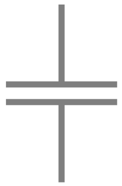
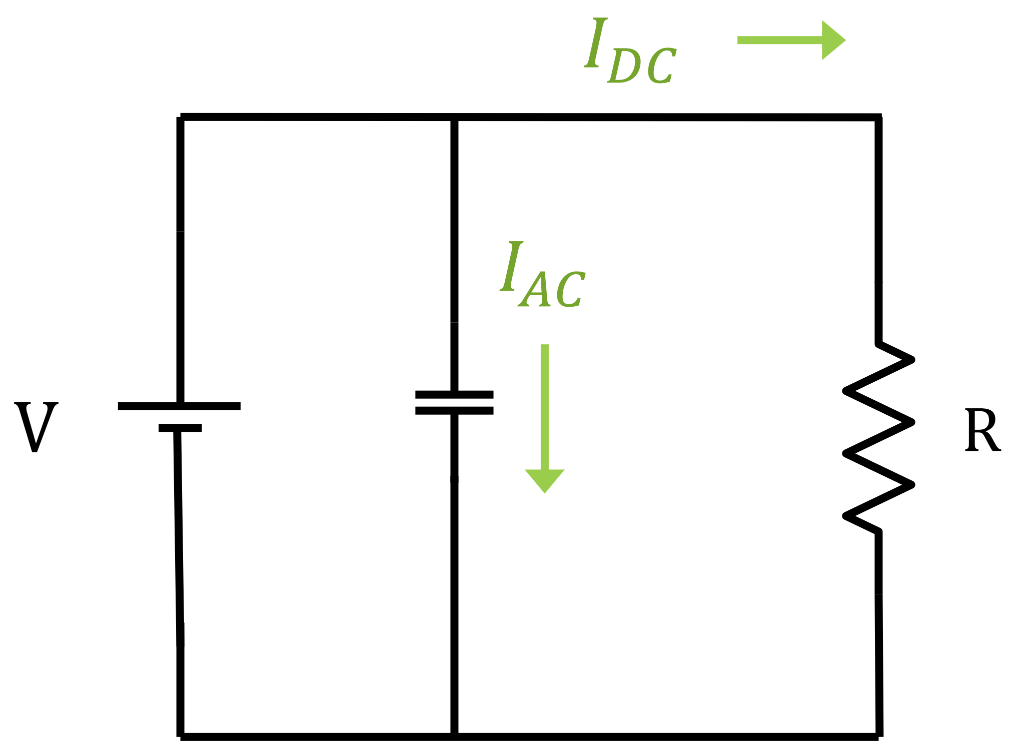
BASIC ELECTRONICS

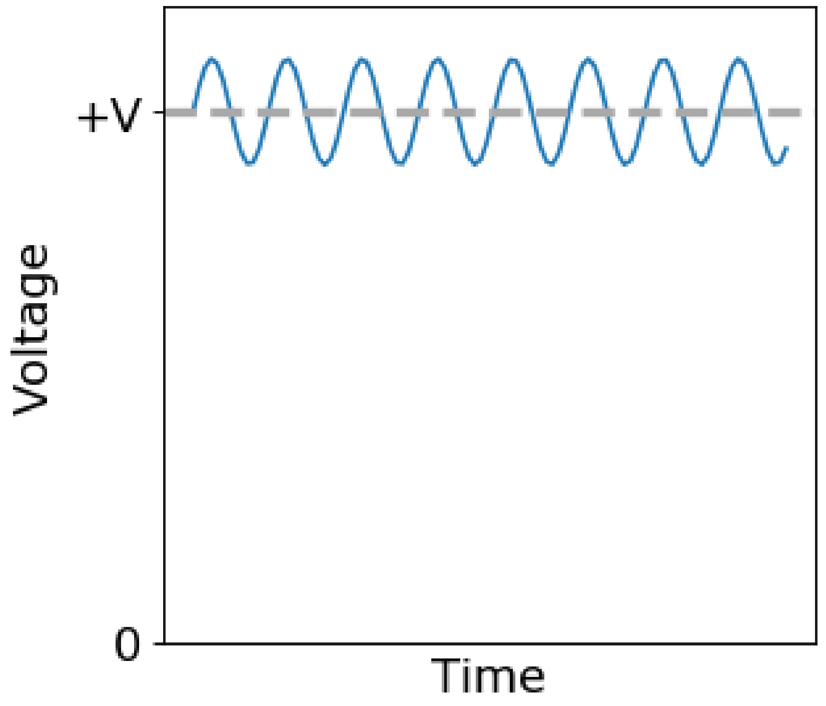
Capacitors



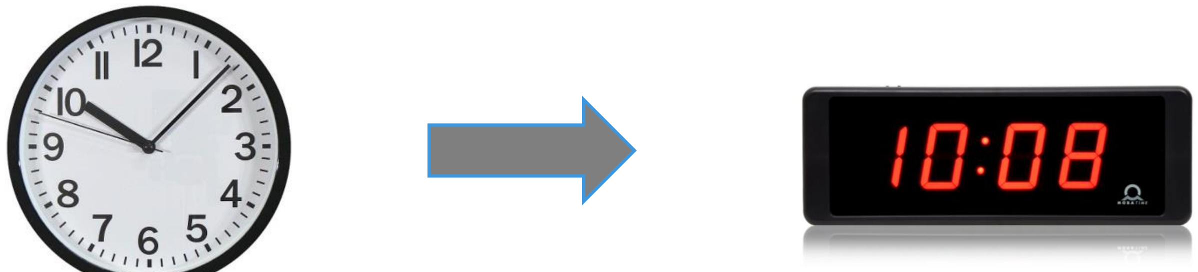
- A capacitor is an insulator sandwiched between two metal plates.
- It can store electric charge, and maintain a voltage across the plates.
- Its most important property is it passes AC current and block DC current
- Units are the Farad

Bypass Capacitors





Analog to digital converters (ADC)

