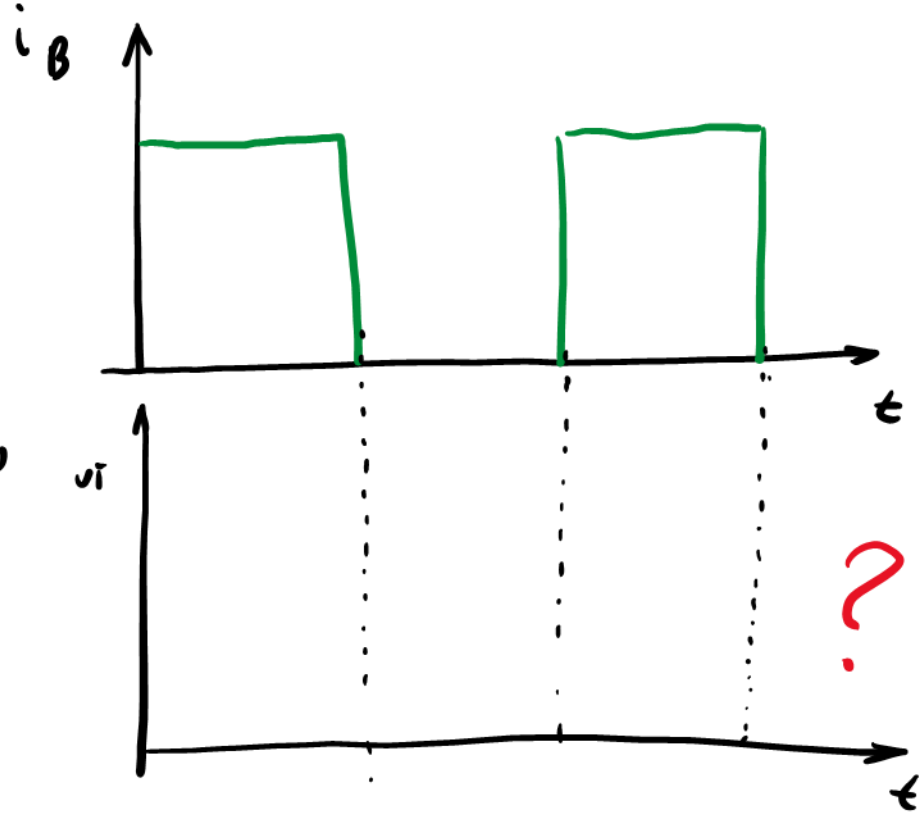
# Common emitter configuration of BJT: output characteristics




The plot above shows the dependence of the collector current (red arrow) on the collector-emitter voltage $V_{CE}$ (right source in the figure above). Remarkably, the collector current does not de pend on $V_{CE}$ – the curves are flat, but it depends on the base current $i_B$ (green arrow).




Could you, please, think on how to sketch the dependence of the Vout on time, if the dependence of the base current on time is given above? We will discuss this problem in class.