Discrete semiconductor devices

⇒ Rectifier (Diode)

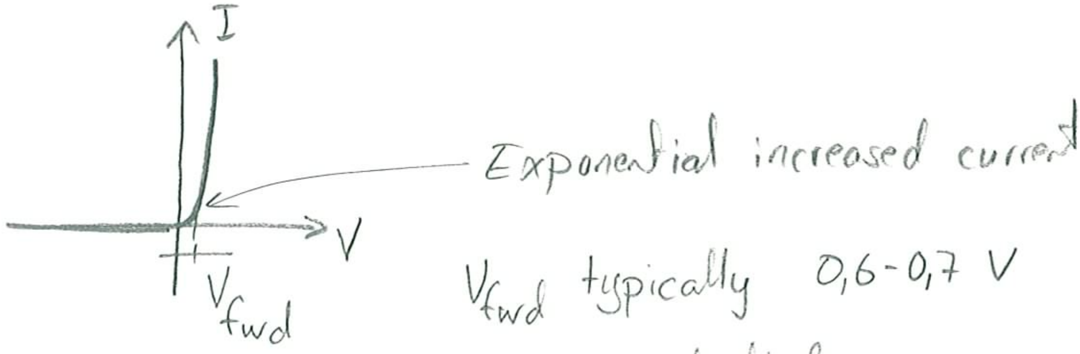
- LEDs
- Zener diodes
- Photodiode

⇒ Transistors

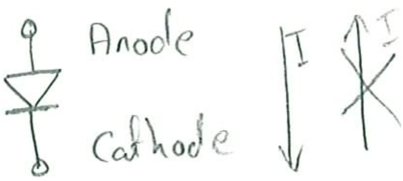
- Bipolar transistors
- MOSFETs

Diodes

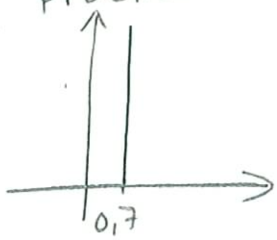
2 terminal device that conduct current in one direction and an isolator in the reverse direction



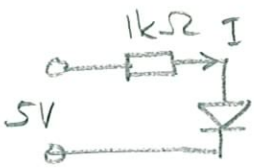
V_{fwd} typically 0,6 - 0,7 V



Practical diode

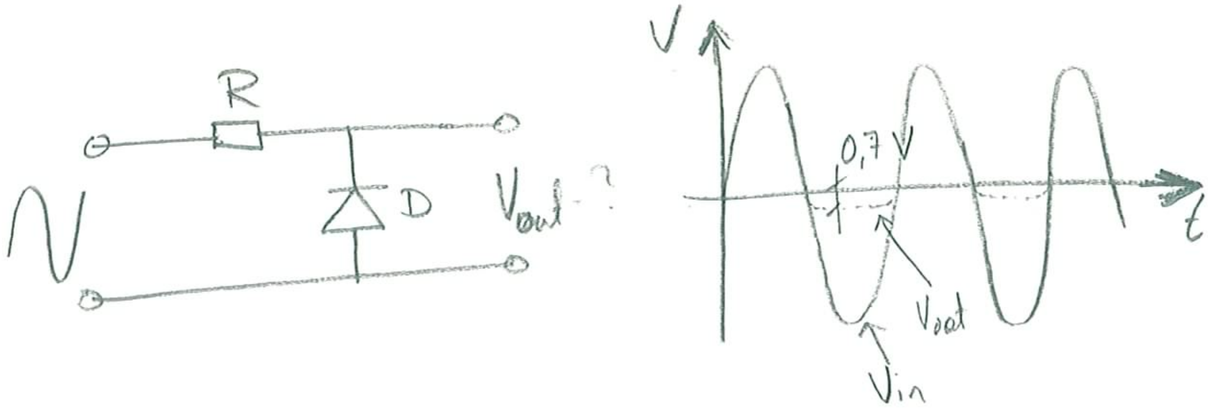


Ex)