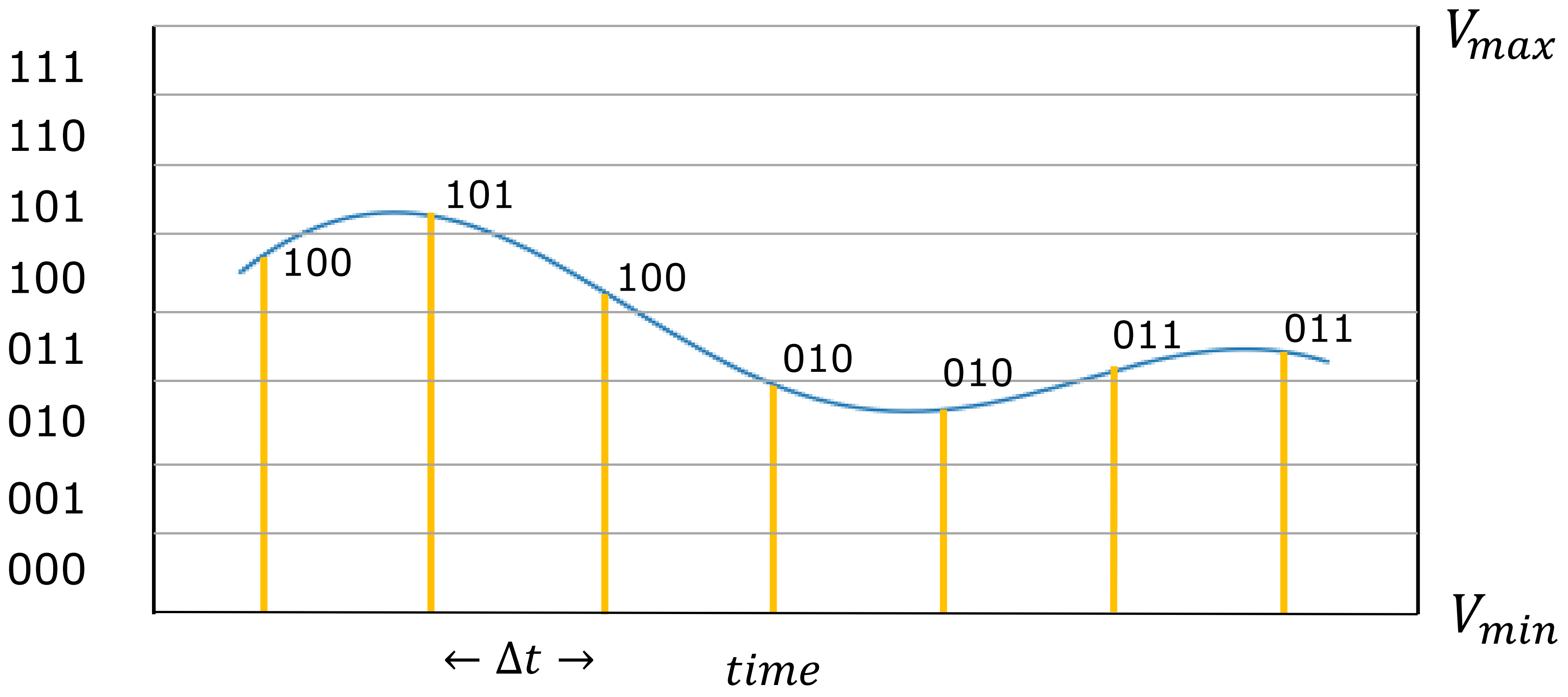


Converts an analog value into a digital (binary) number

All of our sensor outputs are being processed in an ADC

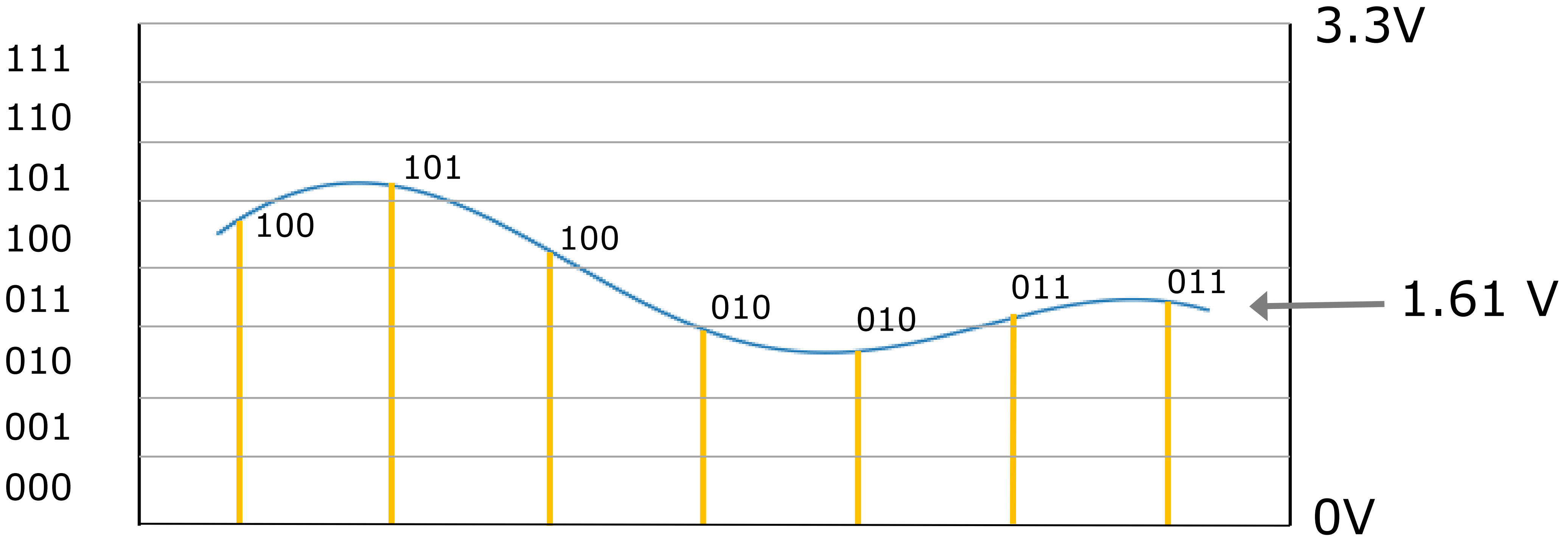
- If the sensor outputs bits/bytes, the ADC is internal to the sensor
- If the sensor output is a voltage (analog), then we use the ADC on the microcontroller to digitize the data

ADC



111
110
101
100
011
010
001
000
V_{max}
V_{min}
100
101
100
010
010
011
011
$\leftarrow \Delta t \rightarrow$
$time$

3-bit example

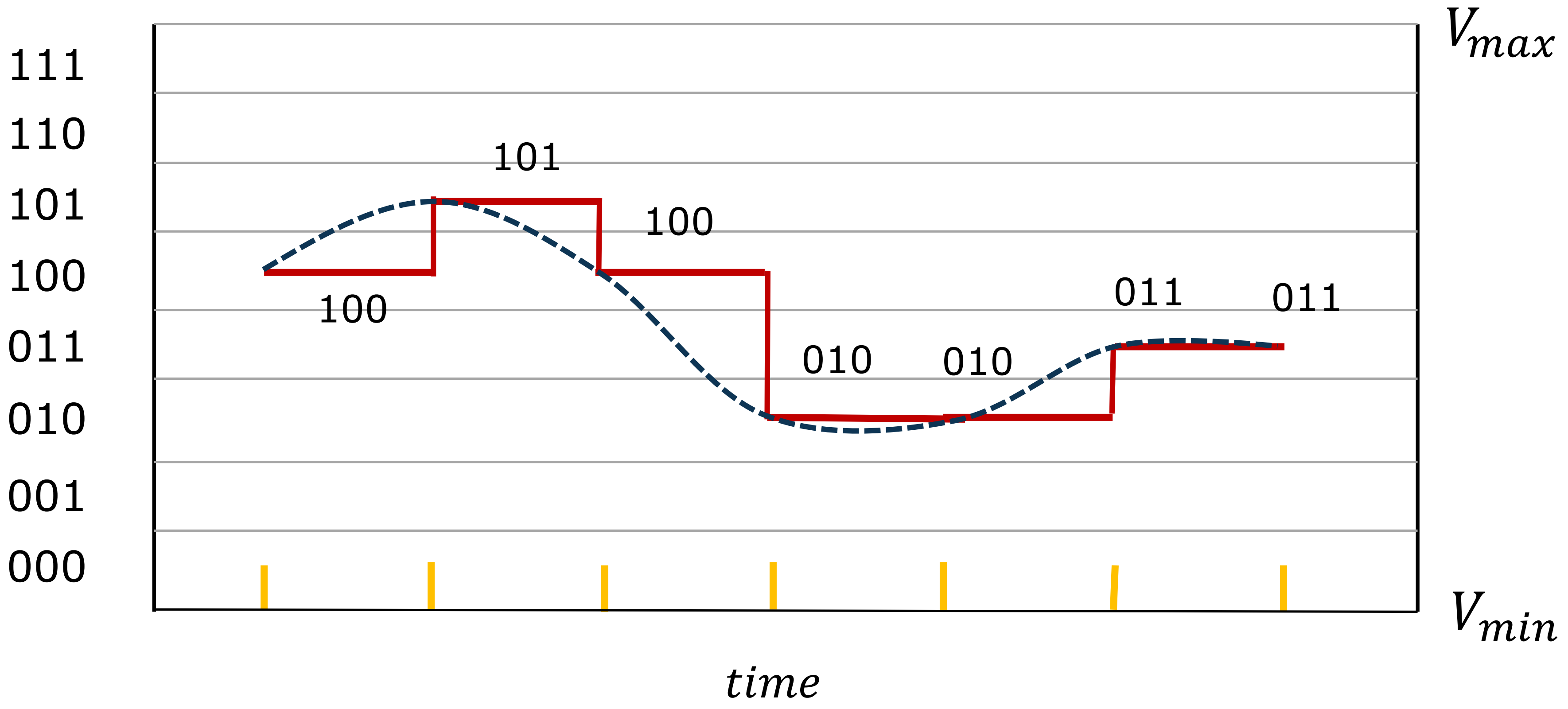


$$\frac{binary\ value\ (x)}{1.61\ V} = \frac{8}{3.3V}$$

$$x = \frac{8}{3.3V} \cdot 1.61\,V = 3 = 011b$$

In a 10-bit ADC, each binary value covers $\frac{3.3V}{1024} = 3.2mV$

Digital to analog converters (DAC)



ADC

CD quality audio:

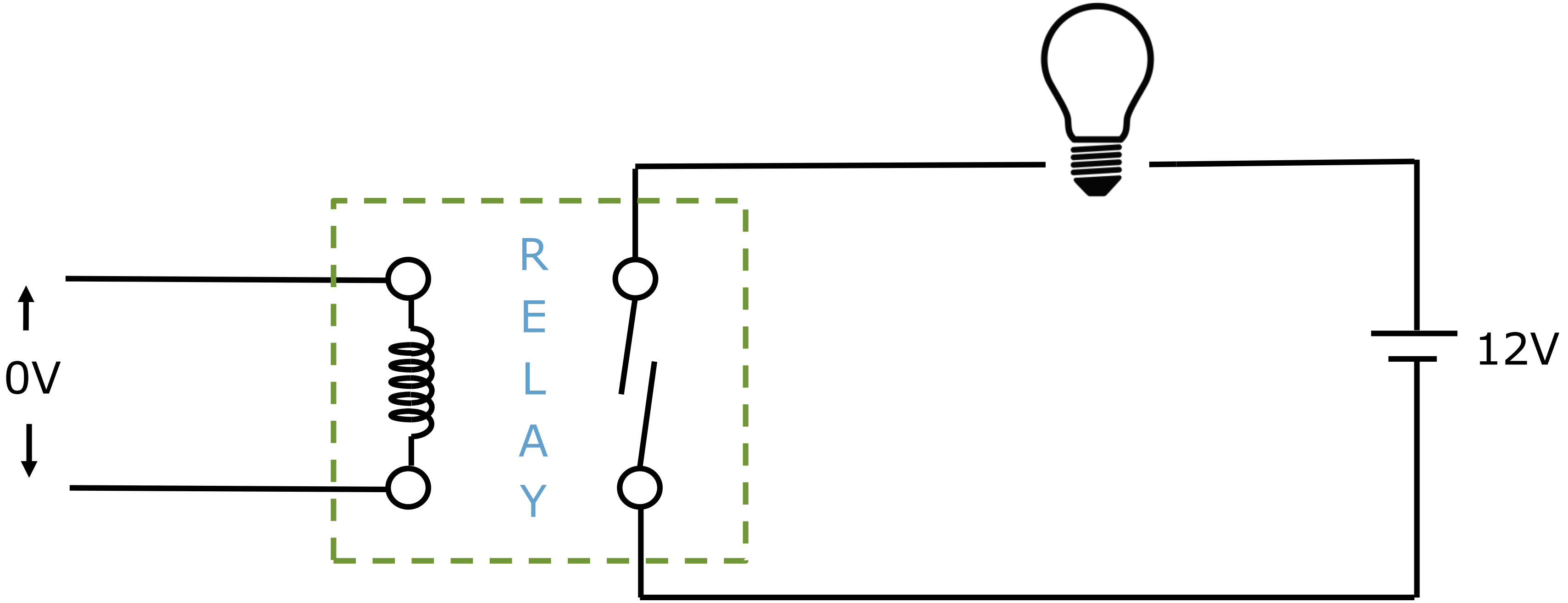
16 bits/sample × 44100 samples/second × 2 channels
= 1411 kbits/s

audio: 128, 160 and 192 kbit/s represent compression ratios of approximately 11:1, 9:1 and 7:1

Relays

(magnetically)

