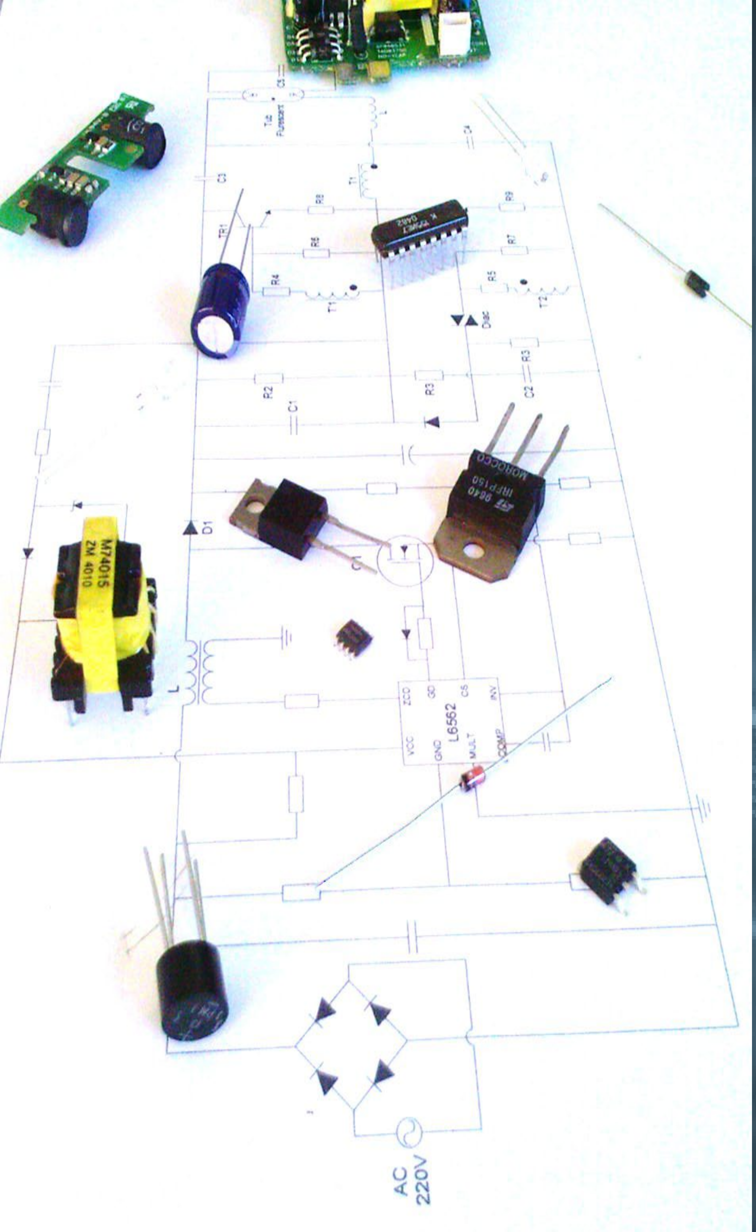
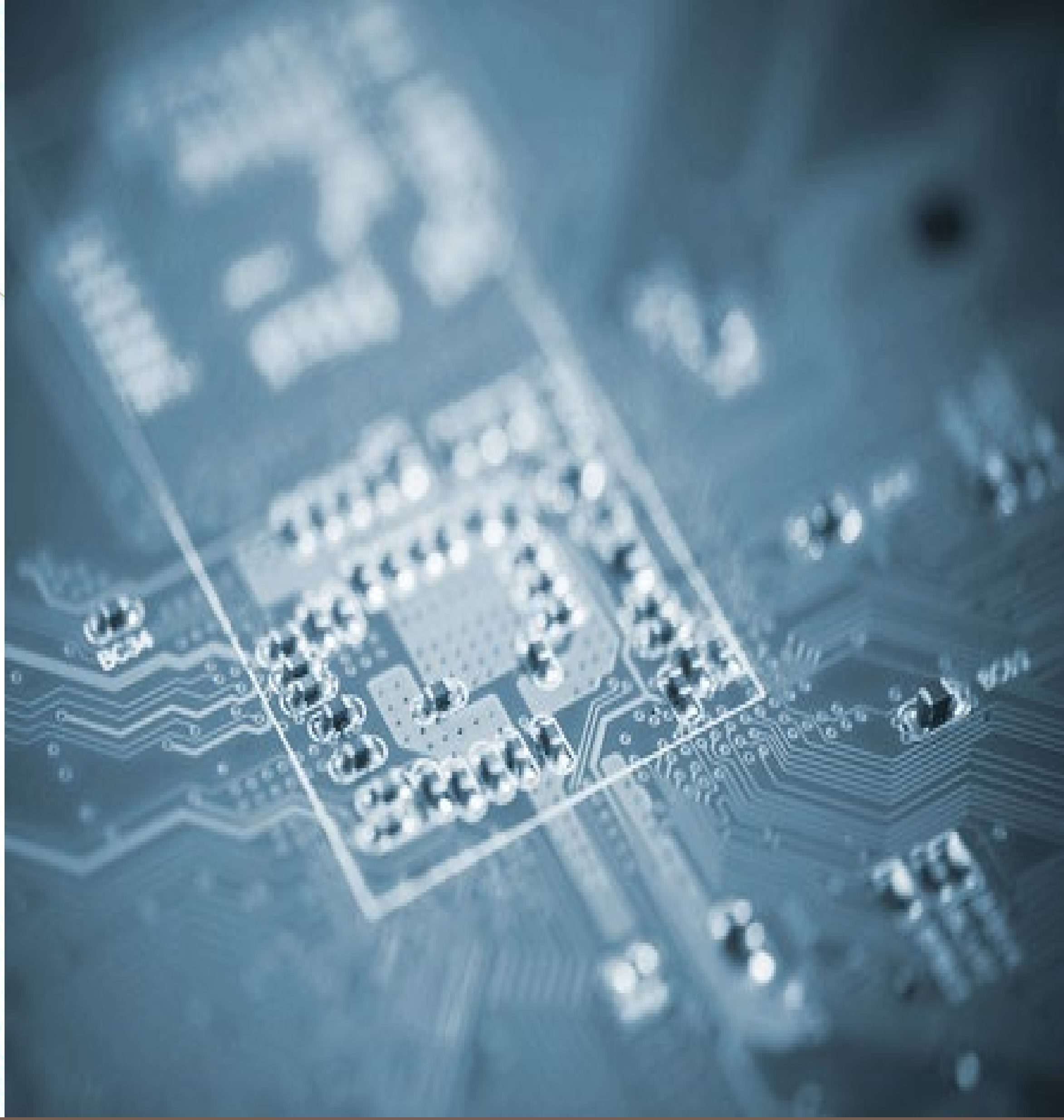
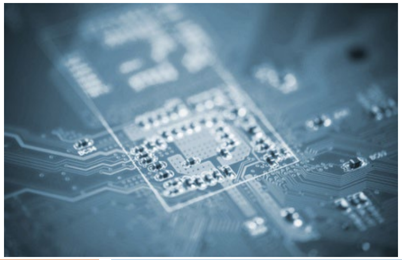




ELECTRONICĂ



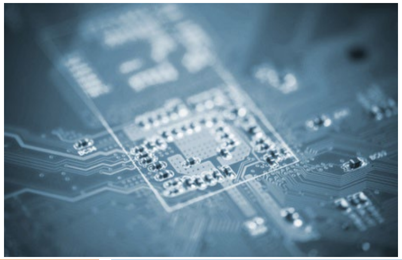
Electronică- Bibliografie

- **Volum 1- Electronica pentru Ingineri Electrotehnicieni, Autor: Richard Marschalko (Marschalko, R. - Electronica pentru ingineri electrotehnicieni, Volumul I, Dispozitive şi circuite electronice fundamentale, Editura Mediamira, Cluj, Romania, 2003)**

- **Volum 2- Electronica pentru Ingineri Electrotehnicieni, Autor: Richard Marschalko** (Marschalko, R. - Electronica pentru ingineri electrotehnicieni, Vol. II, Circuite electronice pentru semnale continue, Editura Mediamira, Cluj, Romania, 2006).

- **Dispozitive Electronice, Thomas Floyd, 2003**

- https://www.ipes.ethz.ch
- https://ece.uwaterloo.ca/~dwharder/Analogy/
- https://www.wisc-online.com
- youtube.com - Eugene Khutoryansky

