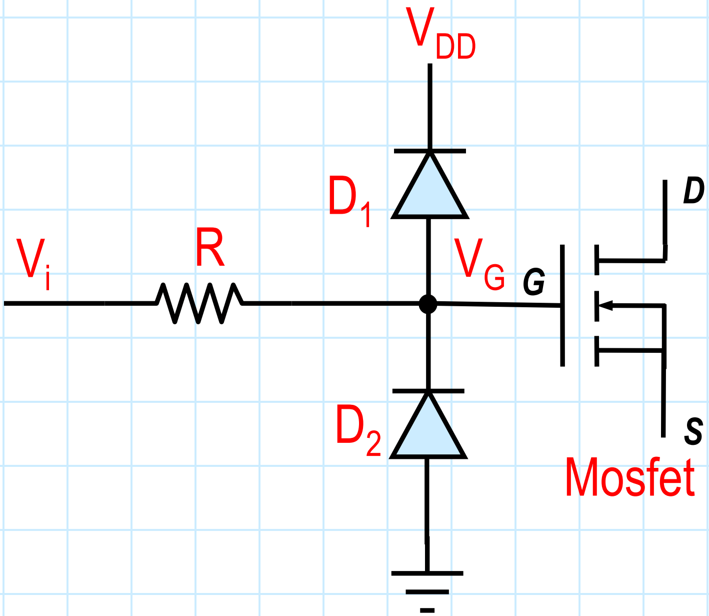
1.3 Diode circuits. Digital inputs protection

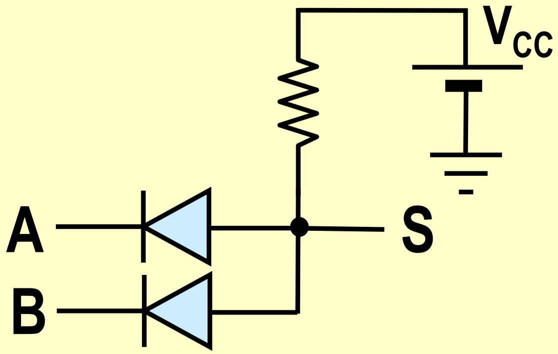
- Clipping diodes: protect the Mosfet inputs of CMOS digital circuits against overvoltages.



- D_1 conducts if $V_i > V_{DD} + 0.7V$
- D_2 conducts if $V_i < -0.7V$
- $-0.7V =< V_G <= V_{DD} + 0.7V$

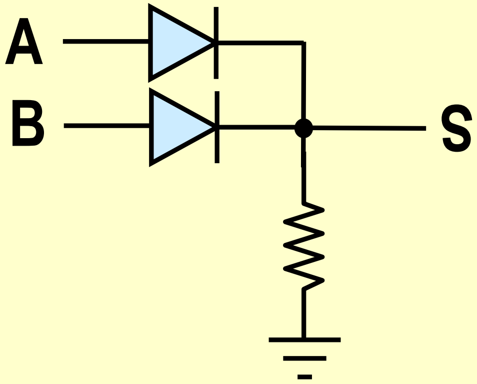
1.3. Diode circuits. Digital applications

AND Gate



A	B	S
0	0	0
0	1	0
1	0	0
1	1	1

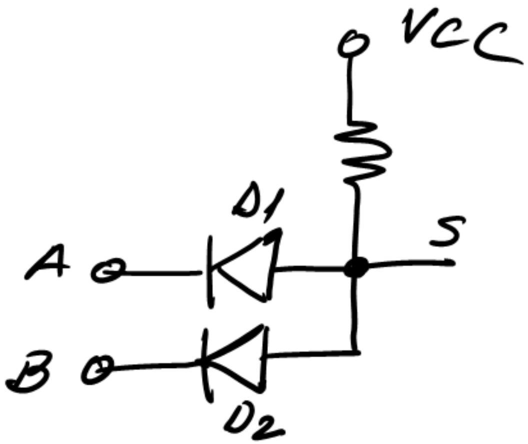
OR Gate



A	B	S
0	0	0
0	1	1
1	0	1
1	1	1

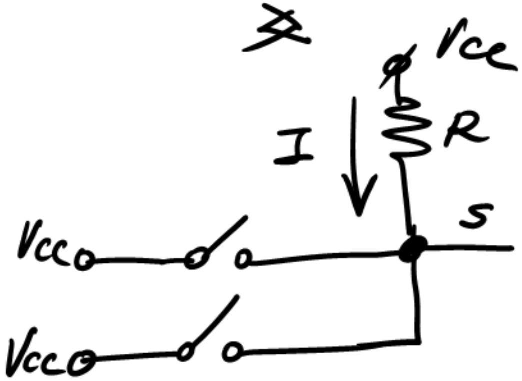
AND

- Case $A = B = 1$; $V_A = V_B = V_{cc}$



D_1 OFF, D_2 OFF (Reverse biased)