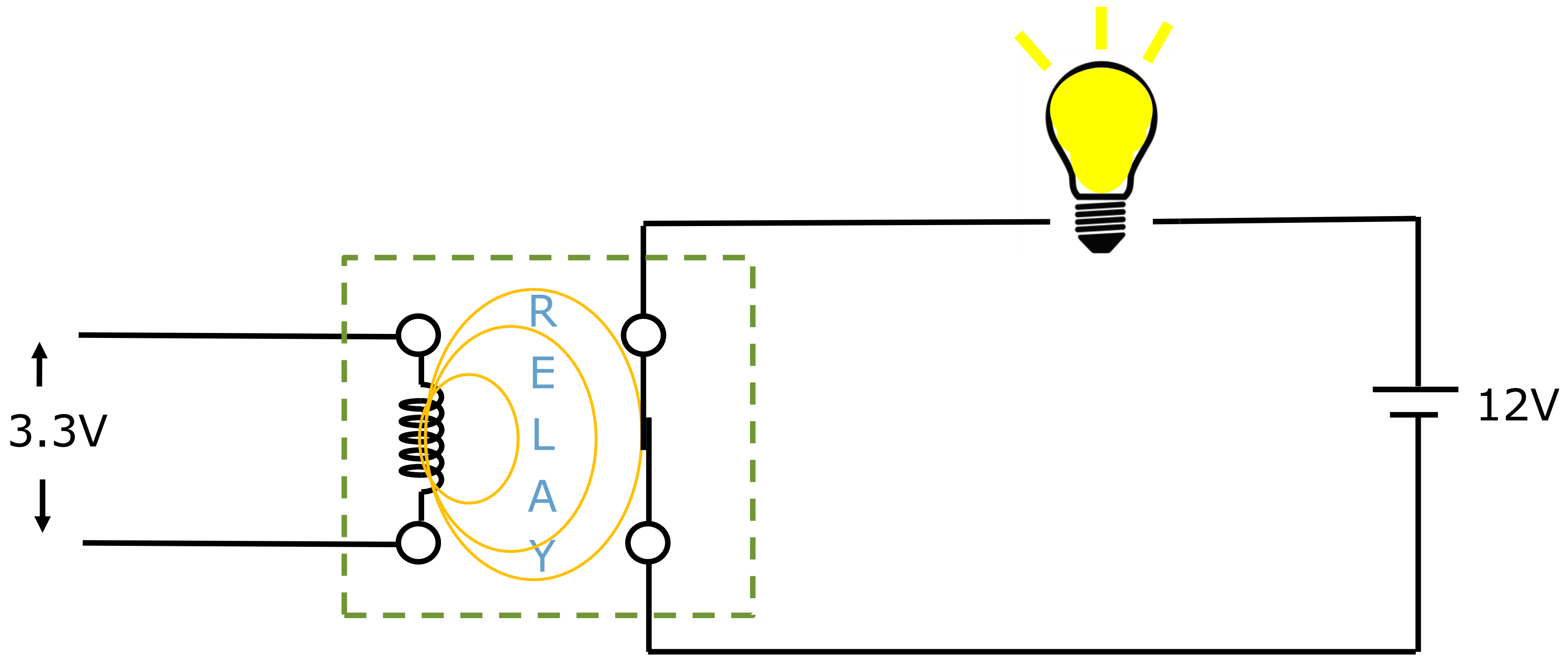
Switches that open and close circuits electromechanically or electronically.



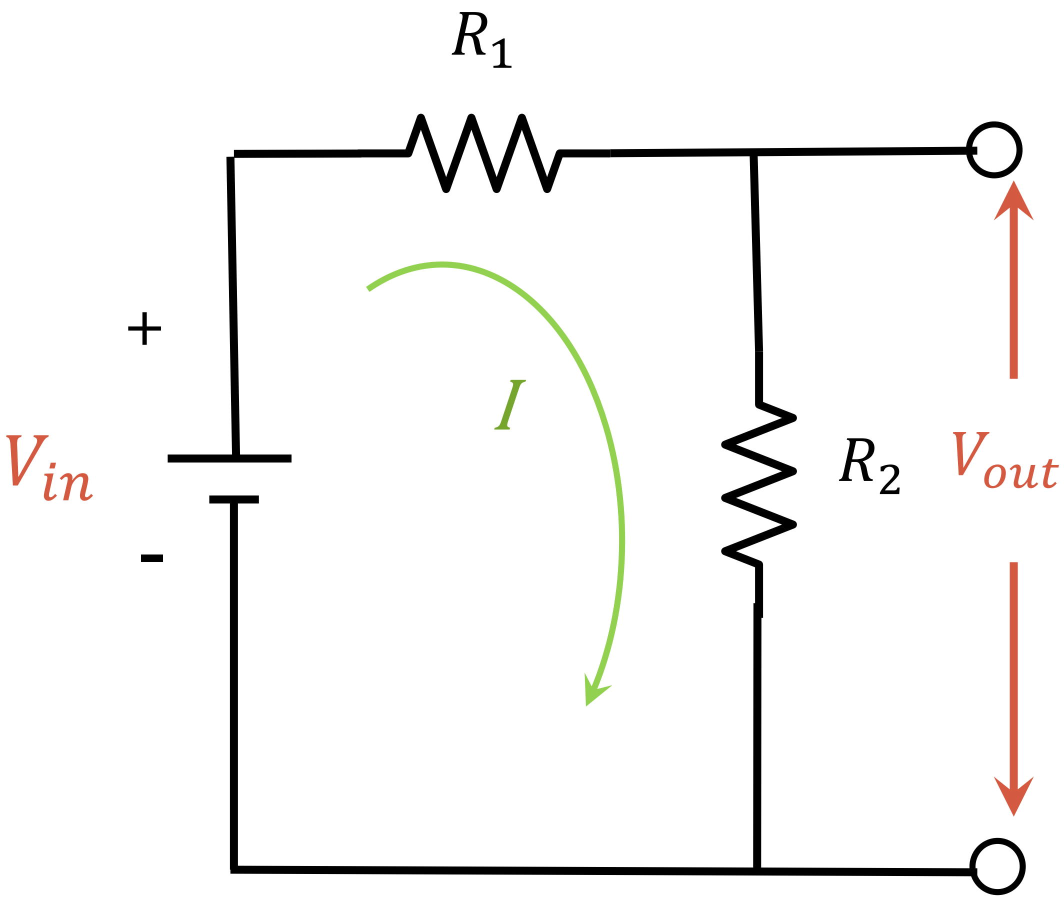
Relays

(magnetically)

Switches that open and close circuits electromechanically or electronically.



Voltage Divider

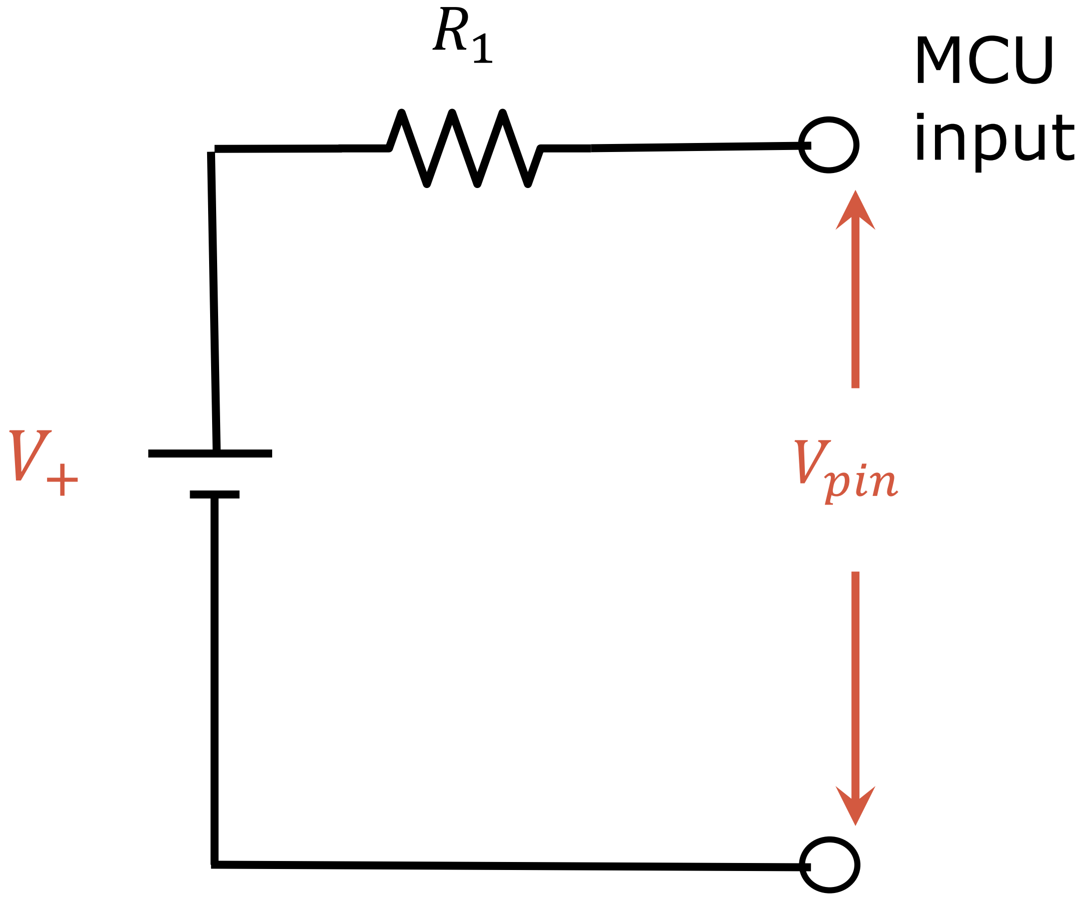


$$V_{out} = V_2 = I \cdot R_2$$

$$I = \frac{V_{in}}{R_1 + R_2}$$

$$V_{out} = \frac{V_{in}}{R_1 + R_2} \cdot R_2 = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

Pull-up Resistor



R_1 is 5-10kΩ

R_2 is MCU pin's input impedence (10 MΩ)

$$V_{pin} = V_+ \cdot \frac{R_2}{R_1 + R_2} \cong V_+$$

Voltage Regulators

Provides a constant desired voltage from some other voltage.