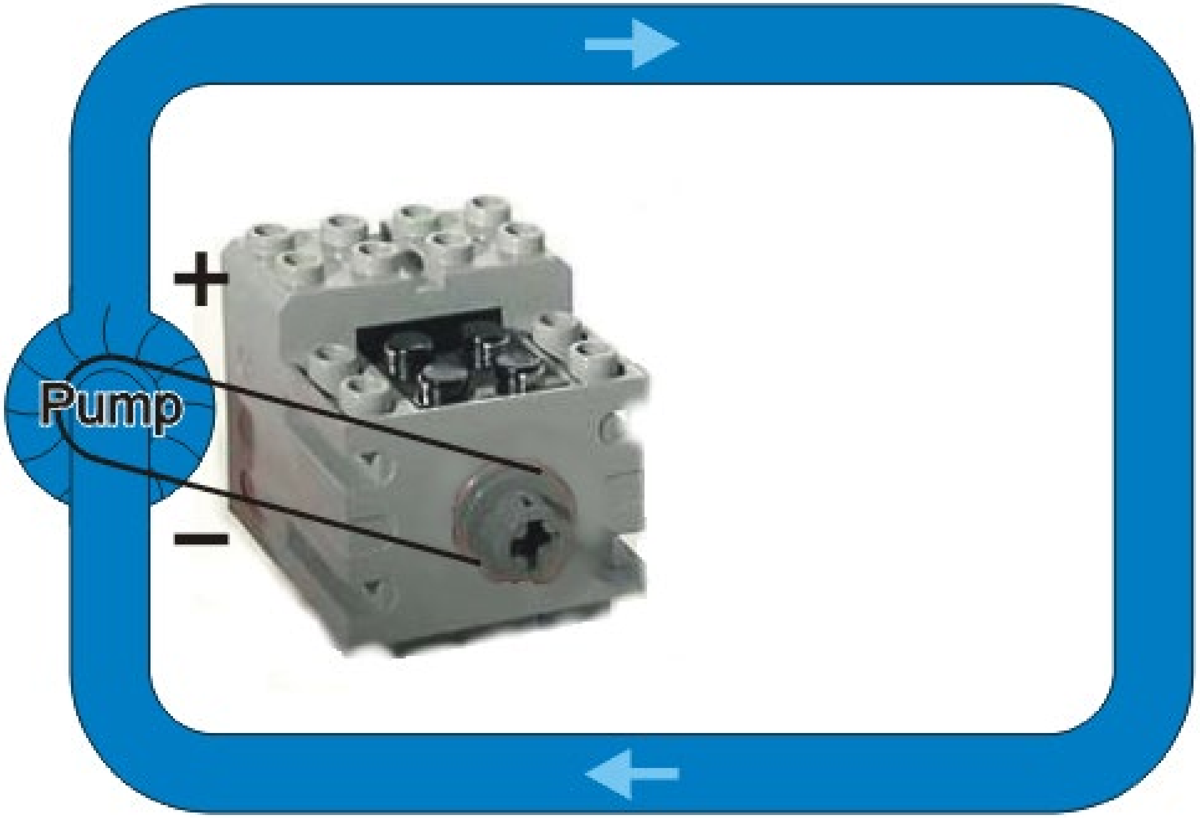


Electronică- Scurtă Istorie

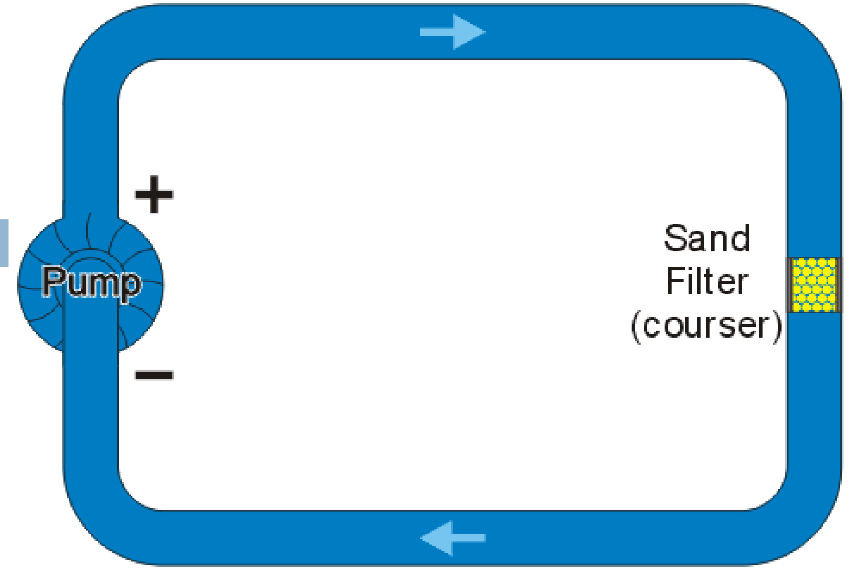
- **Cei de la care a pornit totul…..**

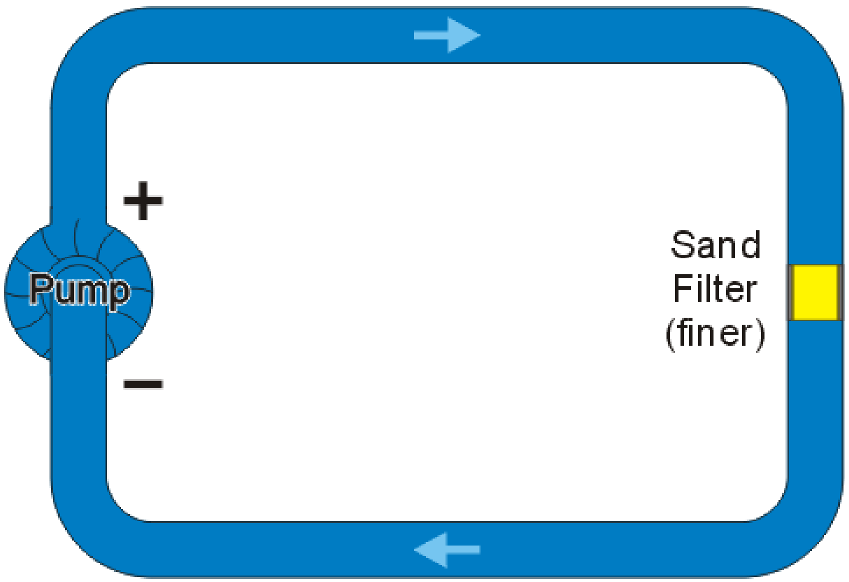
GENERALITATI

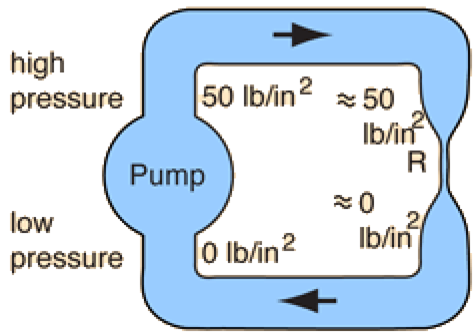
Rezistenta

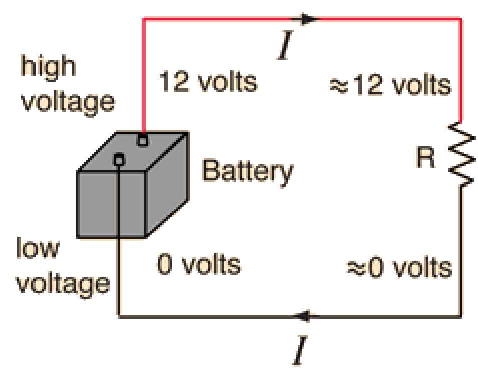


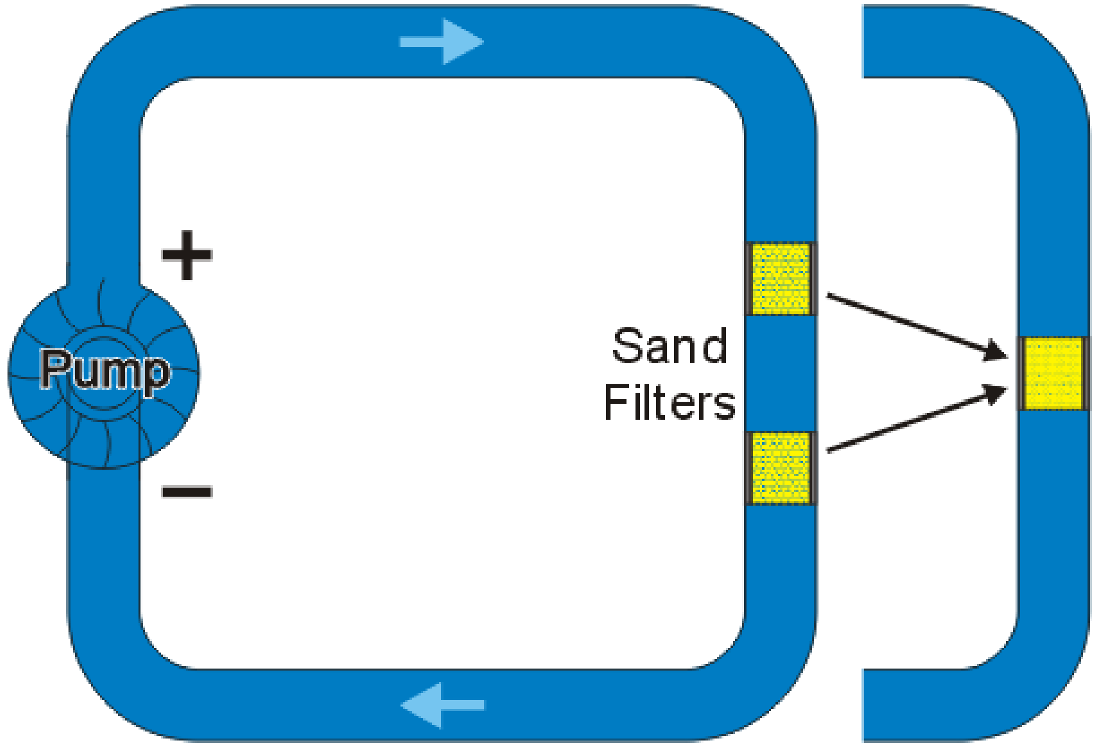

Pump
+
−
Sand
Filter

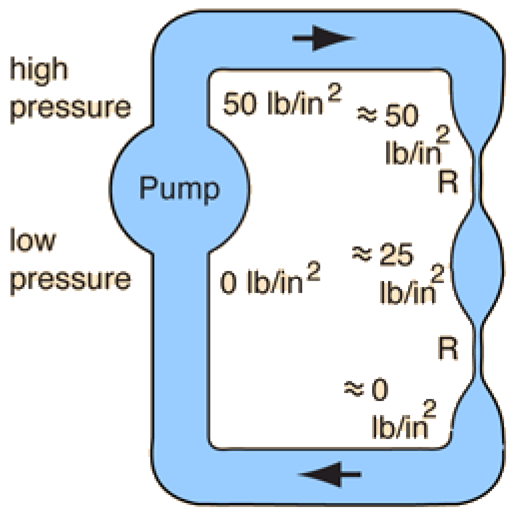

Pump
+
−
Sand
Filter
(courser)

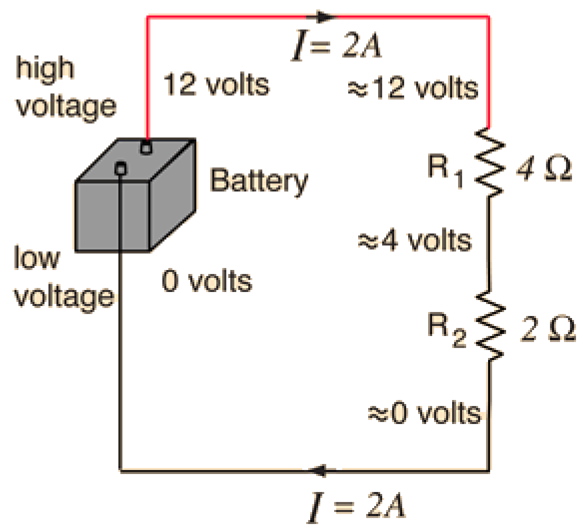

Pump
+
−
Sand
Filter
(finer)

