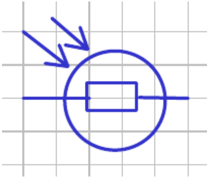
Tutorial 9. Photo sells and rectifier circuits

O.M. Kiselev
o.kiselev@innopolis.ru

Innopolis university

Photoresistors
NP-junction
Usage of the photodiode
Rectifier Circuits

Photoresistors (LDR)

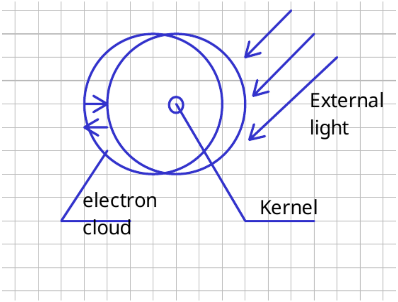


The simplest component which uses a semi-conducting property is a photo resistor or Light Dependent Resistor (LDR). The photo resistor has follow properties:

Model	V_{max}	P_{max}	$^{\circ}C$	peak	Light (10Lx)	Dark	Rise	Decay
PGM5506	100	90mW	-30+70	540nm	$2 - 6k\Omega$	$0.15M\Omega$	30ms	40ms
PGM5659D	150V	100mW	-30+70	560nm	$150 - 300k\Omega$	$20M\Omega$	20ms	00ms

Photoresistors (LDR)

Physical nature of the LDR is based on a pumping of the electrons by the light energy. Typical model for pumping of the electrons by the light energy can be considered as load on a spring.

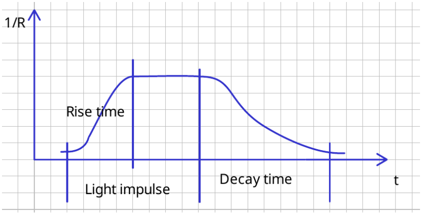


$$u'' + \omega^2 u = f(\nu t).$$

We consider u as a distance between the electronic cloud center and the kernel of the atom. The external force looks as a light electromagnet wave. If the frequency of the oscillator ω and the frequency of the wave ν coincide, then the u grows and the energy is pumped into the atom.

Under such pumping the electron can change energy level and become into the conductivity zone.

Photoresistors (LDR)



The rise curve is defined the numbers of the pumped electrons

$$N = N_0 + D \tanh(\kappa_1 t),$$

where parameter κ_1 depends on the external light impact.

The value D defines a number of vacations for free zones in the conductivity energy level.

The decay process can be considered as inverse process:

$$N = N_0 + D \tanh(\kappa_2 t),$$

but parameter κ_2 depends of recombination of the electrons and wholes in the semi-conductor.

Photoresistors (LDR)

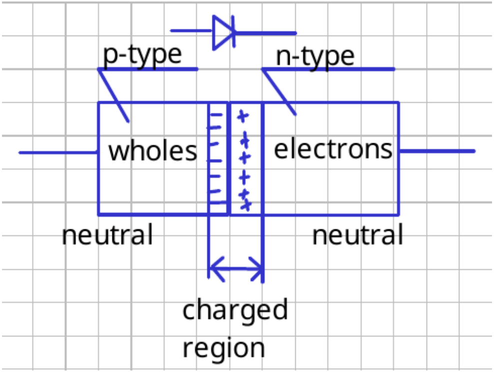
Advantages of the LDR are:

- High reliability;
- low price;
- high sensitivity.

The LDR disadvantages are:

- High time delay for rise and decay.

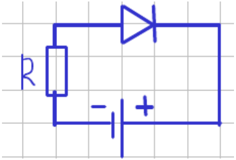
NP-junction with zero bias



A np-junction forms internal voltage without an external electric field. This voltage jump appears because of motion the wholes to the n-doped piece of the diode. The opposite side forms by the electrons which dissipates into the p-doped part of the junction. Near the border a layer is formed with some change of built-in voltage V_b. Typical value of the built-in voltage for the *depletion layer* $V_b \sim 0.6V$

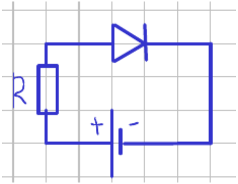
This layer have come capacity which value depends on properties of the junction and area ones.