- Step-up "boost" - provides a higher voltage

Pololu U1V11F5

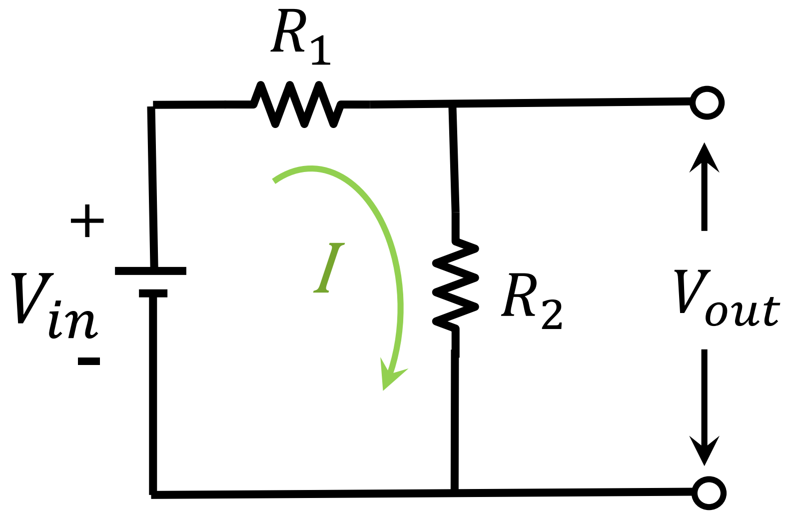
Input voltage (Vin)	0.5 – 5.5V
Output voltage (Vout)	5V
Max input current	1.2A
Efficiency	70-90%

Voltage Regulators

- Step-down "buck" - provides a lower voltage with good efficiency

Pololu D24V5F3

Input voltage	3.4 - 36V
Output voltage	3.3V
Max output current	500mA
Efficiency	80-90%

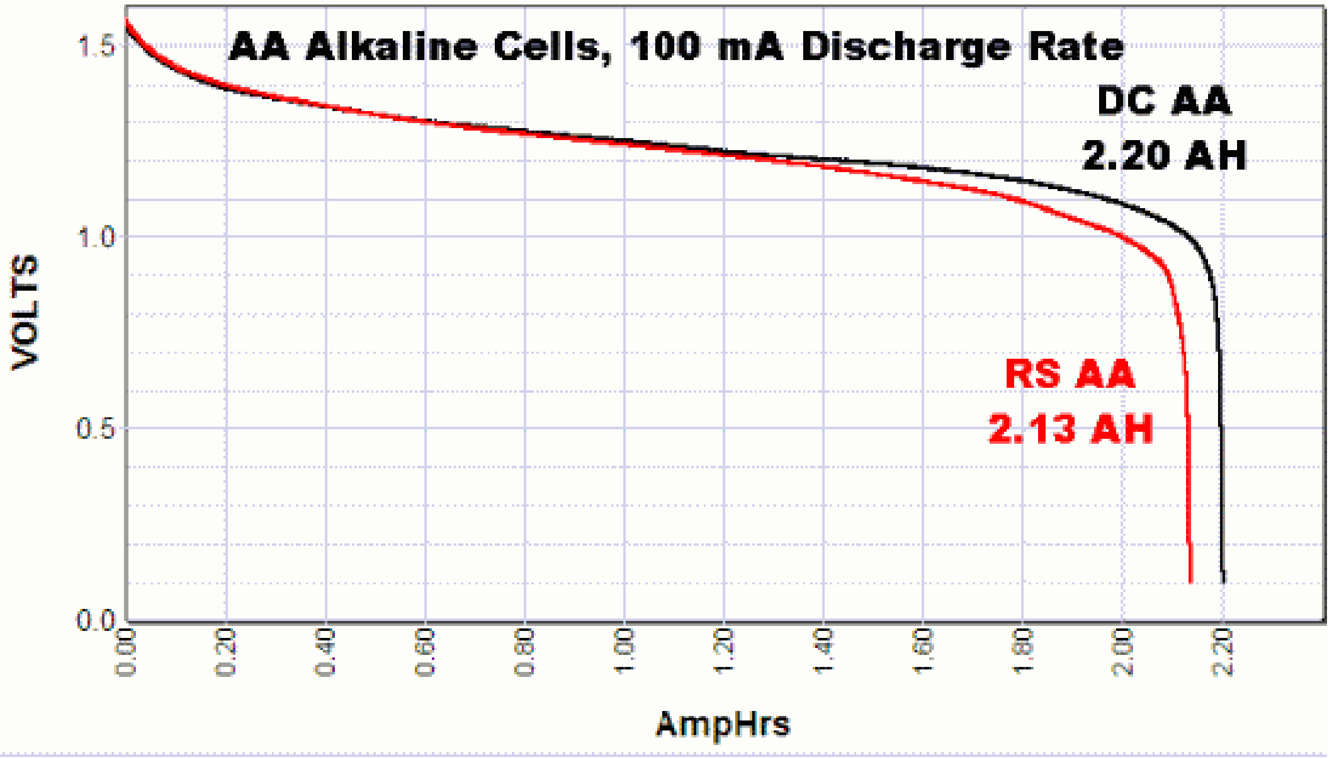


$$\text{Efficiency} = \frac{V_{out}}{V_{in}}$$

- Linear Regulator – simple but poor efficiency

Voltage Regulators

- Step-up/step-down "buck-boost"



Example: **5V sensor** powered by four alkaline batteries in series.

Battery pack

- 6.4V full charge
- dead at 3.6V

Pololu S7V7F5

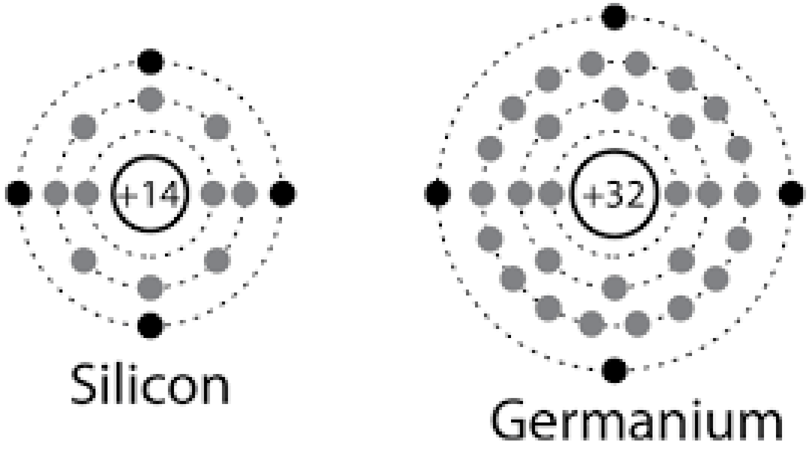
Input voltage	2.7 – 11.8V
Output voltage	5V
Max output current	0.5-1A
Efficiency	80-95%

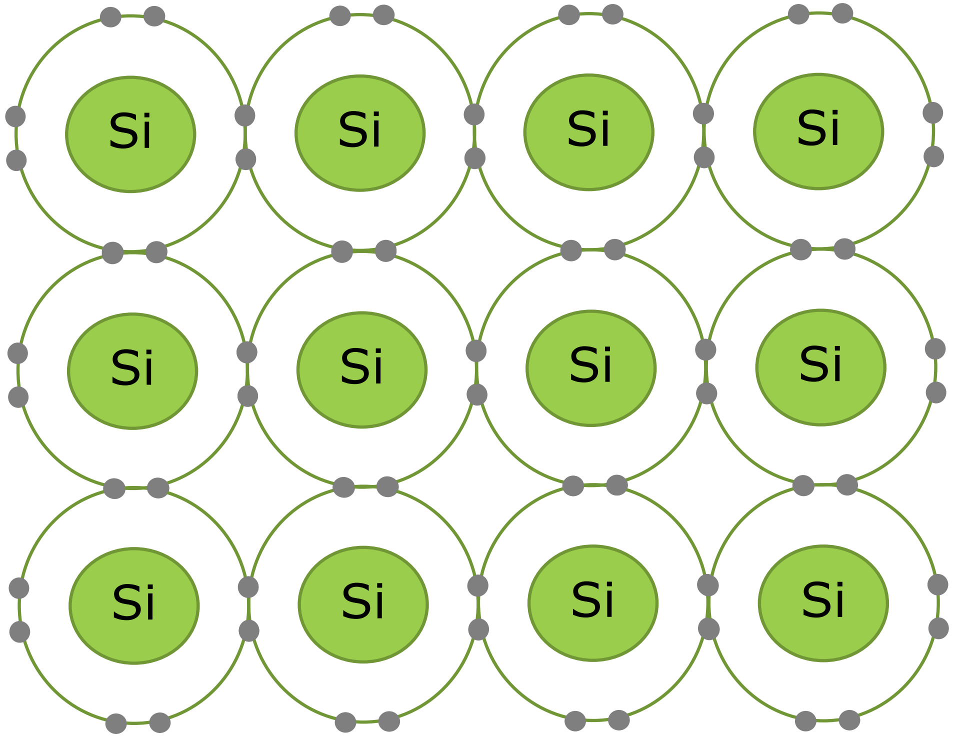
Semiconductors

Semiconductors can have their conductivity change by applying a small voltage to it. They are the switches that allow for binary computing.

Octet rule: According to Octet rule atoms are stable when there are eight electrons in their valence shell. If not, atoms readily accept or share with neighboring atoms to achieve eight valence electrons

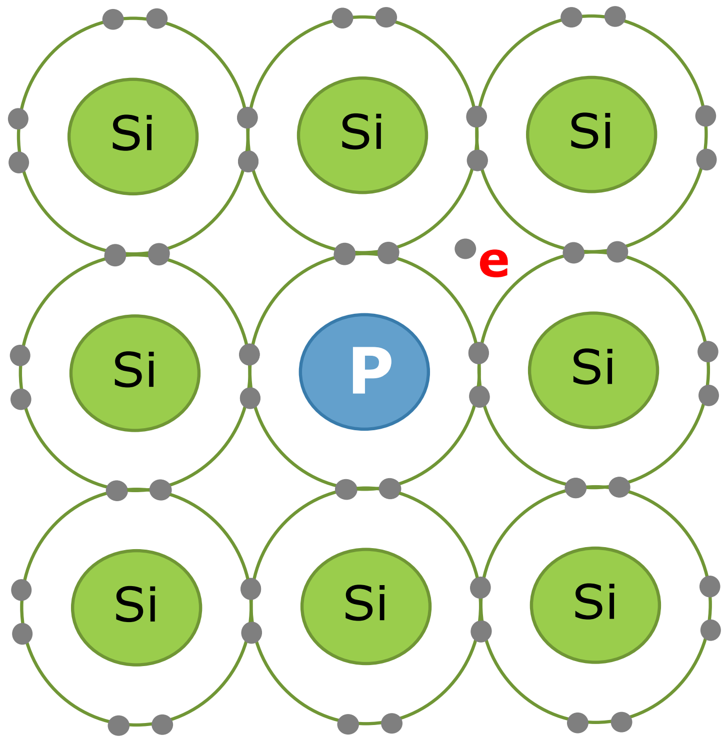
Semiconductors





A pure silicon lattice has no free electrons. We add impurities to it (“doping”) to give it useful electrical characteristics.