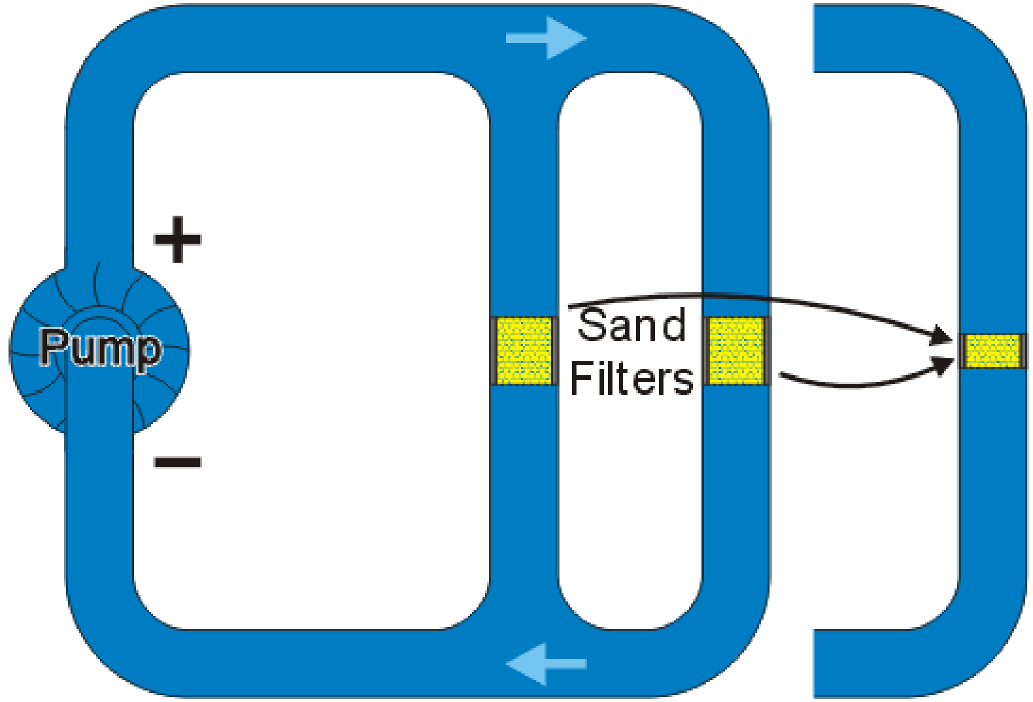

high
pressure
low
pressure
Pump
50 lb/in2
≈ 50
lb/in2
R
≈ 0
lb/in2
0 lb/in2

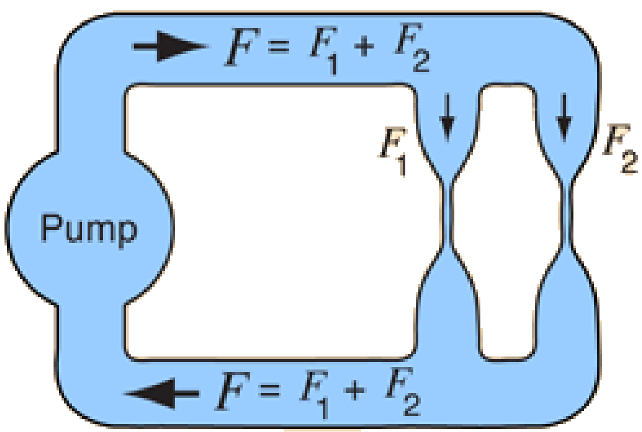

high
voltage
low
voltage
I
12 volts
≈12 volts
Battery
R
0 volts
≈0 volts
I

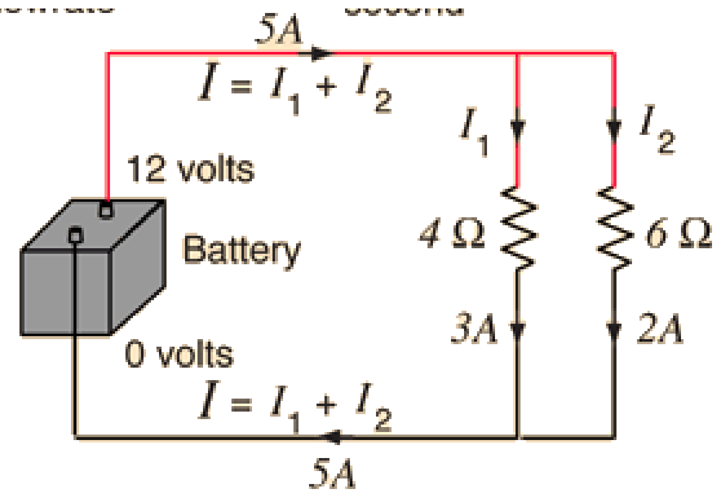

Pump
+
−
Sand
Filters

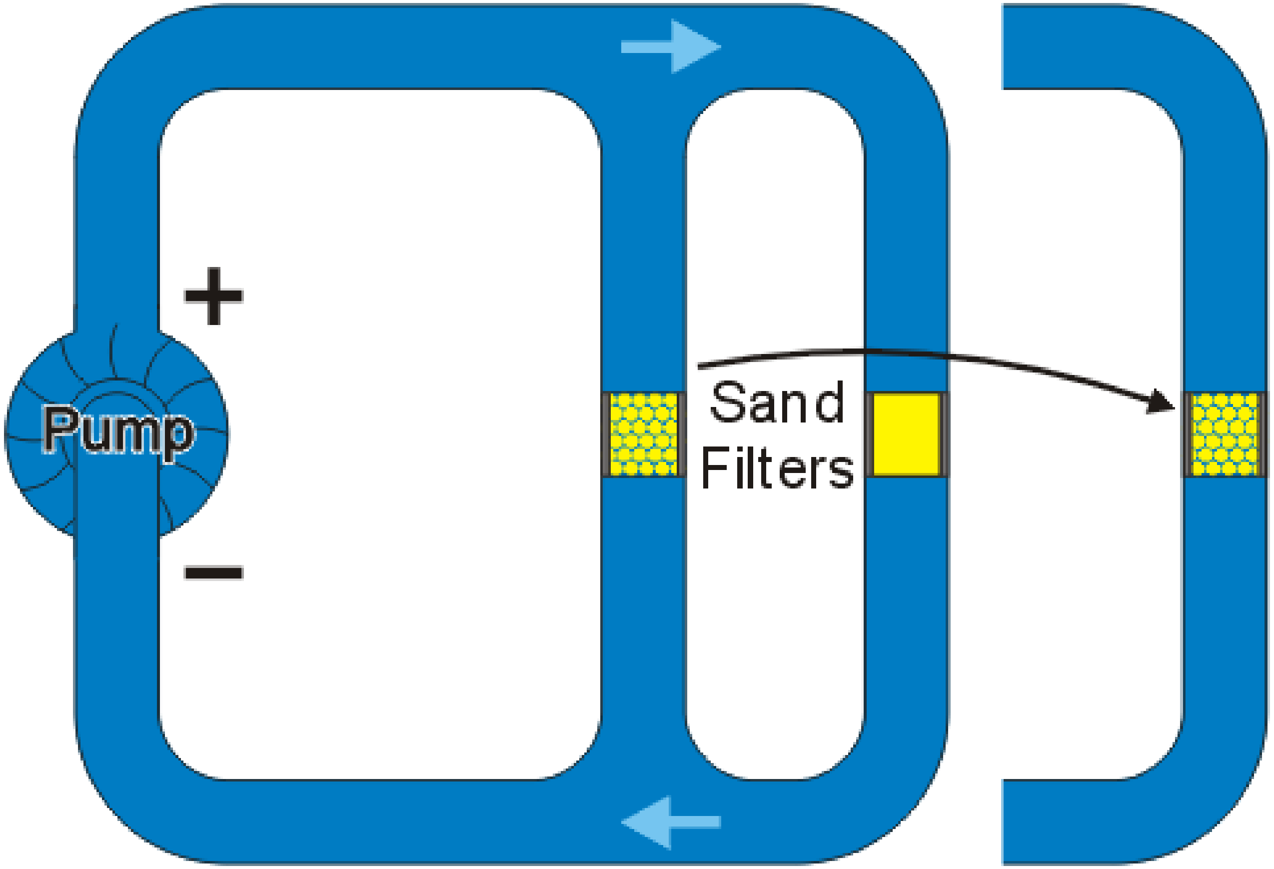

high
pressure
low
pressure
Pump
50 lb/in2
≈ 50
lb/in2
R
0 lb/in2
≈ 25
lb/in2
R
≈ 0
lb/in2

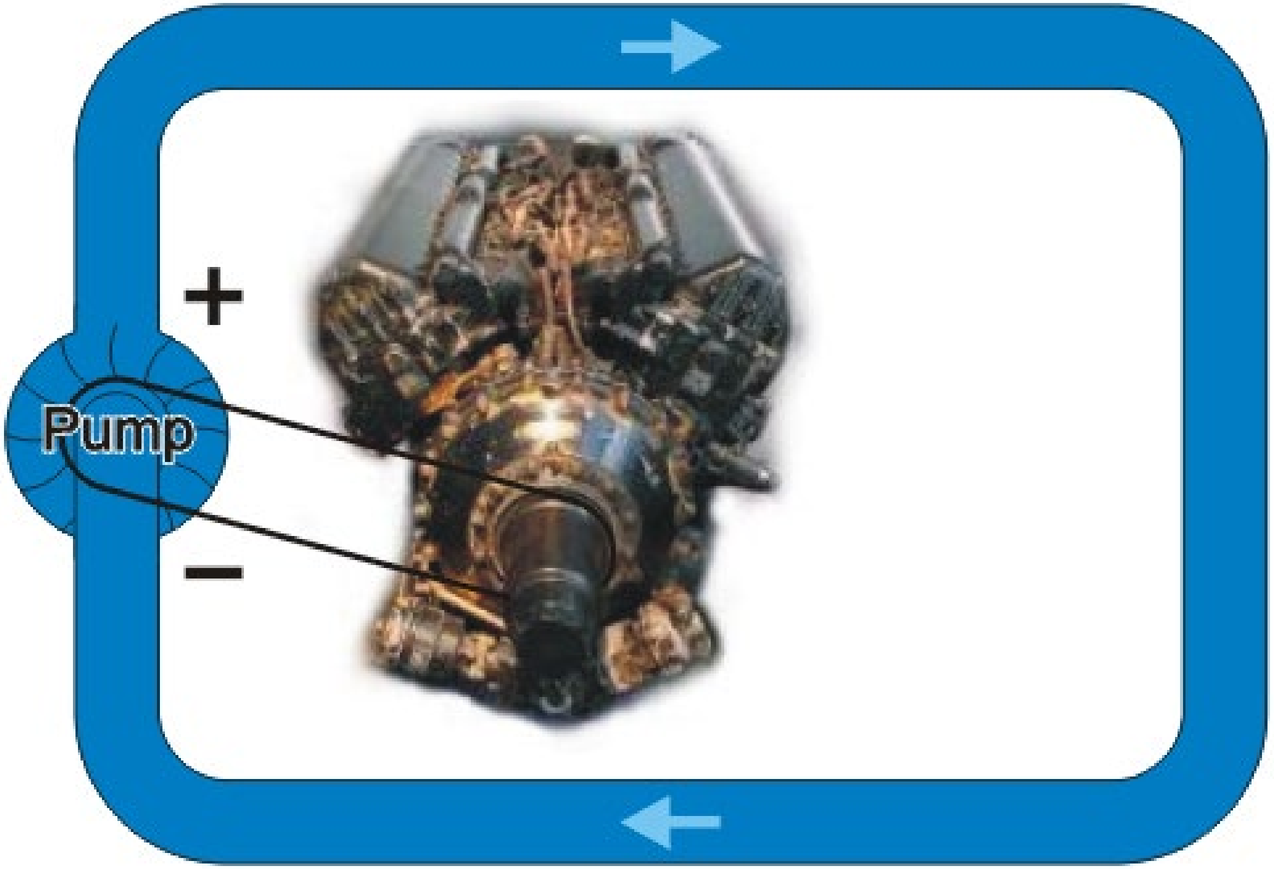

I = 2A
high
voltage
12 volts
≈12 volts
Battery
R1
4 Ω
≈4 volts
low
voltage
0 volts
R2
2 Ω
≈0 volts
I = 2A