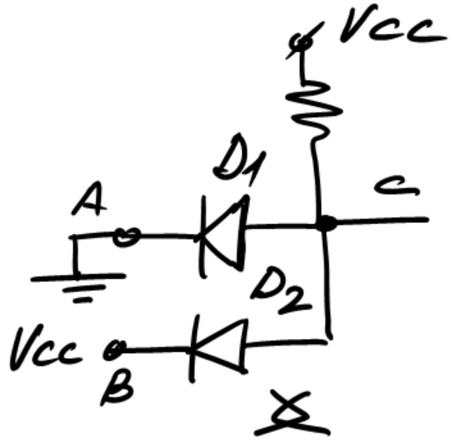
$\not\approx$



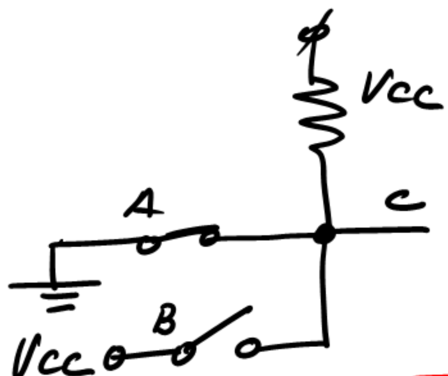
$I = 0 \Rightarrow V_S = V_{cc} - IR = V_{cc}$

Then $\boxed{\left.\begin{matrix} A = 1 \\ B = 1 \end{matrix}\right\} S = 1}$

AND Case • $A=0,\ B=1;\ V_A=0V;\ V_B=V_{cc}$



D_1 ON
D_2 OFF

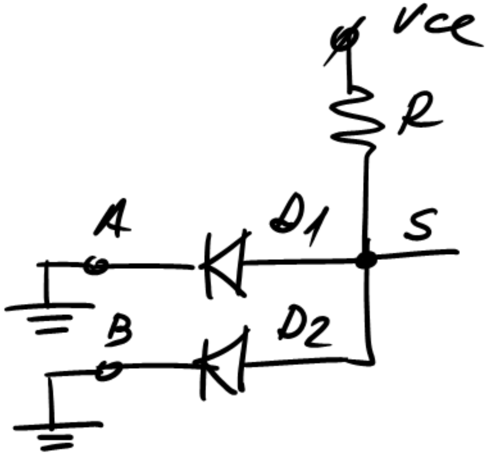


$V_c = 0V \Rightarrow c = 0$

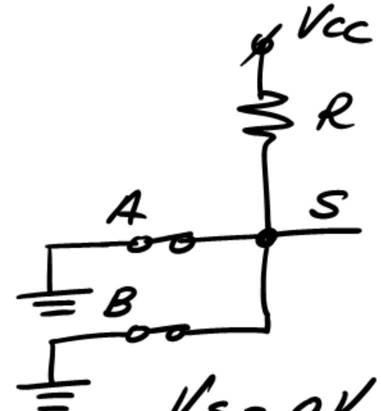
Then $\boxed{\left.\begin{array}{l} A=0 \\ B=1 \end{array}\right\} c=0}$; on the same way:

• Case $A=1;\ B=0$ $\rightarrow$ $\boxed{\left.\begin{array}{l} A=1 \\ B=0 \end{array}\right\} c=0}$ (simmetry $A \rightleftarrows B$)

AND • Case $A=B=0$; $V_A=V_B=0V$



D_1 ON
D_2 ON $\Rightarrow$



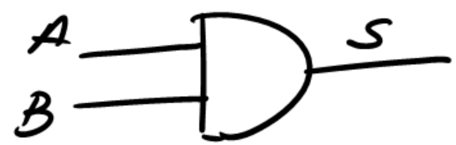
$V_S = 0V \Rightarrow$

$$\boxed{\left.\begin{array}{l} A=0 \\ B=0 \end{array}\right\} S=0}$$

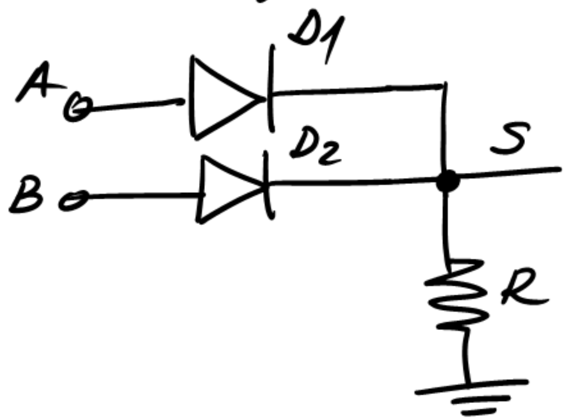
Summary:

A B	S
0 0	0
0 1	0
1 0	0
1 1	1

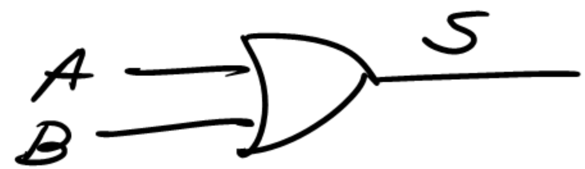
$\Rightarrow$ $\boxed{S = A \cdot B \text{ (AND)}}$



OR gate



A	B	D_1	D_2	V_S	S
0	0	OFF	OFF	0	0
0	1	OFF	ON	Vcc	1
1	0	ON	OFF	Vcc	1
1	1	ON	ON	Vcc	1



$$\boxed{S = A + B}$$

1.3 Other applications in digital circuits

As we will see throughout the course, diodes are present in almost all digital integrated circuits:

- Digital gates based on bipolar transistors (ex: TTL) use diodes for adjusting the voltage levels.

  NMOS transistors

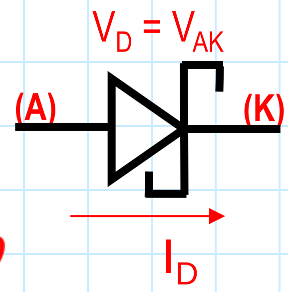
- Each MOS transistor inside NMOS or CMOS digital circuits have implicitely several diodes in reverse mode.

  CMOS $\left\{ \begin{array}{c} \text{NMOS} \\ \text{PMOS} \end{array} \right\}$ transistors

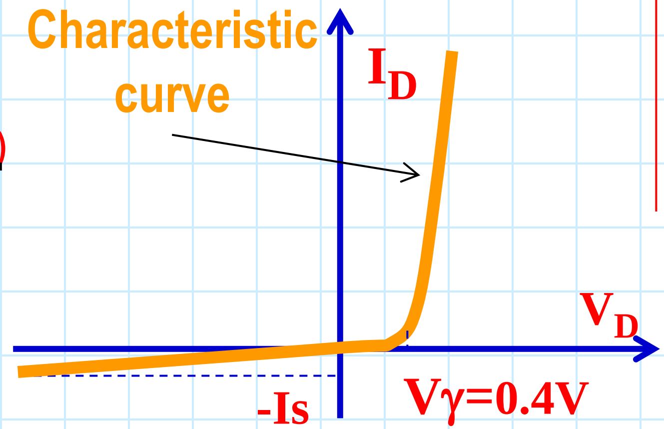
1.4 Special purpose diodes. Schottky diodes

- Special diodes for switching circuits
- Based on a metal (Al)- *(*)* semiconductor (“n” not many doped) junction
- High Is (1000 times bigger)
- Low $V\gamma$ (0,4V approx.)
- Very fast switching
- Application to high-speed digital circuits

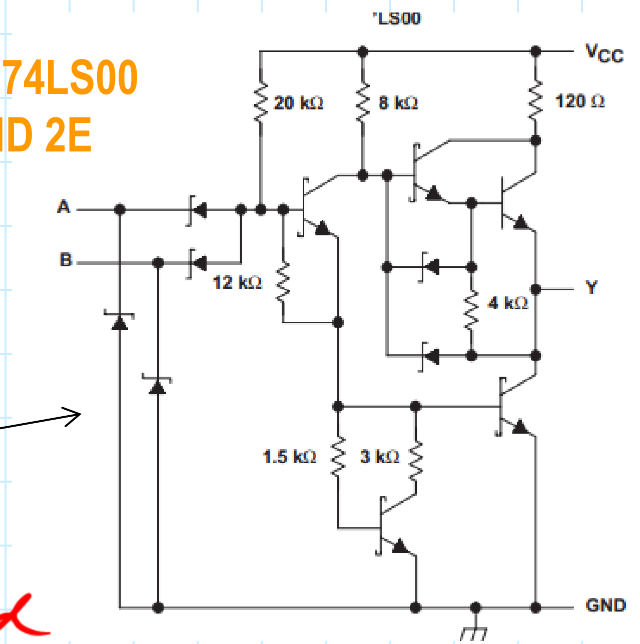
Symbol:



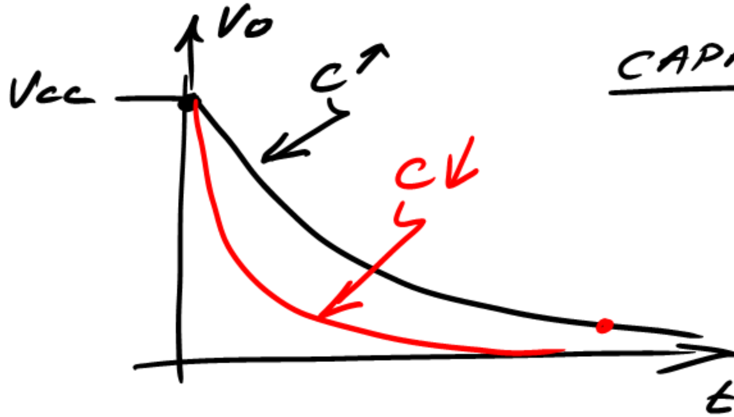
Characteristic curve



Example: 74LS00
4 * NAND 2E

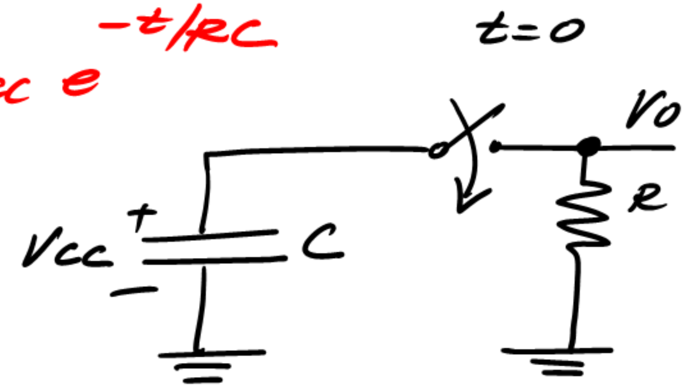


This juntion minimizes parasitic capacitance ⇒ less C ⇒ More speed



CAPACITOR DISCHARGE

$$V_o = V_{cc}\, e^{-t/RC}$$



$RC \rightarrow$ Timing constant

$C\uparrow \rightarrow RC\uparrow \Rightarrow$ More delay $\Rightarrow$ less speed

Shottky: $C\downarrow \Rightarrow RC\downarrow \Rightarrow$ Less delay $\Rightarrow$ More speed

C : Parasitic capacitance

1.4 Special purpose diodes. LED

light e^- E_1 E_2

$h \rightarrow$ Plank constant

$f \rightarrow$ freq.

$E_1 - E_2 = h \cdot f$

ELECTROLUMINESCENCE

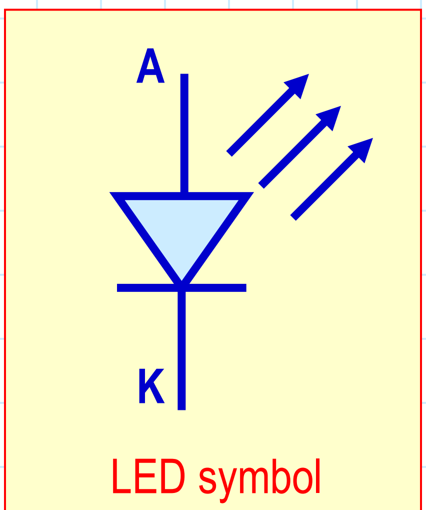
- LED: Light Emitting Diode

- When diode is forward-biased, majority carriers are injected in the P-N junction . The carriers recombinate in order to restore the equilibrium, emitting energy in the form of heat or light.