Semiconductors - N-type (negative)

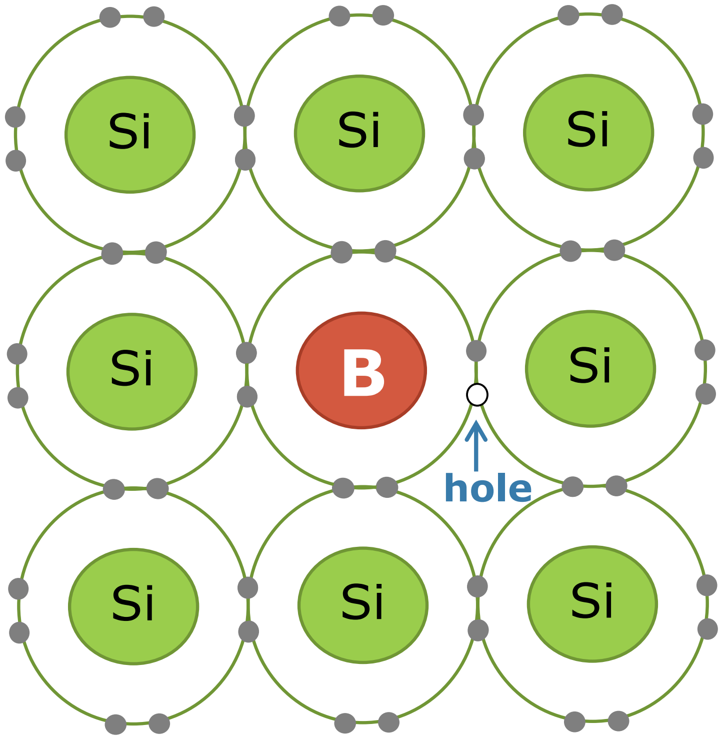


"Doping" with ***penta***valent atoms such as phosphorus or arsenic leaves free electrons in the lattice

Doping ratios are $1{:}10^4$ to $1{:}10^9$

Doping turns a silicon lattice from a good insulator into a viable conductor – a semiconductor.

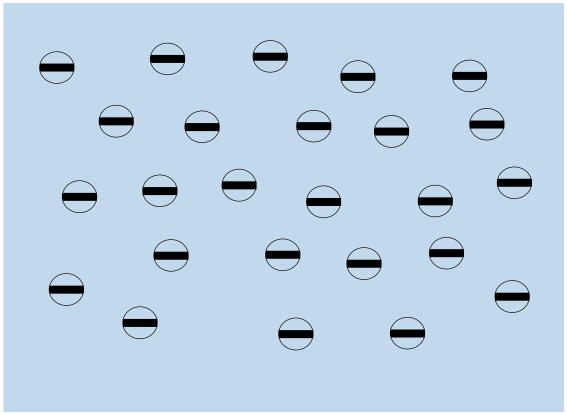
Semiconductors P-type (positive)



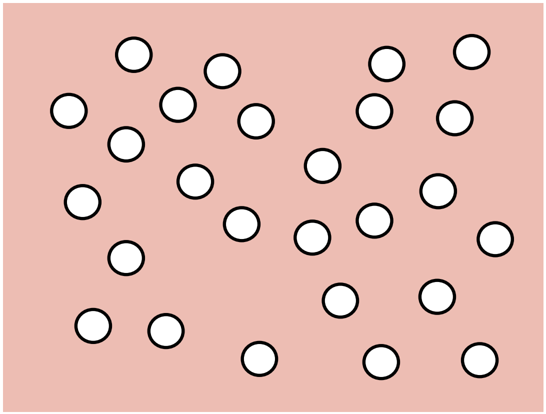
Doping with ***tri***valent atoms such as boron or gallium leaves “holes” in the valance band

The free electrons (N-type) and holes in N-type are known as “charge carriers”

Doped silicon semiconductors



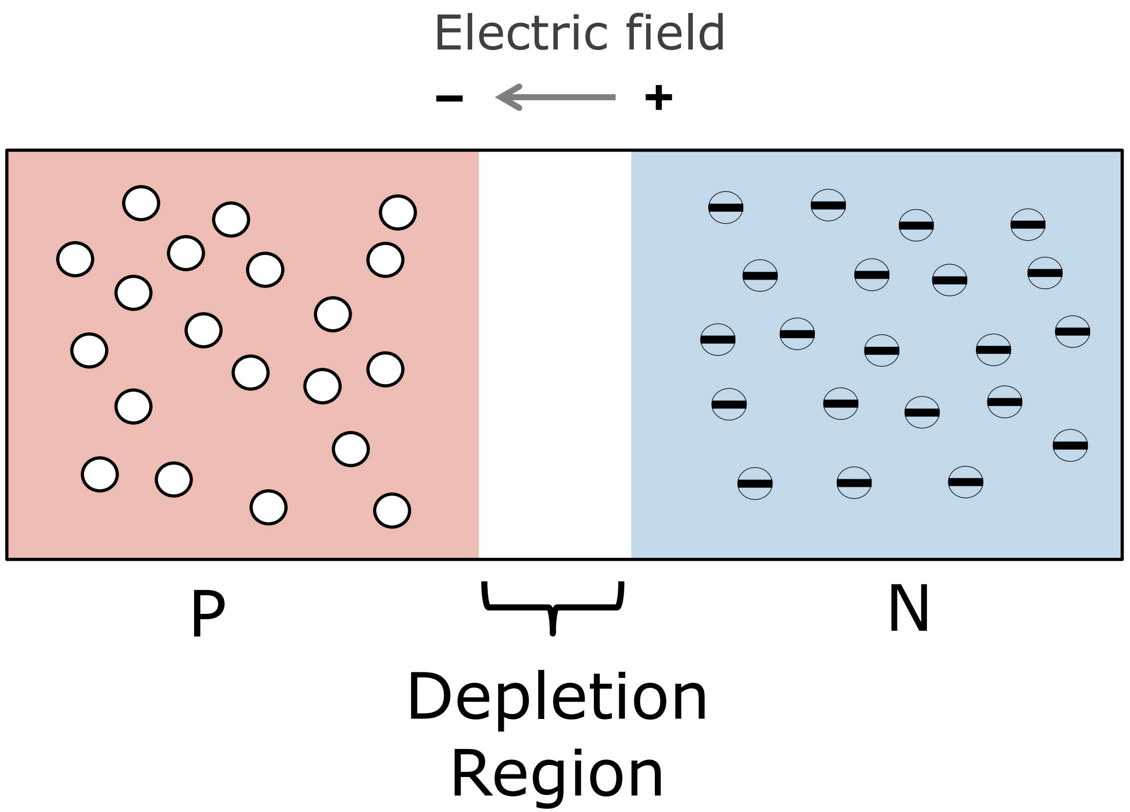
N-type



P-type

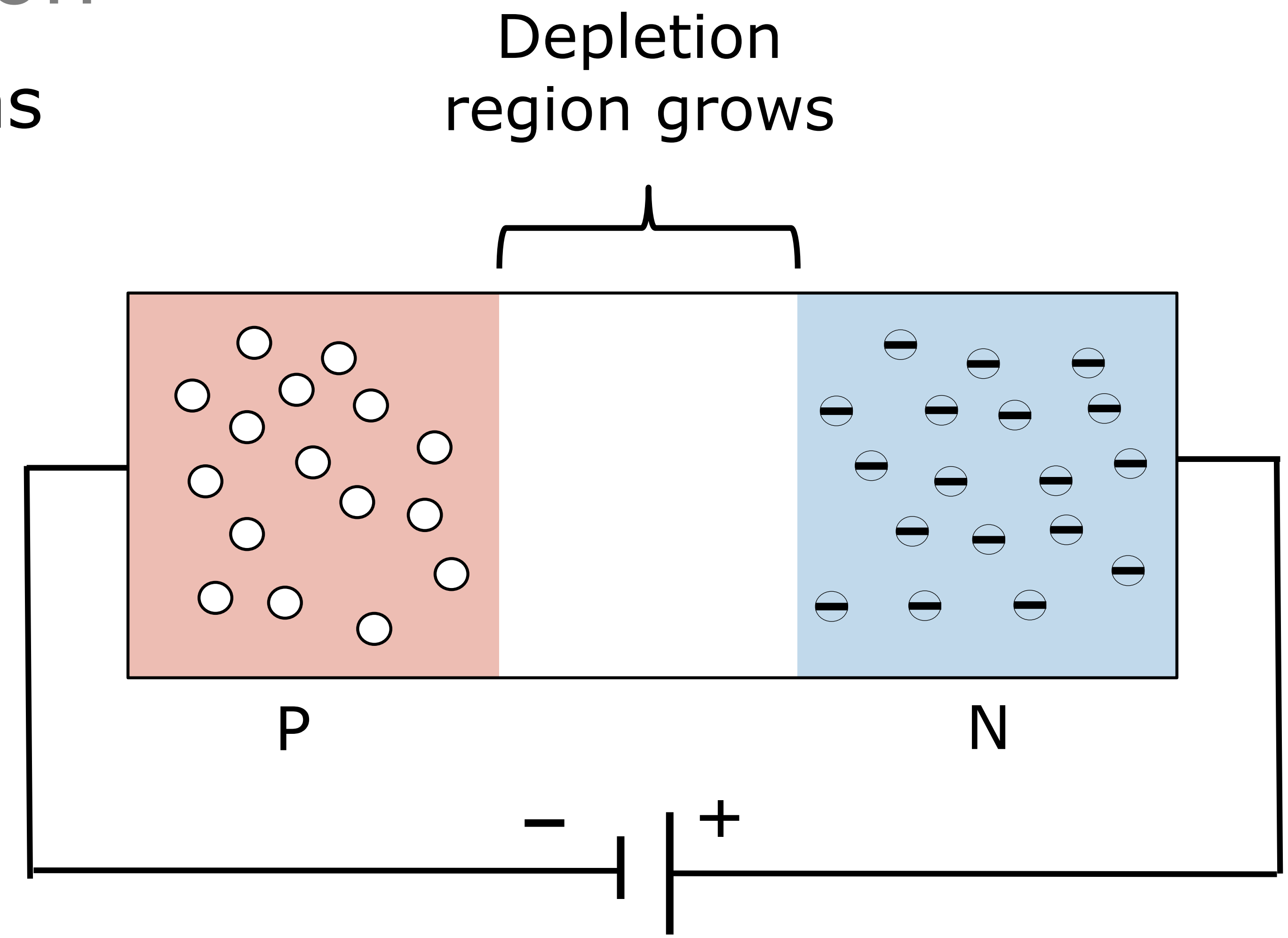
These are still electrically neutral with no special electrical characteristics