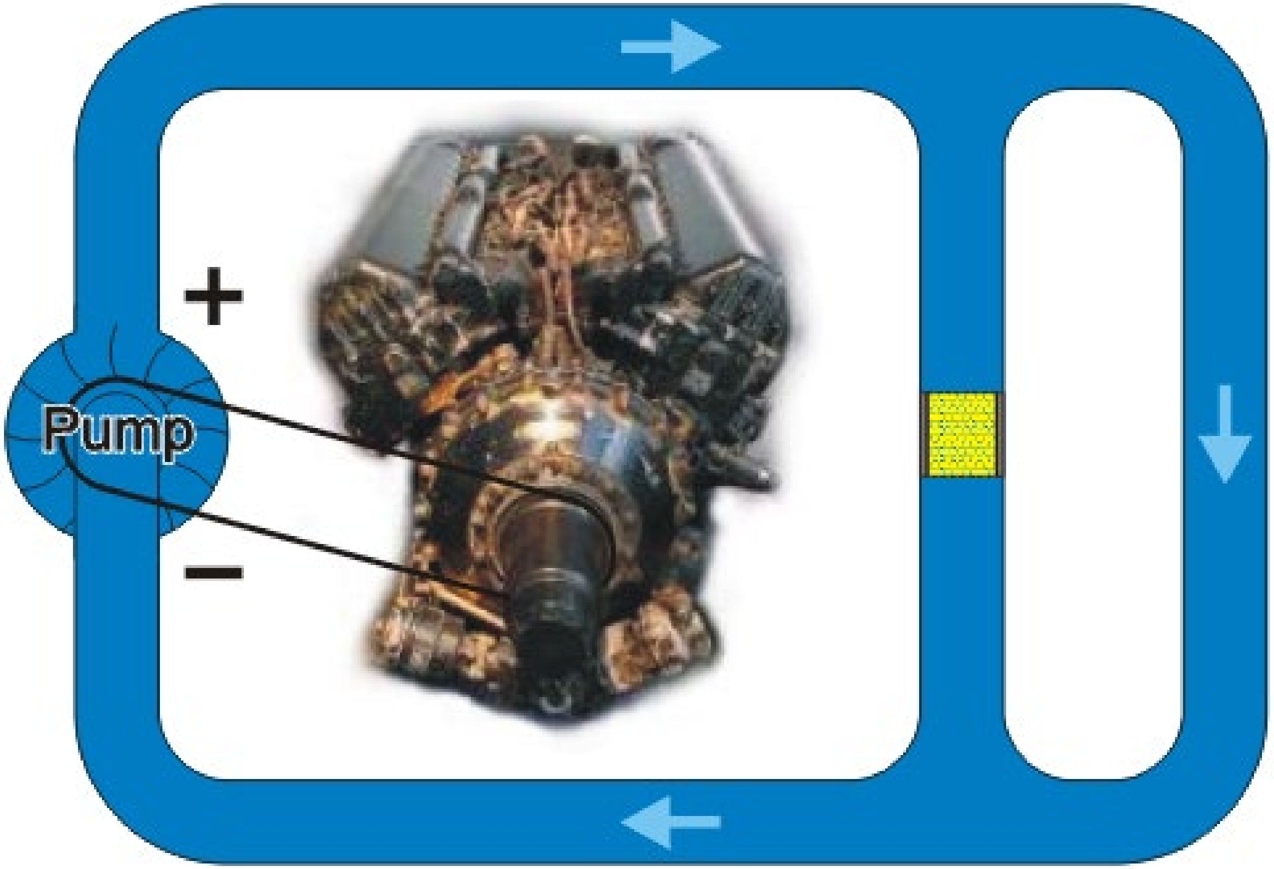

+
Pump
−
Sand
Filters


$F = F_1 + F_2$
F_1
F_2
Pump
$F = F_1 + F_2$

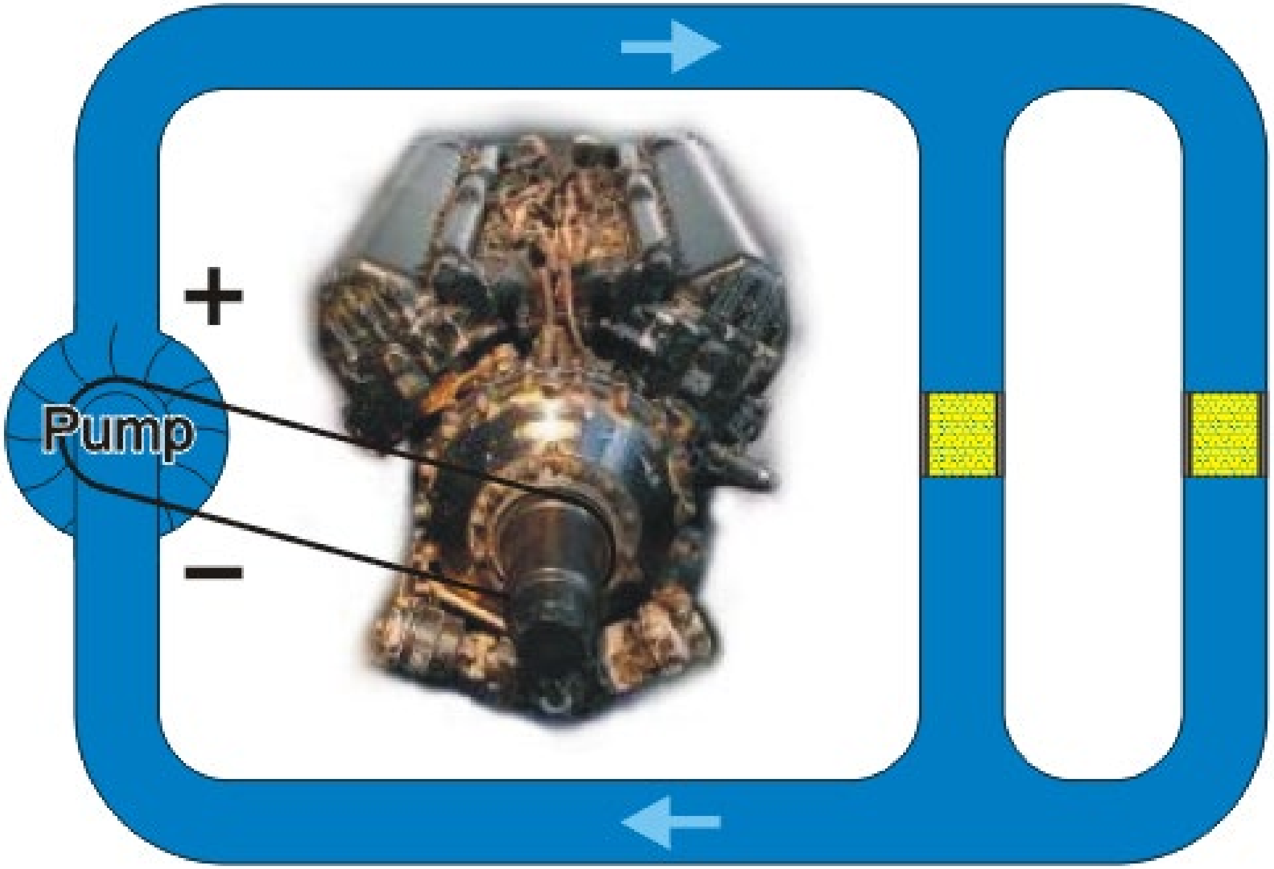

5A
$I = I_1 + I_2$
I_1
I_2
12 volts
Battery
4 Ω
6 Ω
3A
2A
0 volts
$I = I_1 + I_2$
5A