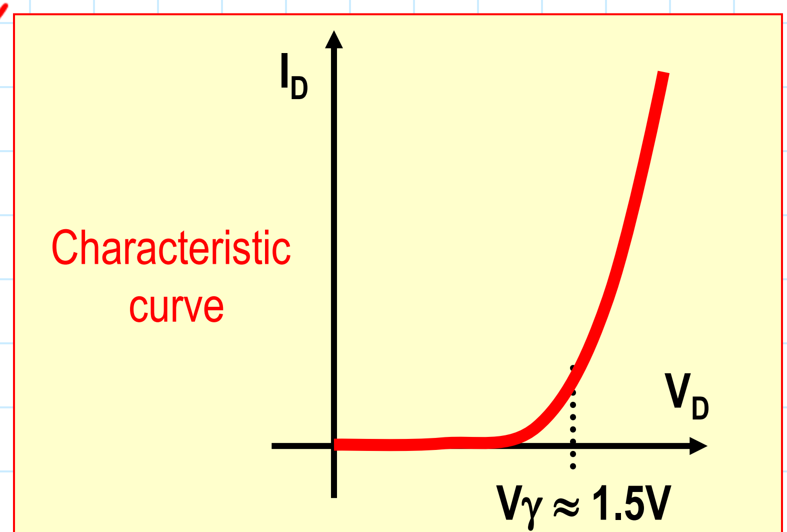
- This last case (light emitting) is produced only in the case of special semiconductor materials: GaAs, GaAsP, SiC, ...

infrared

blue



LED symbol

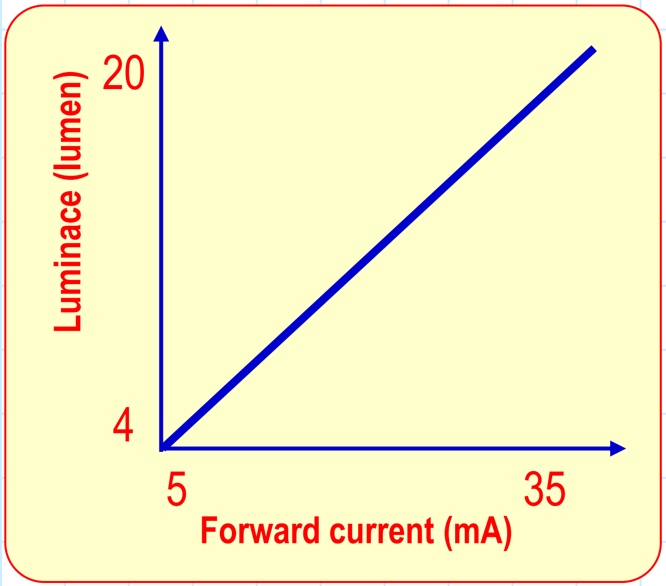


Characteristic curve

1.4 LED features

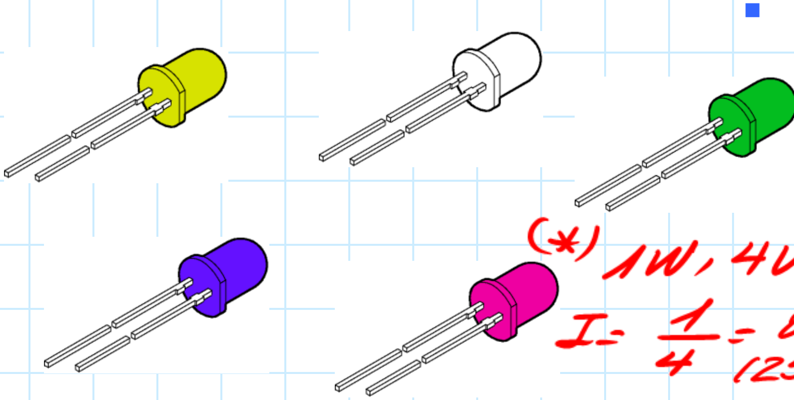
Infrared, Red .... Blue, Ultraviolet

- $V\gamma$ is among **1.5V to 4V**
- The emitted luminace is directly proportional to the forward current
  - (for a good visibility, a forward current from **10 to 20mA** is required)
  - The modern high power LEDs (1 W or more), require more current (*)
- The radiation is almost monochrome (only one color)



- Radiation frequency of LEDs:
  - Infrared (with a lot of applications)
  - Red (the most typical)
  - Yellow
  - Green
  - Blue
  - Ultraviolet

Blue, Ultraviolet: The latest ones



(*) 1W, 4V ⇒

$I = \frac{1}{4} = 0.25A$ (250mA)

1.4 Blue LED

- In 2014 the Nobel Prize in Physics was delivered to the discoverers of blue LED : Akasaki, Amano and Nakamura.
- To produce white light, blue LED was missing for many years:

  Red, green: already invented

  - White light with 3 LEDs: red, green and blue (RGB)
  - White light with one blue LED+ optical filter of Phosphorus
- After several failed attempts, in 1994 they first obtained a "high" efficiency blue LED (for that time).
- They used a semiconductor based on InGaN / AlGaN, and obtained an efficiency of about 2.7% (incandescent bulbs have an efficiency of a 4%). ≃50%
- Now we have more efficiency:

5W led ≃ 50W halogen (1/10 reduction on power consumption)