PN Junction



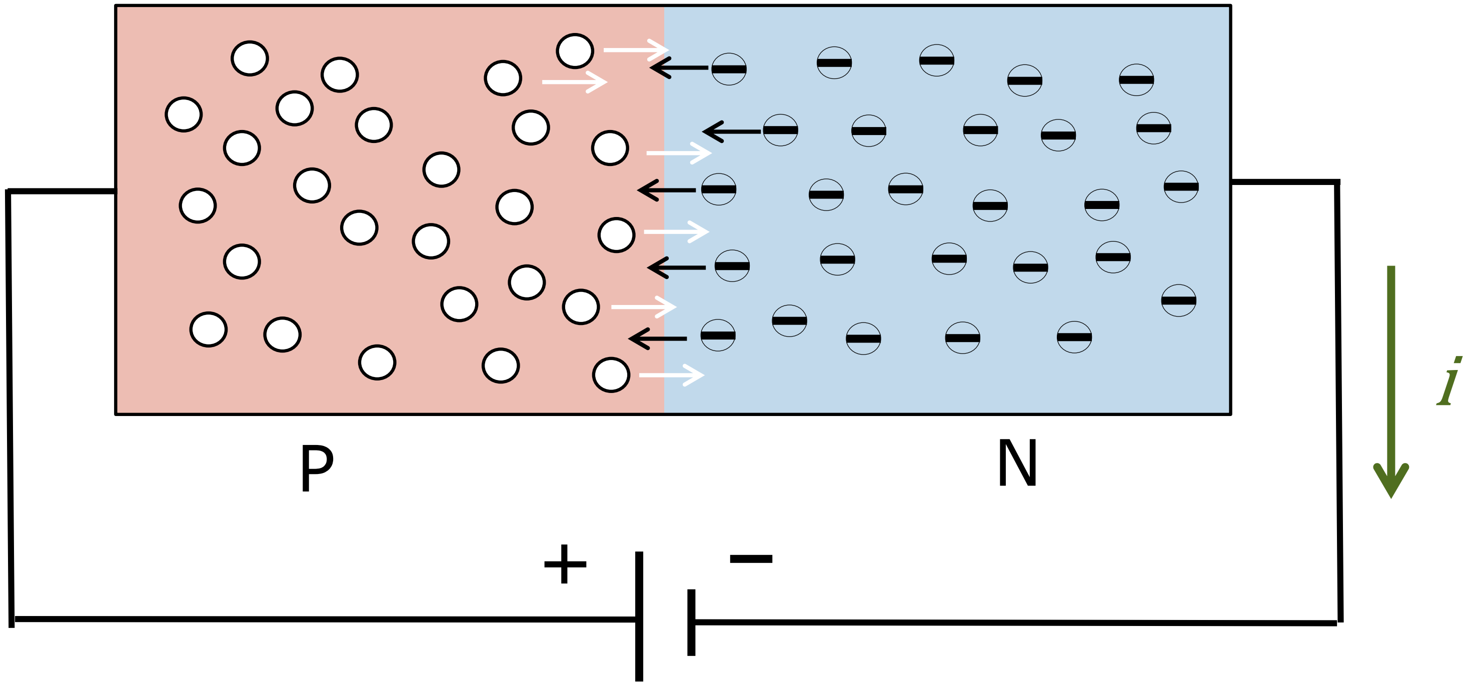
PN Junction

Reverse Bias



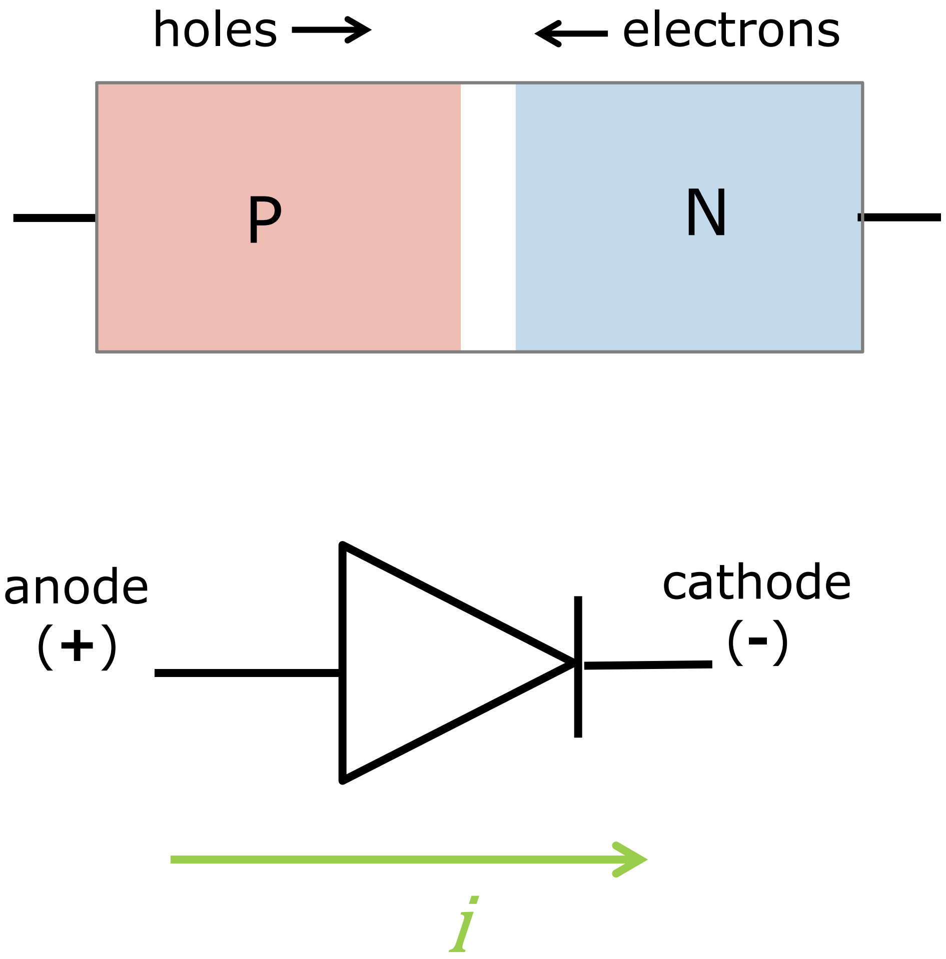
PN Junction

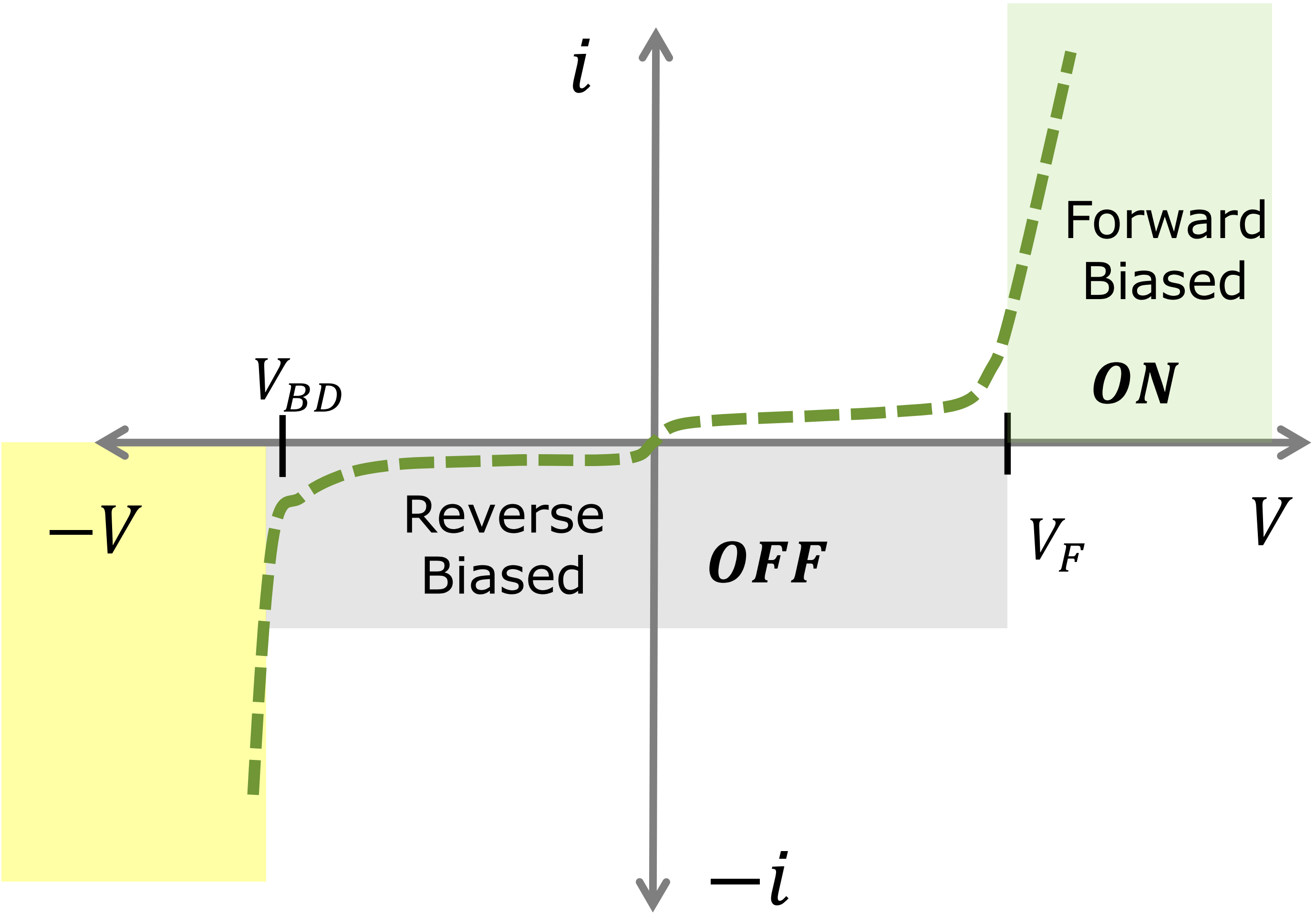
Forward Bias



V > 0.6V in silicon

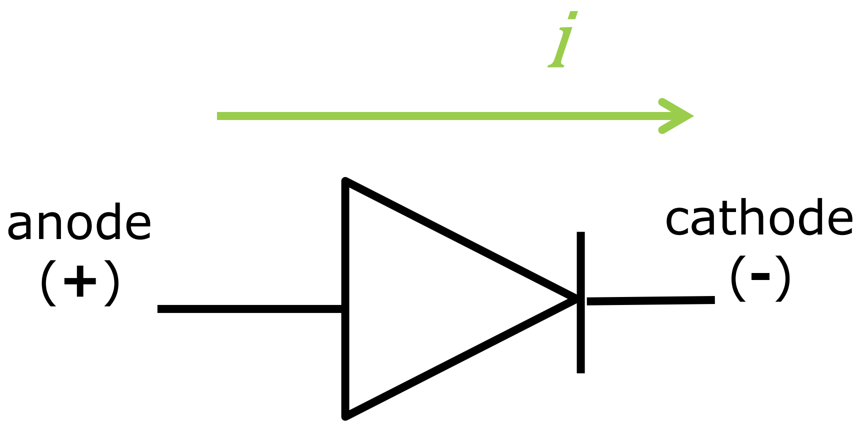
Diode





$V_F \approx 0.6 \;\; for\; silicon$

Diodes

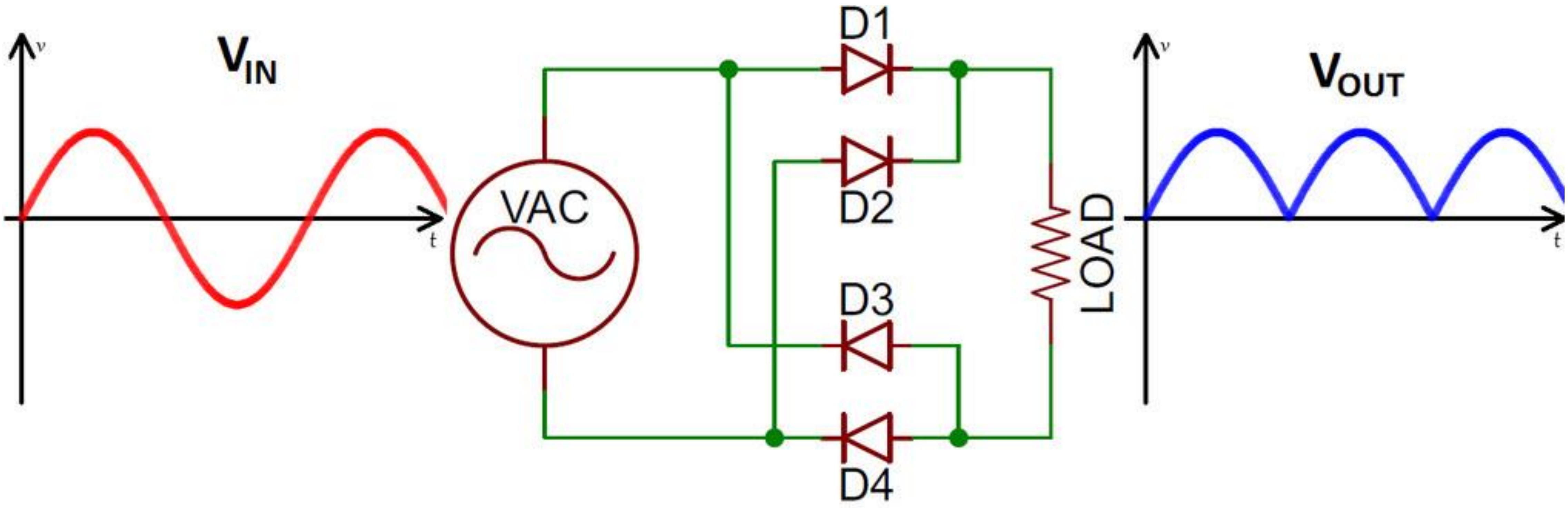


The key function of a silicon diode is to control the direction of current flow

Uses:

- circuit protection
- AC to DC conversion

Example: AC to DC



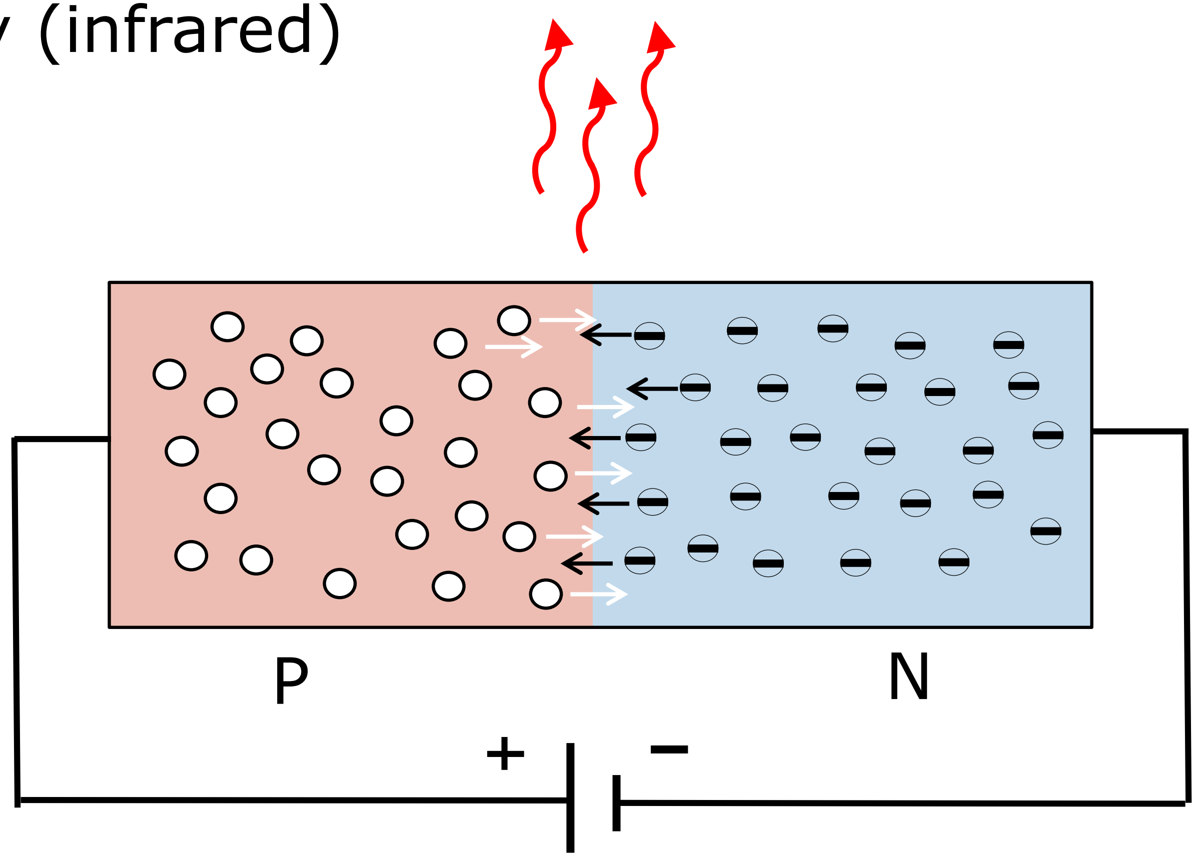
Full Wave Bridge Rectifier

elprocus.com

Light Emitting Diode (LED)

An ordinary silicon diode emits a photon with every electron-hole recombination

- low energy (infrared)



Light Emitting Diode (LED)

- The color of light emitted from a LED* is determined by the energy difference between the electrons and holes (‘bandgap’)
- Common semiconductor materials for LEDs:
  - Aluminum-gallium-arsenide (AlGaAs): red & infrared
  - Gallium phosphide (GaP): yellow & green
  - AlGaInP: *high brightness* red, yellow, orange
  - Gallium nitride (GaN): blue & green
  - InGaN: *high brightness* green, blue, ultra-violet

LED datasheets

Red

ELECTRO-OPTICAL CHARACTERISTICS $T_A=25^\circ C$ $I_f=20mA$

PARAMETER	MIN	TYP	MAX	UNITS	TEST COND
PEAK WAVELENGTH		660		nm	
FORWARD VOLTAGE		1.8	2.3	V_f	
REVERSE VOLTAGE	4.0			V_r	$I_r=100\mu A$
AXIAL INTENSITY /B	250	300		mcd	$I_f=20mA$
/C	360	430		mcd	$I_f=20mA$