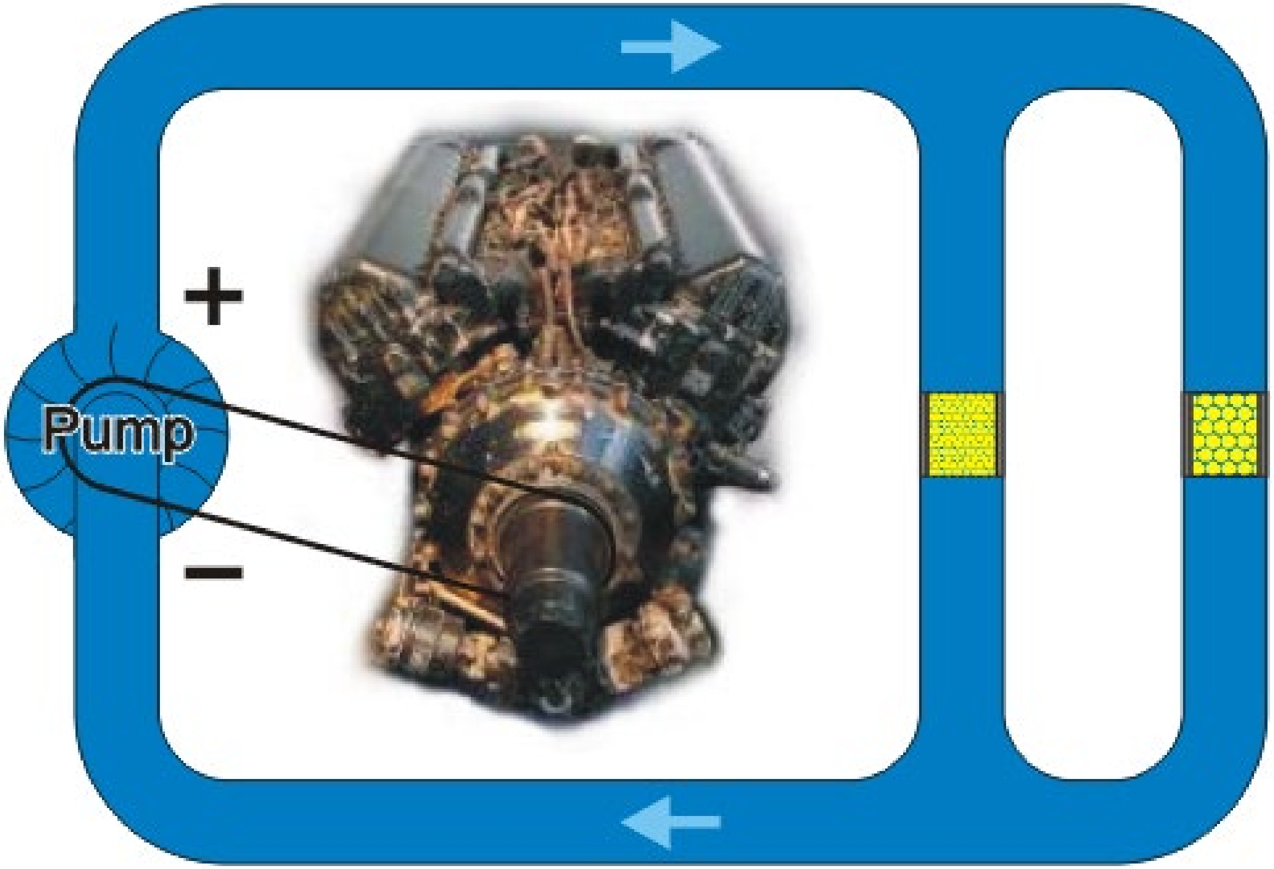

+
Pump
–
Sand
Filters


+
Pump
–

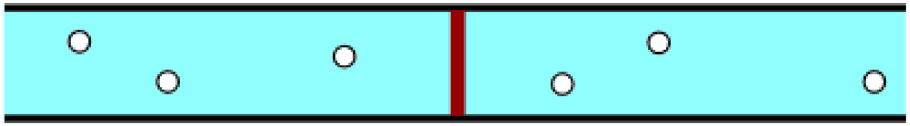


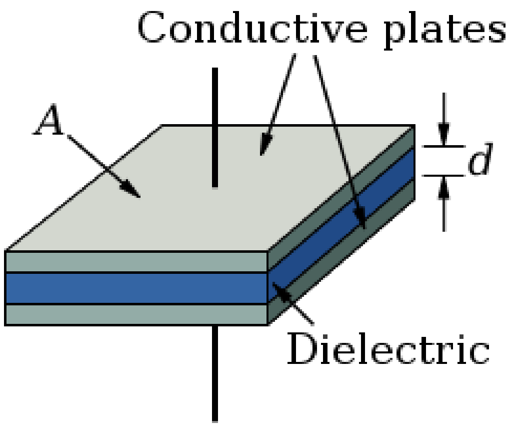
+
Pump
–

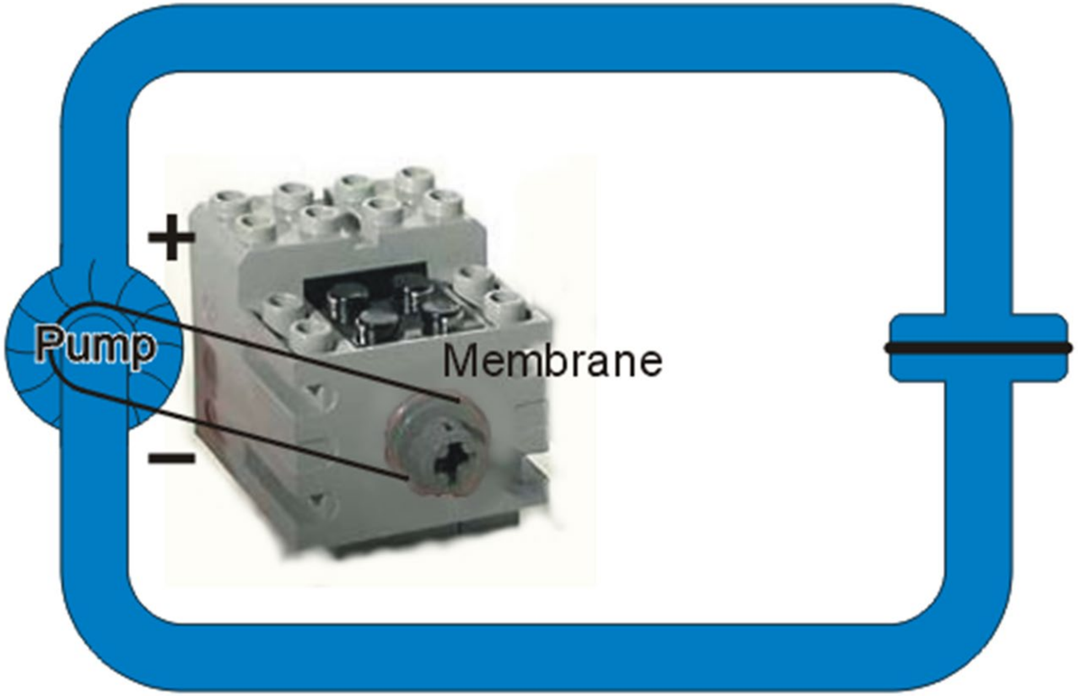

+
Pump
–


+
Pump
–

Condesatorul Analogie







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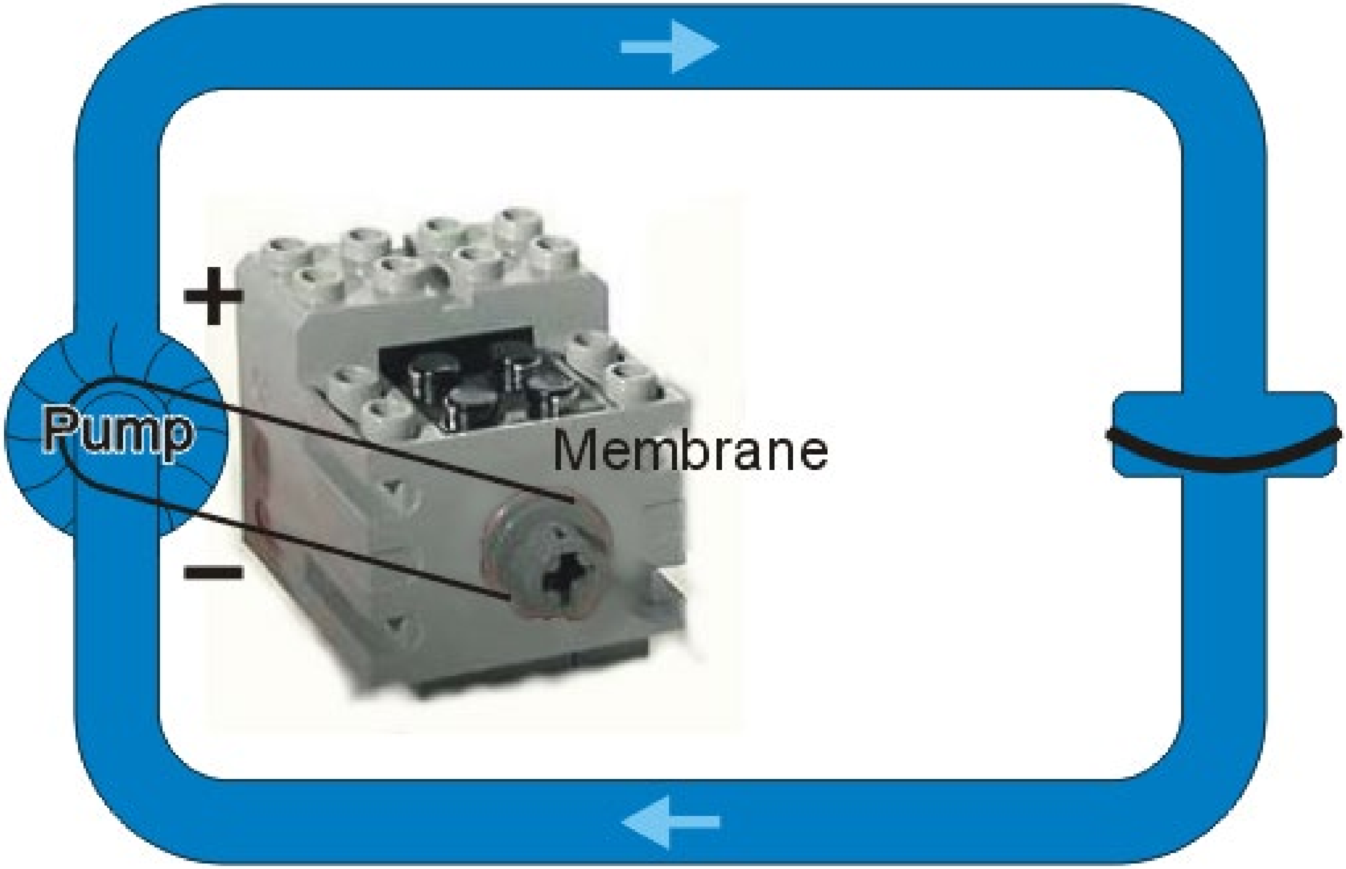

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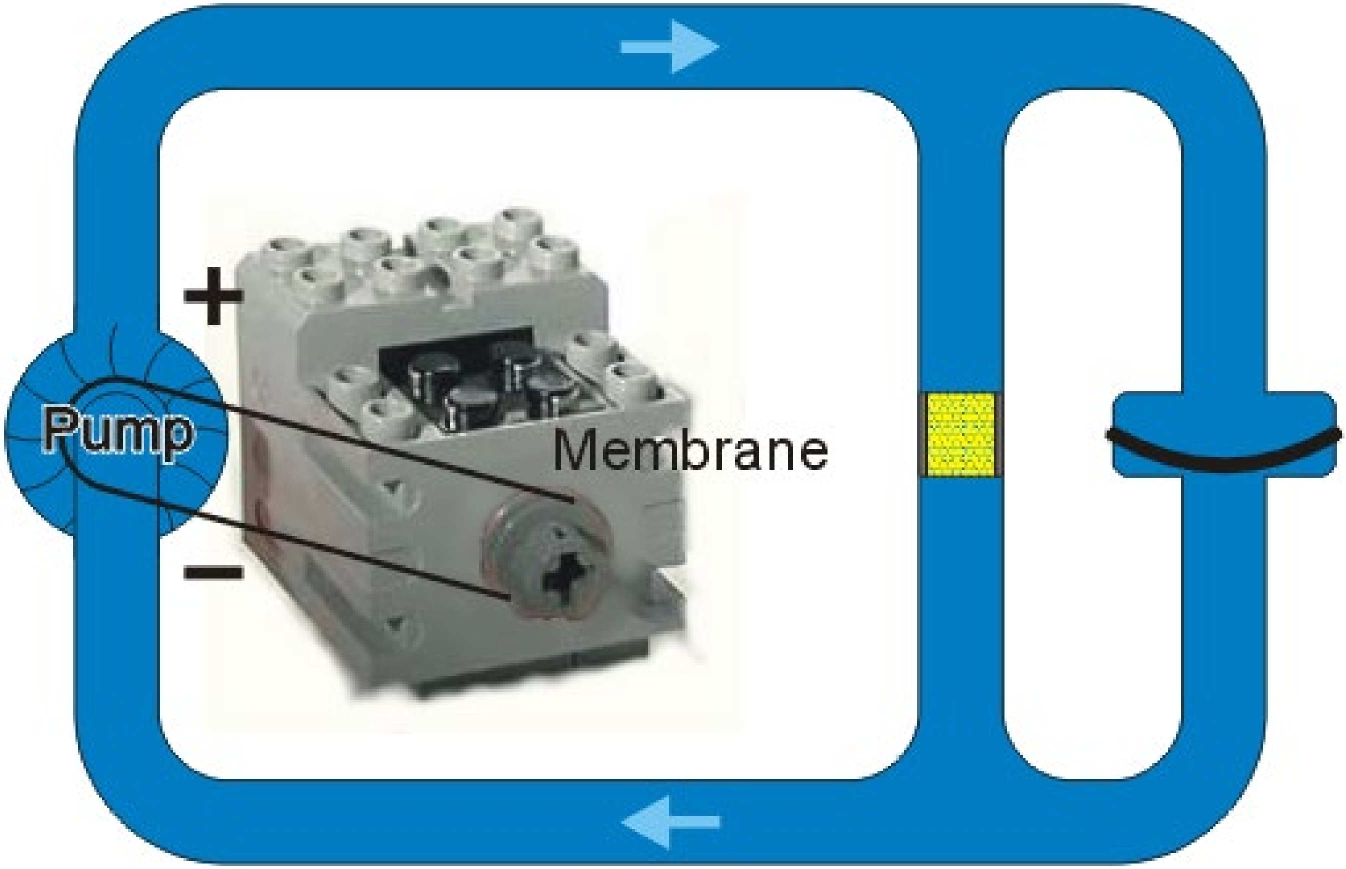