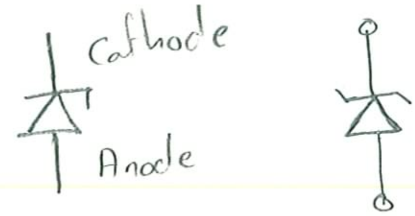
$V > 0{,}7\,V \rightarrow$ Diode conducts $\rightarrow V_D = 0{,}7\,V$

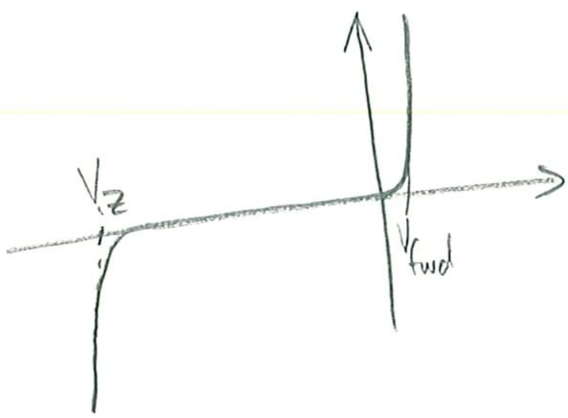
$$I = \frac{V_R}{R} = \frac{5 - 0{,}7}{1k} = \frac{4{,}3}{1k} = 4{,}3\,mA$$



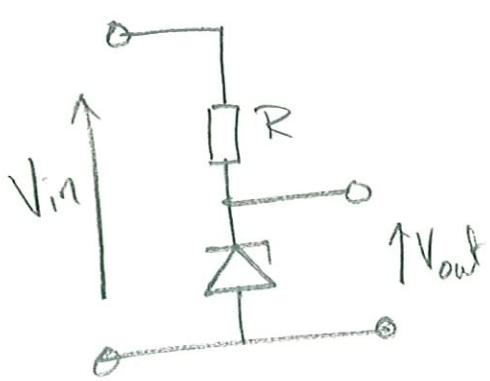
Zener diode

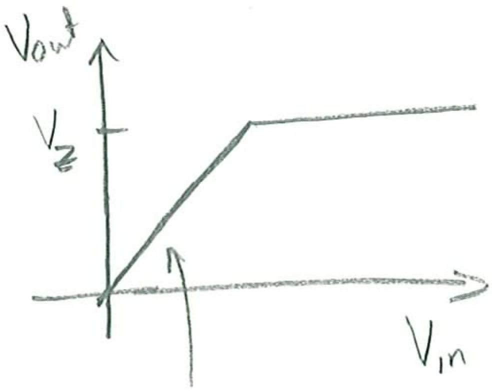
Diode that also starts to conduct at a specific reverse voltage, V_Z.





Zener diodes are often used to give a constant voltage





$V_{in} < V_Z \rightarrow$ Diode isolator $\rightarrow I = 0 \rightarrow V_R = 0$

$\Rightarrow V_{out} = V_{in}$

$V_{in} > V_Z \rightarrow$ Diode conducts with

$V_D = V_Z = V_{out}$

Light emitting diode (LED)

Diode that emitts light when current flows in forward direction

V_F depends on what color the specific diode shines with. on is approximately

$$V_{Fwd} \approx h\nu = h \frac{c_0}{\lambda}$$

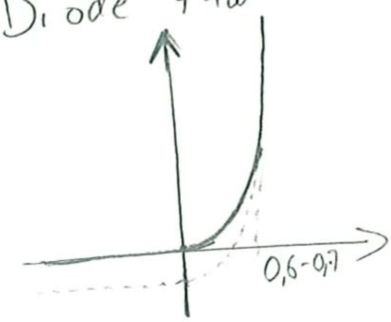
↑ Plank const in eV

Ex Red LED with $\lambda = 660nm$

$$V_{Fwd} = h \cdot \frac{c_0}{\lambda} = 4{,}14 \cdot 10^{-15} \frac{3{,}0 \cdot 10^{8}}{660 \cdot 10^{-9}} = 1{,}9\ V$$

Photodiode

Diode that reacts on incoming light



Leakage current in reverse direction increases proporitional to the incoming light.