NP-junction reverse bias



In case
of the commutation
in the reverse
way the diode does
not provide the current.
The positive charges
tend out of the junction
and the negative charges which are electrons tend out the opposite direction of the junction.
As a result the depletion region increases and the current can't flow through the diode.

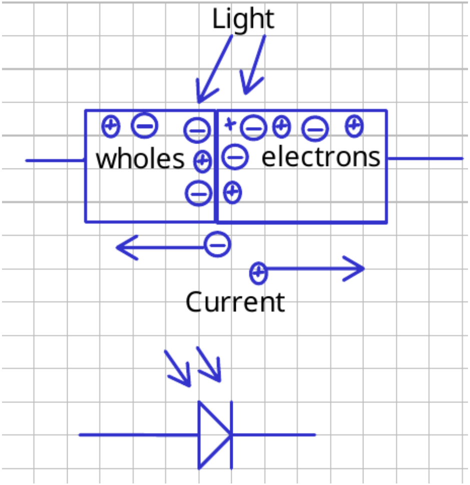
NP-junction forward bias



In case of forward connection the positive charges are pushed though the depletion region and the same force with opposite direction actions on the electrons.

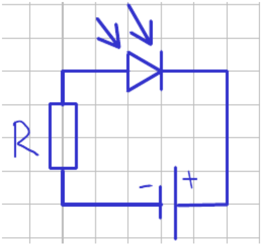
If the external voltage is gross than the V_b then the carries move through the junction and full the wholes these motion forms the current.

NP-junction under Light radiation



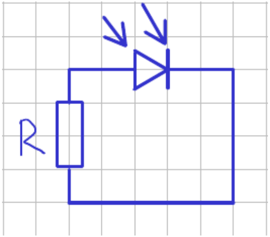
Under light radiation the pairs of electrons and wholes appear. In this case the minor charges which are wholes in the n-doped part and the electrons in the p-doped part of the diode move because of built voltage through the pn-junction and form the current. So the current appears because of action of the external light radiation. The element with such property is called photo diode.

Usage of the photo diodes



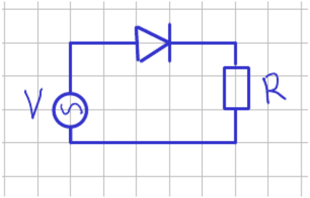
The photo diode can be considered as a photo detector. In this case the diode connect as a reverse bias. The current without the light the inverse current is about μA, but the current with the light is about $10mA$.

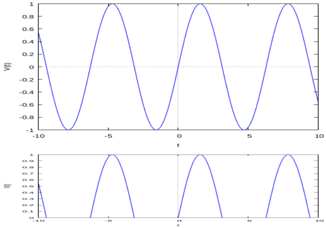
Usage of the photo diodes



The photo diode can be used as a generator of the current. In this case the photo diode form the current. A value of the current depends on the length of light wave and a light power. Typical values are $\sim 0.5 A/W$ as $\lambda \sim 850 nm$.

Diode rectifier





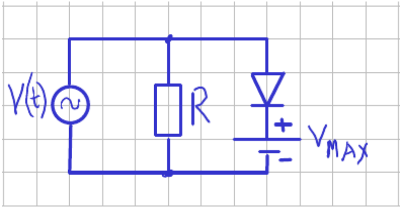
Assume the AC voltage is

$$V(t) = A\sin(\omega t), \quad A, \omega \in \mathbb{R}.$$

For ideal
diode on the load one gets:

$$V_R(t) = \frac{1}{2}\left(|A\sin(\omega t)| + A\sin(\omega t)\right).$$

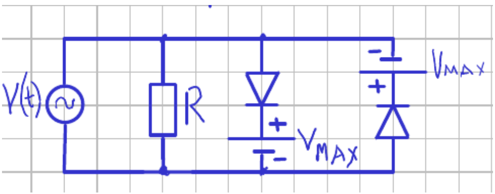
Diode clipper



Assume
$v(t) = A\sin(\omega t)$ and $v_{max} \in \mathbb{R}$
This circuit provides
the voltage on the load as:

$$V_R = \begin{cases} A\sin(\omega t), A\sin(\omega t) < v_{max}; \\ v_{max}, A\sin(\omega t) > v_{max}. \end{cases}$$