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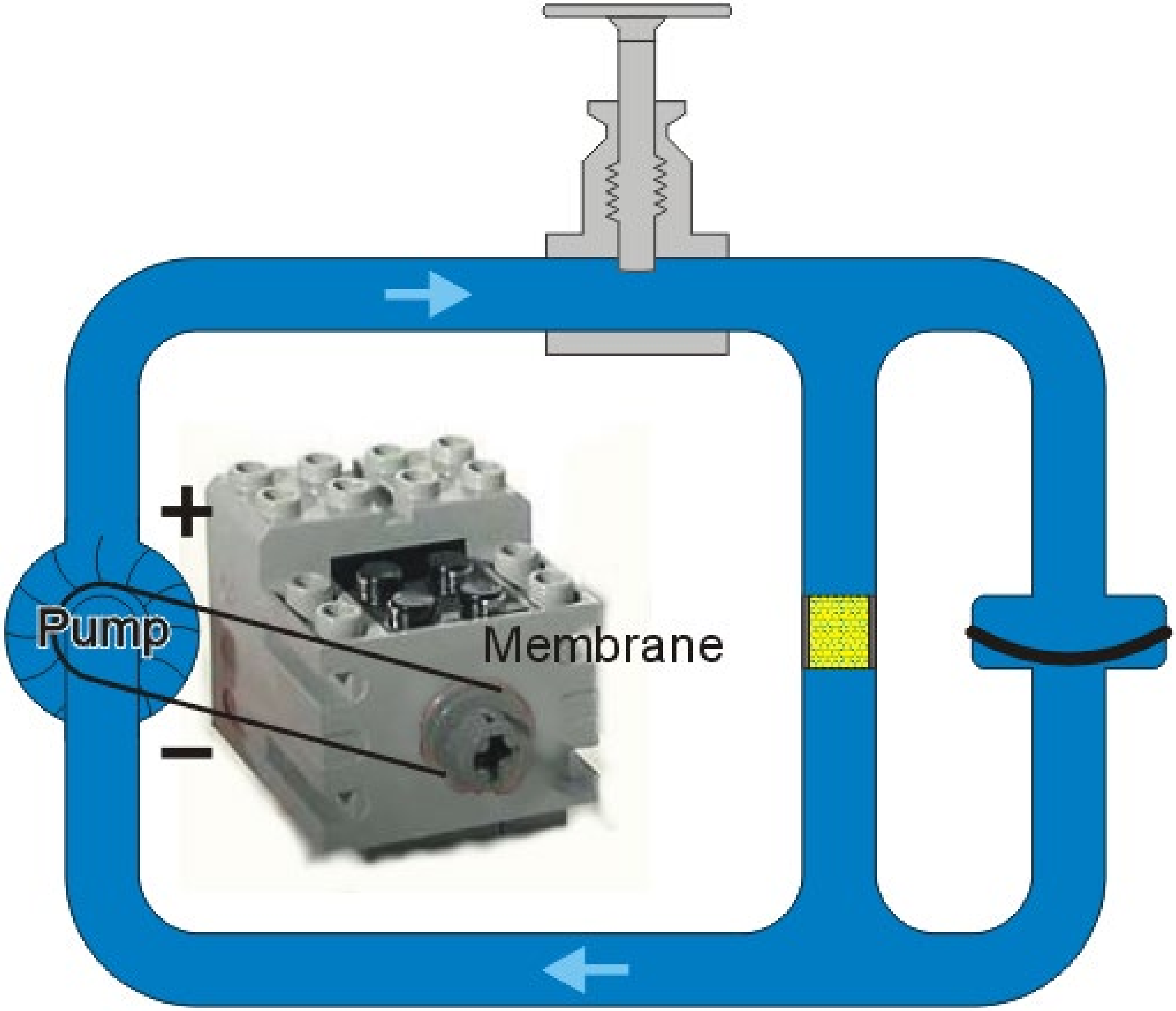

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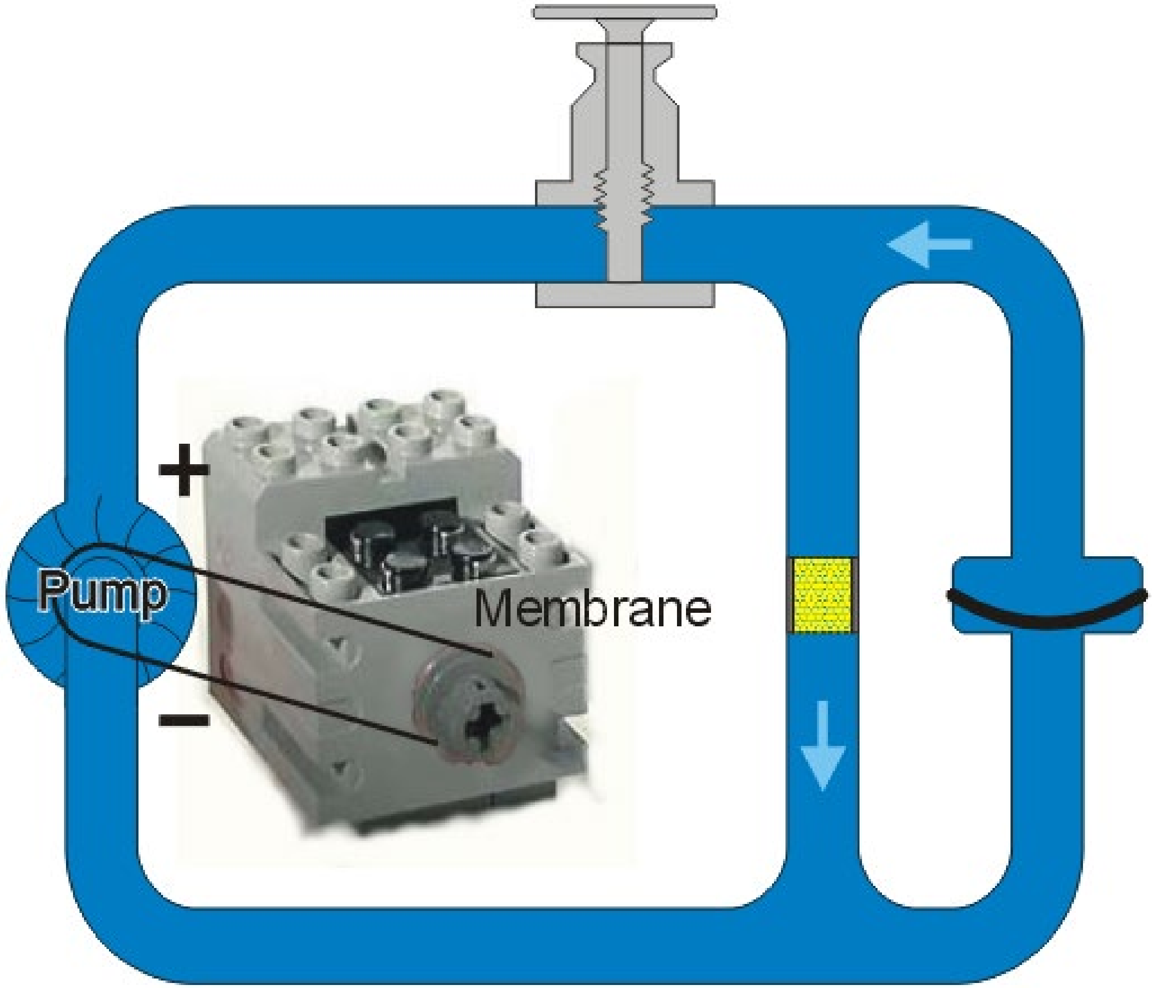