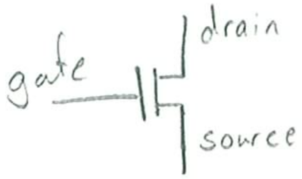
Can be used both at zero volt or any reverse bias.

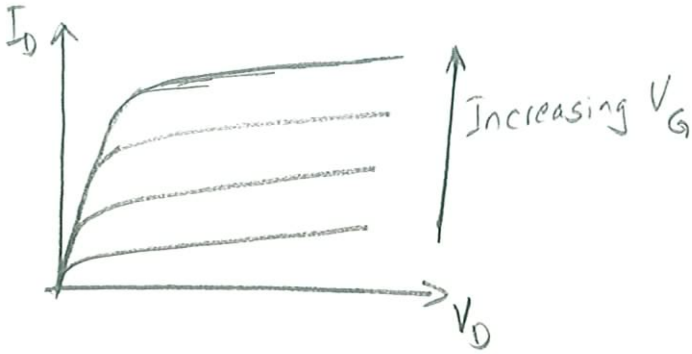
Transistors

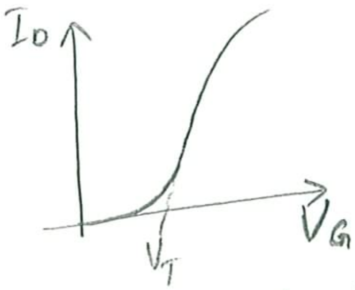
- Electronic 'valve'
  - The electron current is controlled with either a voltage or a current
- Millions of transistors is connected in integrated circuits
- Discrete transistors is often used in power applications
  - Driving high currents
  - Blocking high voltages

MOSFET

A MOSFET is voltage controlled device







Treshhold voltage

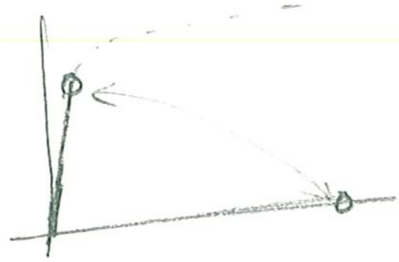
$\Rightarrow$ Gate isolated

$I_G = 0$

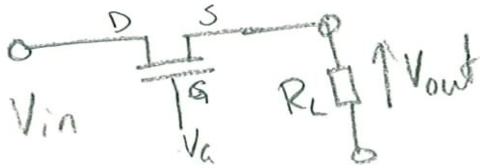
Often used as a switch i switched power applications.

$V_G = 0 \Rightarrow I = 0$

$V_G > V_T \Rightarrow I \approx \frac{V_D}{R_{DSon}}$

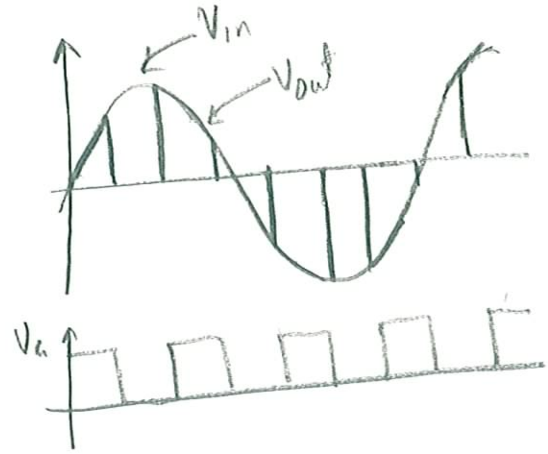


Ex) Switching analog signal



$V_G = 0 \Rightarrow V_{out} = 0$

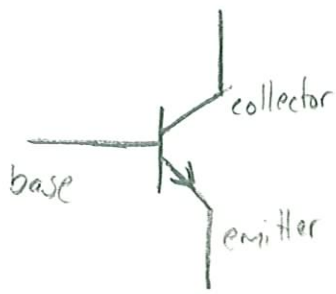
$V_G > V_{Th} \Rightarrow V_{out} = V_{in}$ (If $R_L >> R_{DSon}$)