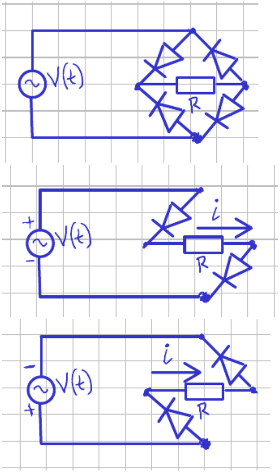
Diode clipper



Assume $v(t) = A\sin(\omega t)$ and $v_{max} \in \mathbb{R}$
This circuit provides the voltage on the load as:

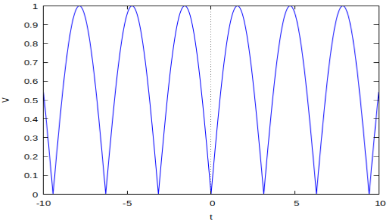
$$V_R = \begin{cases} A\sin(\omega t), |A\sin(\omega t)| < v_{max}; \\ v_{max}, A\sin(\omega t) > v_{max}; \\ -v_{max}, A\sin(\omega t) < -v_{max}. \end{cases}.$$

Diode bridge

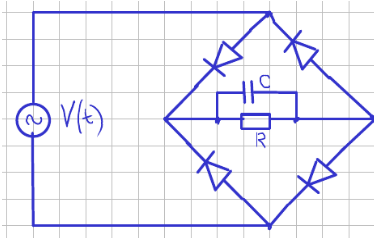


Assume $v(t) = A\sin(\omega t)$.
This circuit provides
the voltage on the load as:

$$V_R = |A\sin(\omega t)|.$$

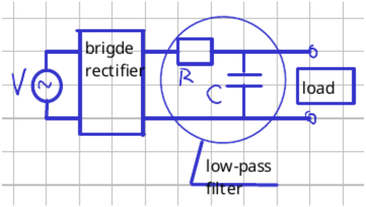


Diode bridge



Assume $v(t) = A\sin(\omega t)$.
In general case $\omega = 2\pi 50$rad/sec..
Then the ripple
frequency is about 314rad/s..

Diode bridge with filter



Typical values for the low-pass filter where

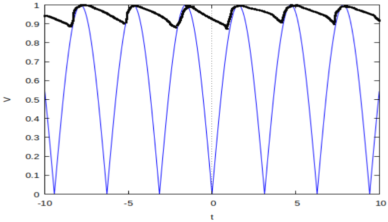
$$|H(j\omega)| = \frac{1}{\sqrt{\left(\frac{\omega}{\omega_0}\right)^2 + 1}}, \quad \omega_0 = \frac{1}{RC}.$$

$\omega_0 \ll \omega$, for example $\frac{1}{RC} = \omega_0 \sim 2\pi\text{rad/sec.}$. Let $C = 470\mu F$, then

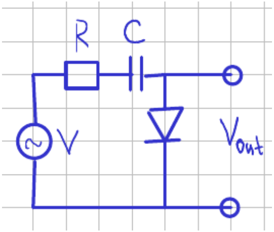
$$R = 1/(\omega_0 C) = (1/2\pi \times 470 \times 10^6)$$
$$R \sim 340\Omega.$$

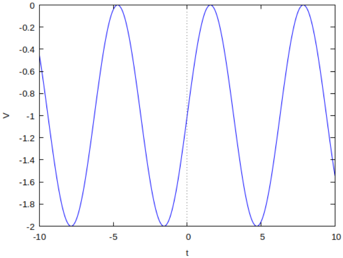
Diode bridge with low-pass filter

This circuit provides the voltage:



Diode clamp





This circuit uses to get a waveform to a fixed DC value.

- The diode conduct the current when the capacitor's pin has positive charge, so $V < 0$.
- The capacitor charges when $V > 0$, which is a half-cycle of v.
- Therefore the voltage on the load can be negative only. Positive one discharges through the diode.