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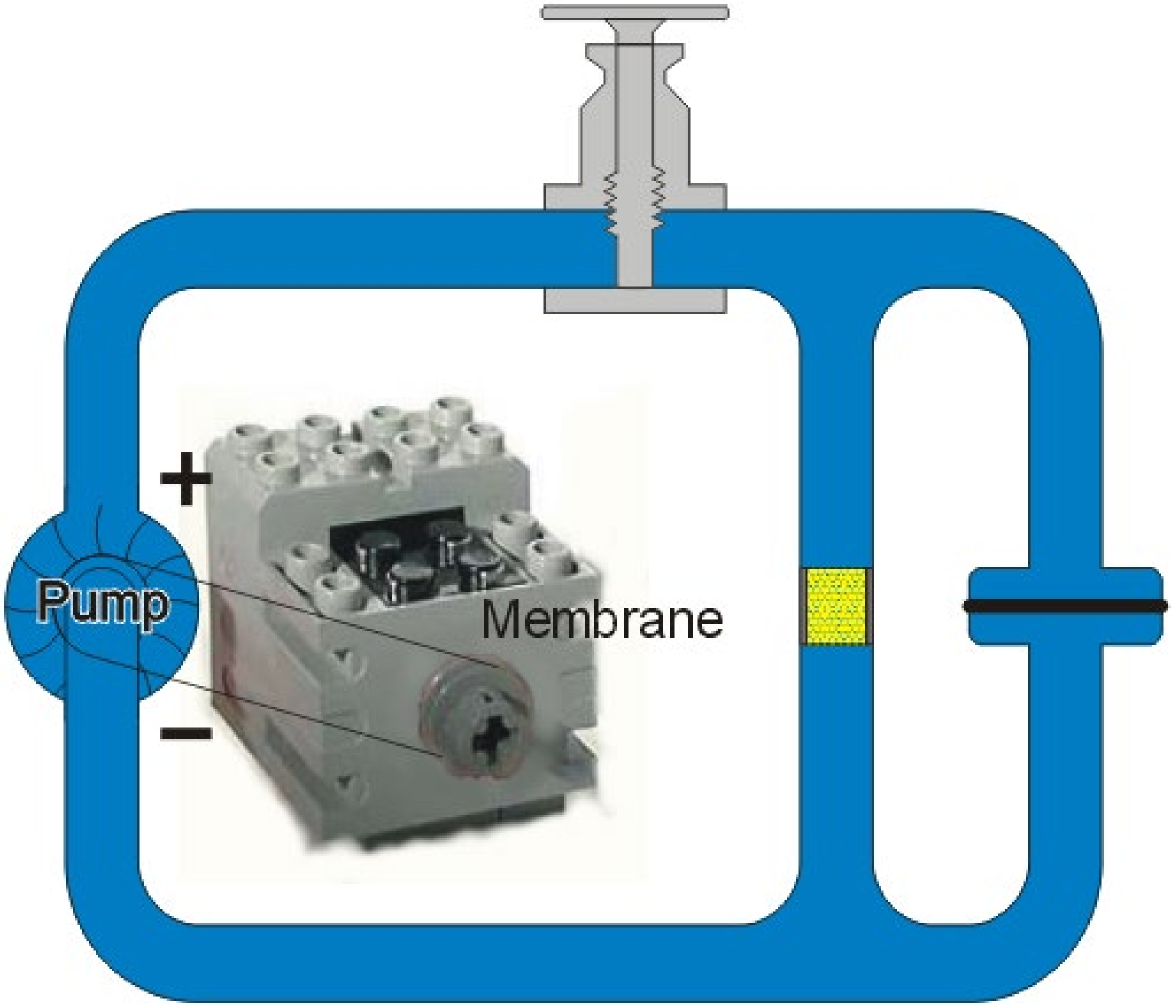

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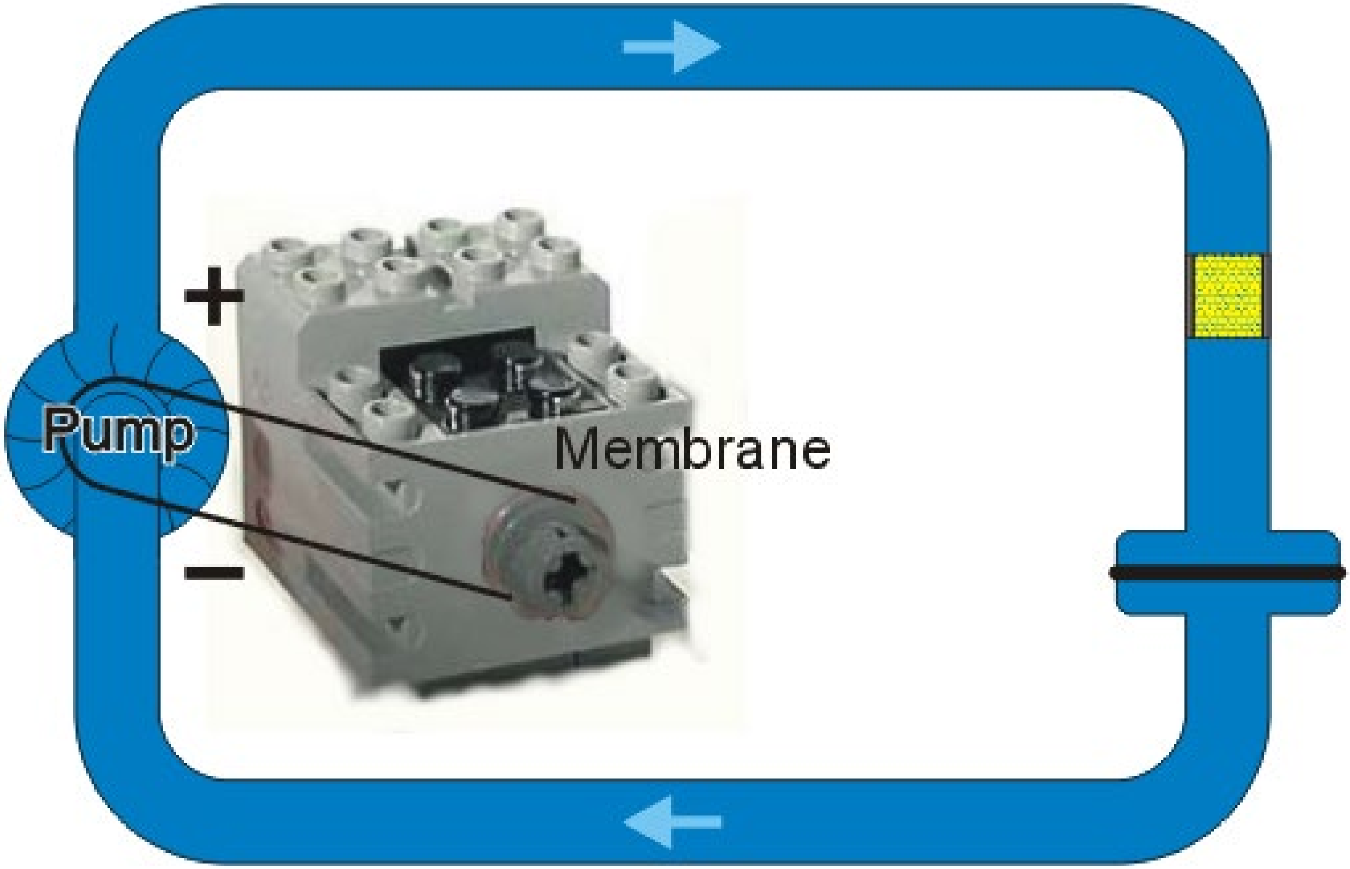

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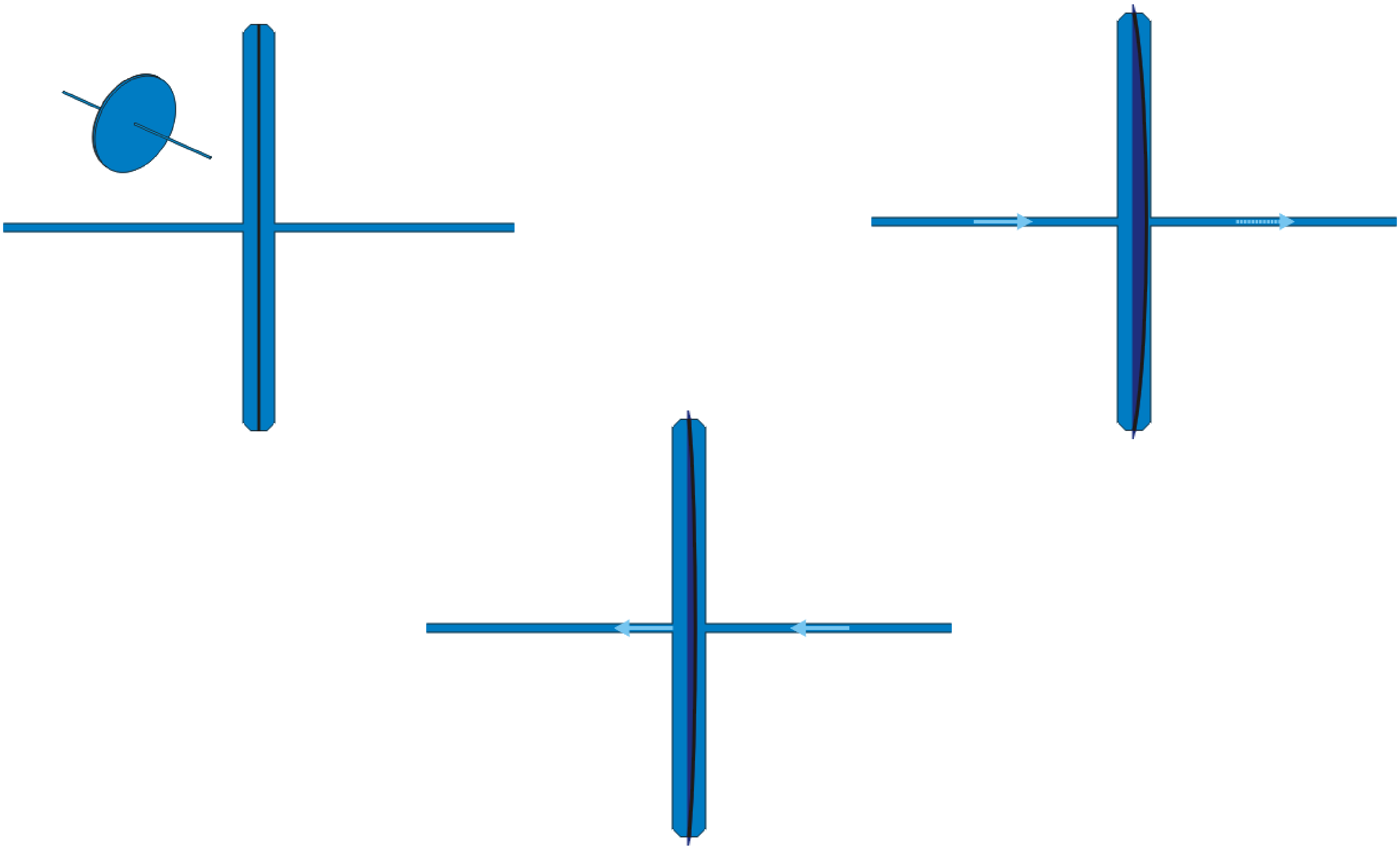
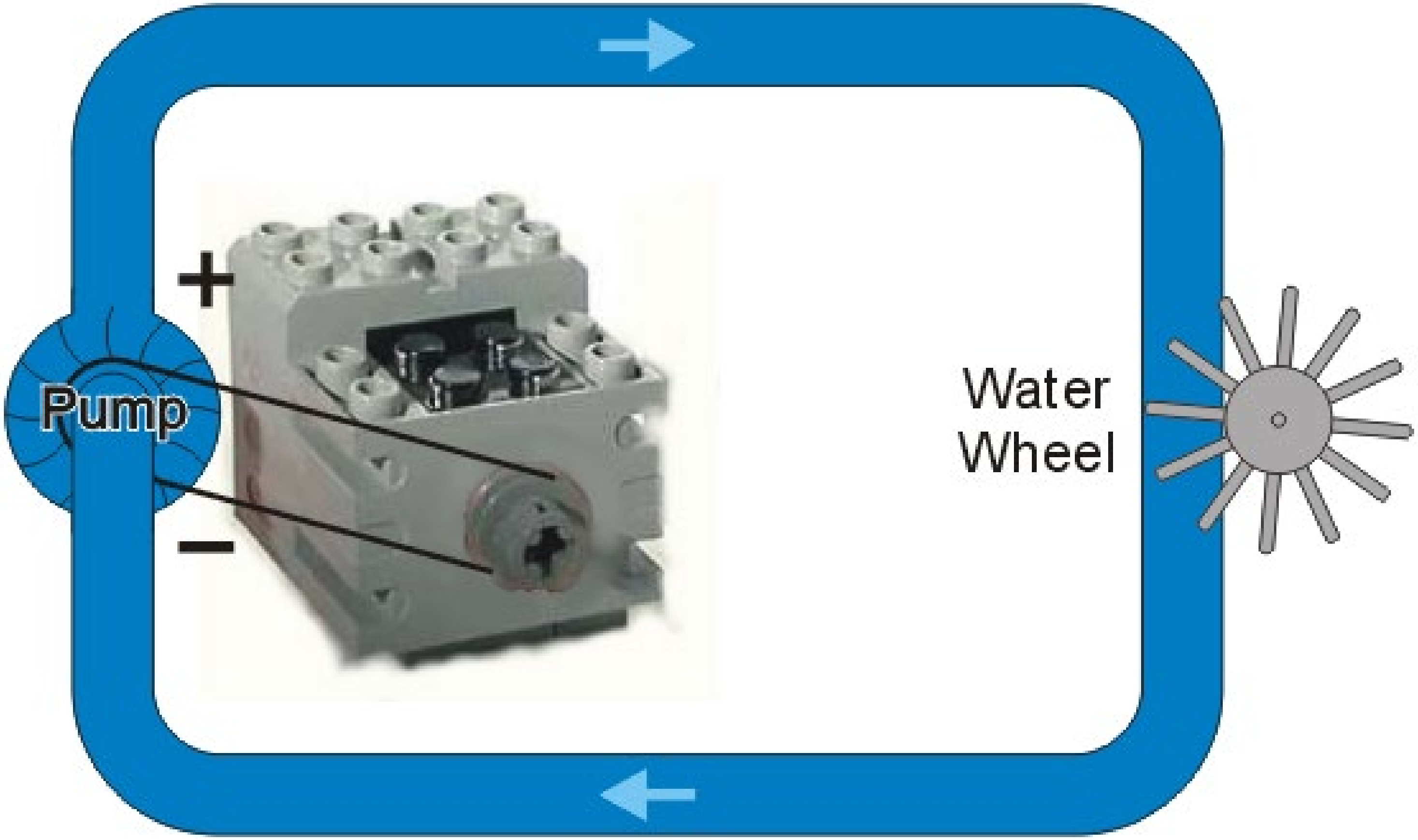