Notice that the source voltage most low enough so that $V_{GS} > V_{Th}$

Bipolar transistors

- Current controlled



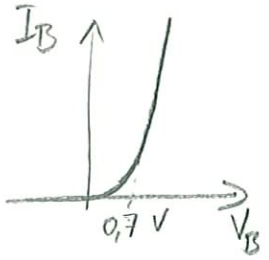
NPN

- A small base-emitter current I_b controls a larger collector-emitter current I_c

$I_c = \beta \cdot I_b$ where β is the current amplification factor.

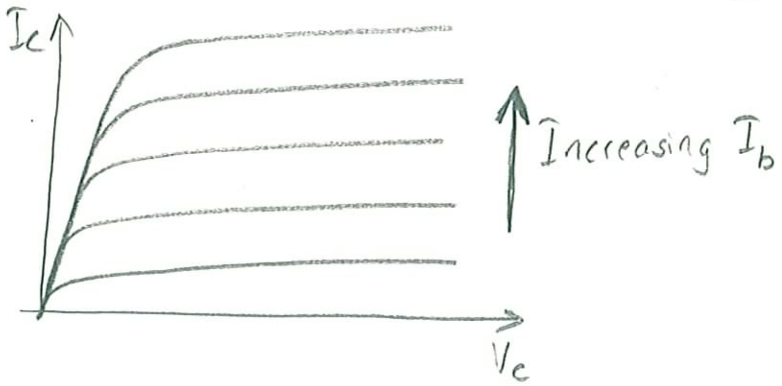
β is typically 10-500

The base-emitter junction is a p-n diode junction

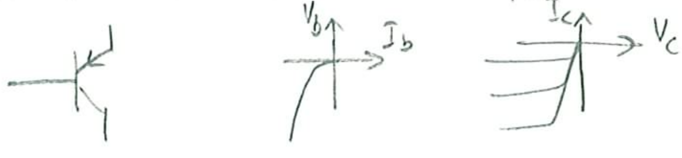


The collector current saturates shortly to

$I_c = \beta \cdot I_b$



A PNP transistor have opposite characteristics

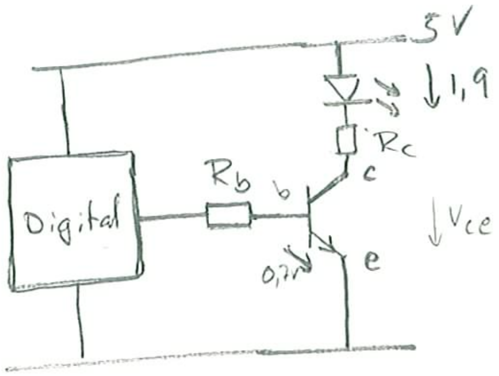


Ex Driving a LED from a digital output

$I_{omax} = 1\,mA$, $V_{cc} = 5V$
$V_{out} = 5V$

LED $V_F = 1,9V$
$I_{F_{MAX}} = 30mA$

Transistor $\beta_{min} = 50$



Design

$I_{F_{MAX}} = 30mA \rightarrow I_{C_{MAX}} = 30mA$

In saturation V_{ce} is low typically 0,2 V and can be neglected

$$R_C = \frac{V_{RC}}{I_C} = \frac{5-1,9}{30mA} = 103$$

select 110 Ω

β is at least 50 times

$$\Rightarrow I_b = \frac{I_C}{100} = \frac{30mA}{100} = 0,6\,mA$$

$$R_b = \frac{V_{Rb}}{I_b} = \frac{5-0,7}{0,6m} = 7,2\,k\Omega$$

select 6,8 kΩ