LIMITS OF SAFE OPERATION AT 25°C

PARAMETER	MAX	UNITS
PEAK FORWARD CURRENT*	150	mA
STEADY CURRENT	30	mA
POWER DISSIPATION	100	mW

Blue

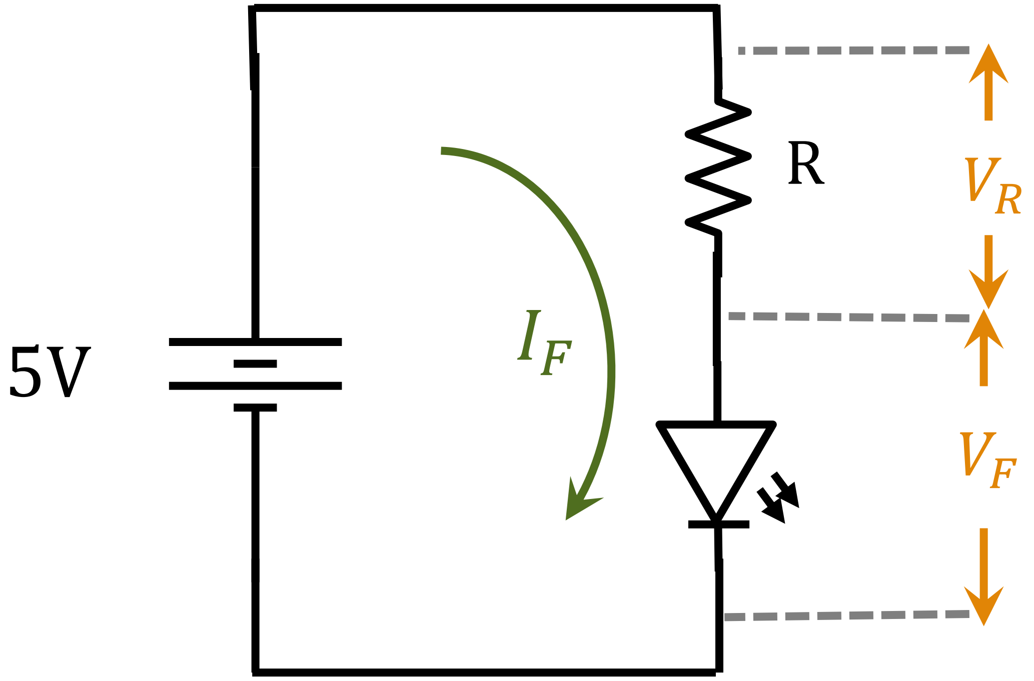
A ELECTRO-OPTICAL CHARACTERISTICS $T_A=25^\circ C$ $I_f=20mA$

PARAMETER	MIN	TYP	MAX	UNITS	TEST COND
PEAK WAVELENGTH		470		nm	
FORWARD VOLTAGE		3.5	4.0	V_f	
REVERSE VOLTAGE	5.0			V_r	$I_r=10uA$
AXIAL INTENSITY		1000		mcd	$I_f=20mA$

A LIMITS OF SAFE OPERATION AT 25°C

PARAMETER	MAX	UNITS
PEAK FORWARD CURRENT*	98	mA
STEADY CURRENT	30	mA
POWER DISSIPATION	100	mW

LED circuit



LED specs:

$$Forward\ voltage\ (V_F) = 3.5\ V$$

$$Forward\ current\ (I_F) = 30mA$$

From Kirchoff’s voltage law:

$$V_R = 5 - 3.5 = 1.5\text{V}$$

$$R = \frac{V_R}{I_F} = \frac{1.5}{0.03} = 50\Omega$$

Photodiode light detectors

Photons of sufficient energy are absorbed in the PN junction, exciting electrons from their holes and creating charge carriers.

Photovoltaic (solar cells)

- requires no external power source

Photoconductive

- use a voltage source to reverse bias the PN junction
- linear current with light intensity
- more responsive

Photovoltaic (Solar cell)

Photons with sufficient energy knock electrons out of the depletion zone where they migrate to the N side

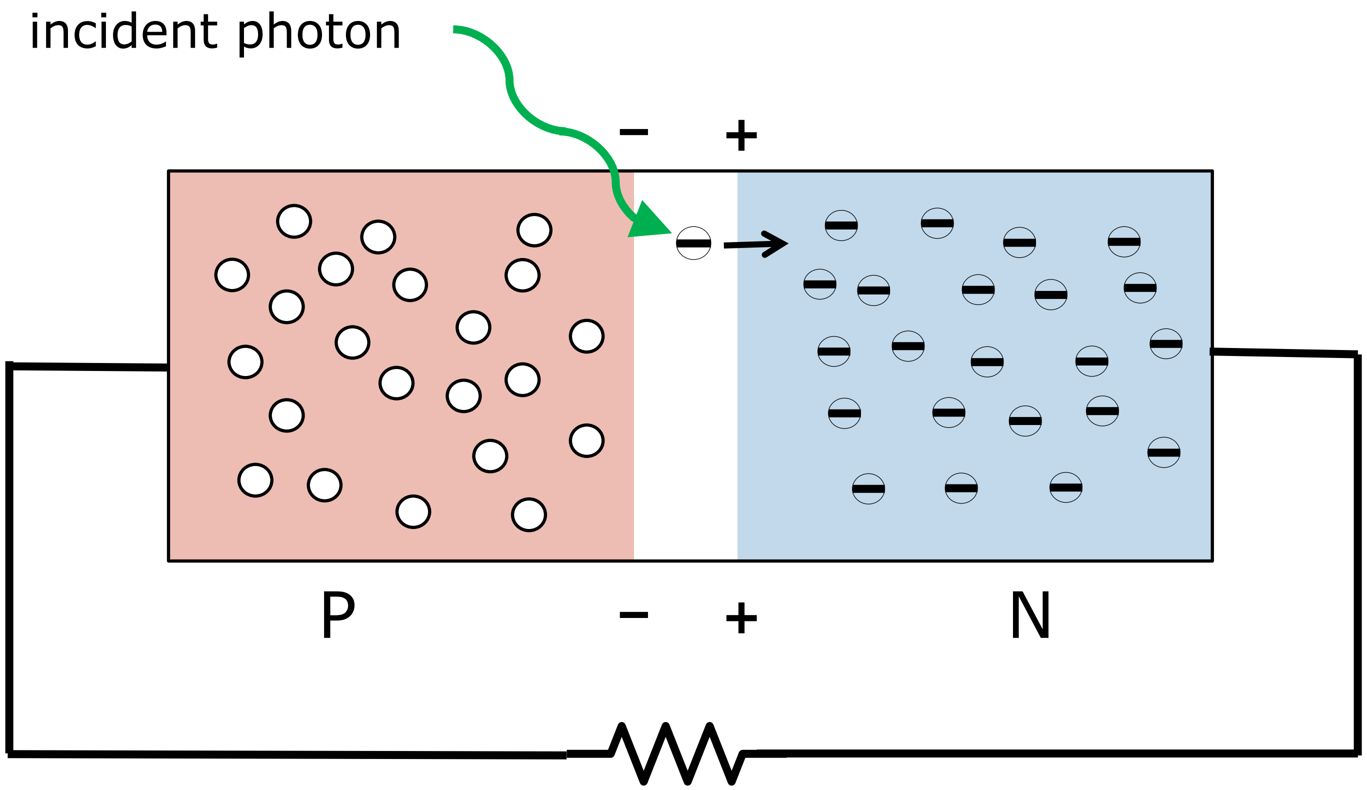
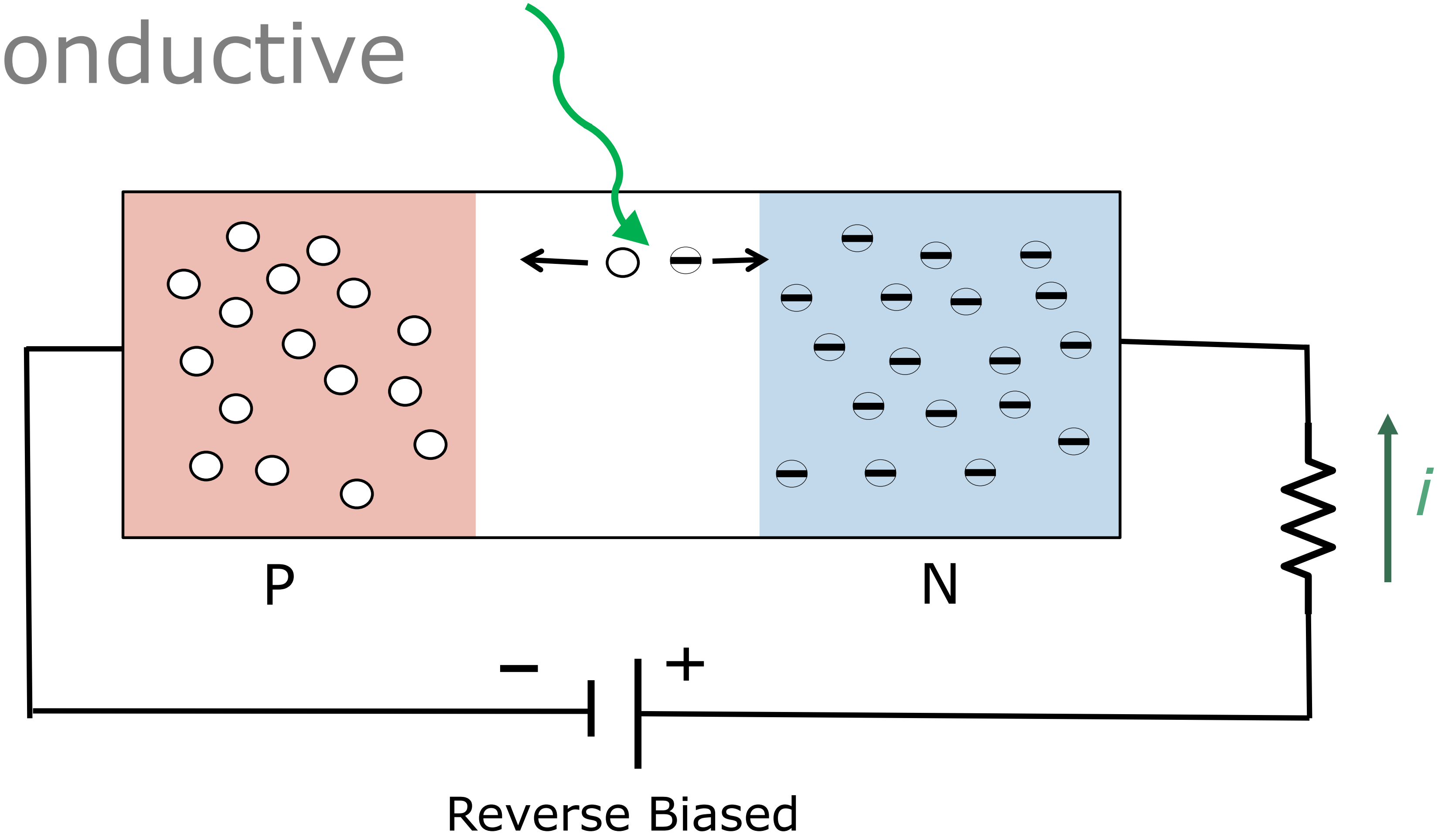


Photo conductive



- Fairly linear: current vs light intensity
- Good sensitivity