Bobina Analogie



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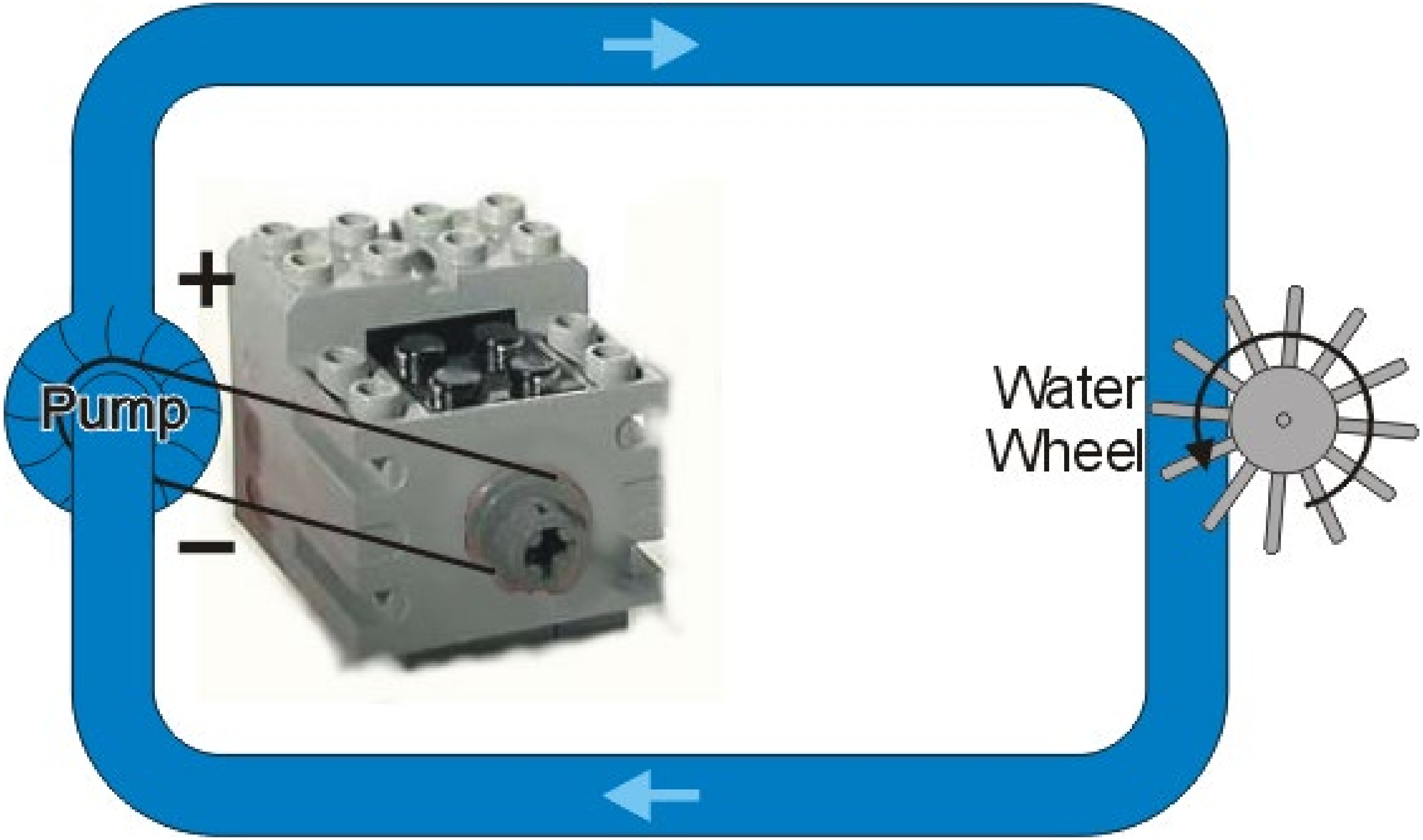

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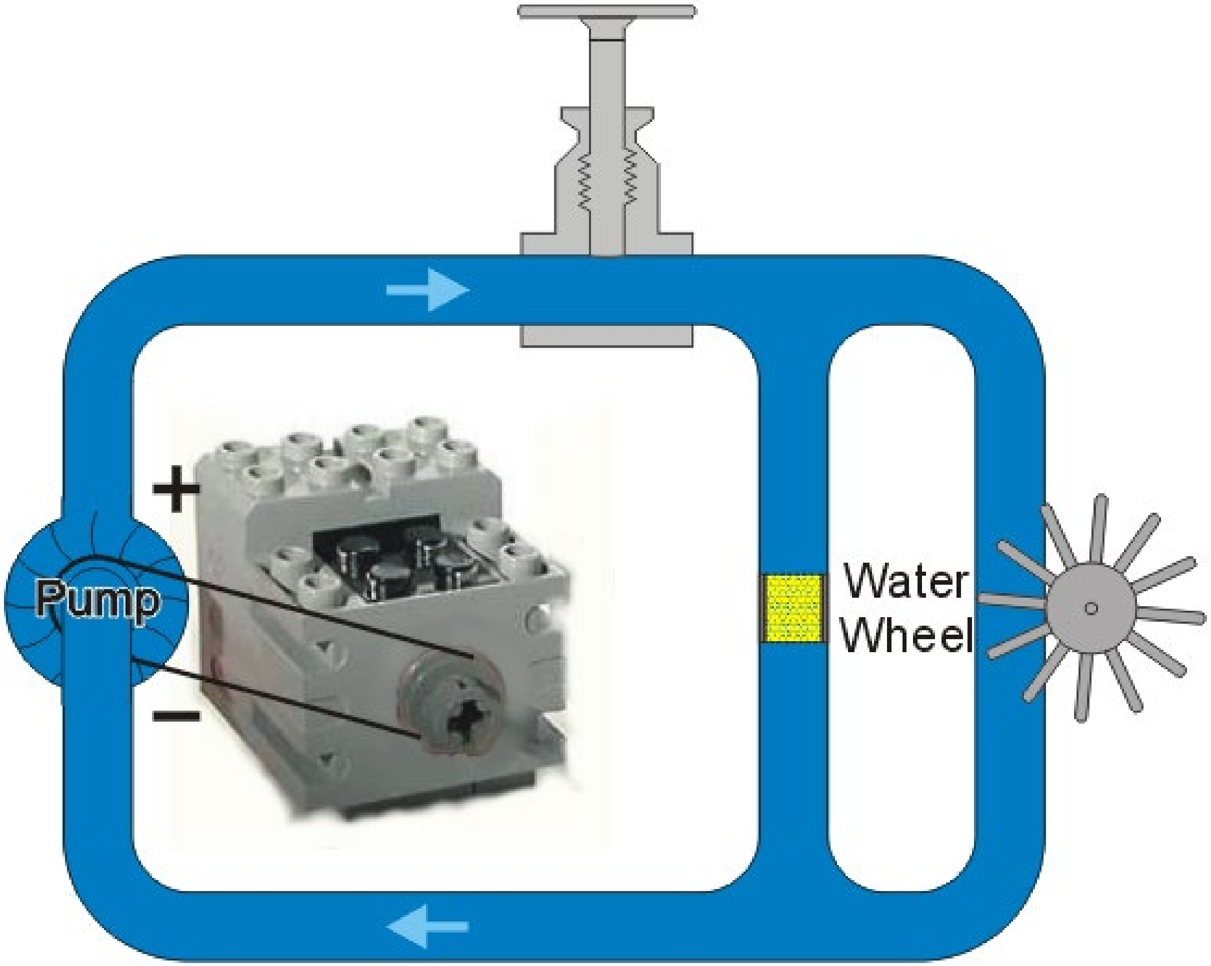

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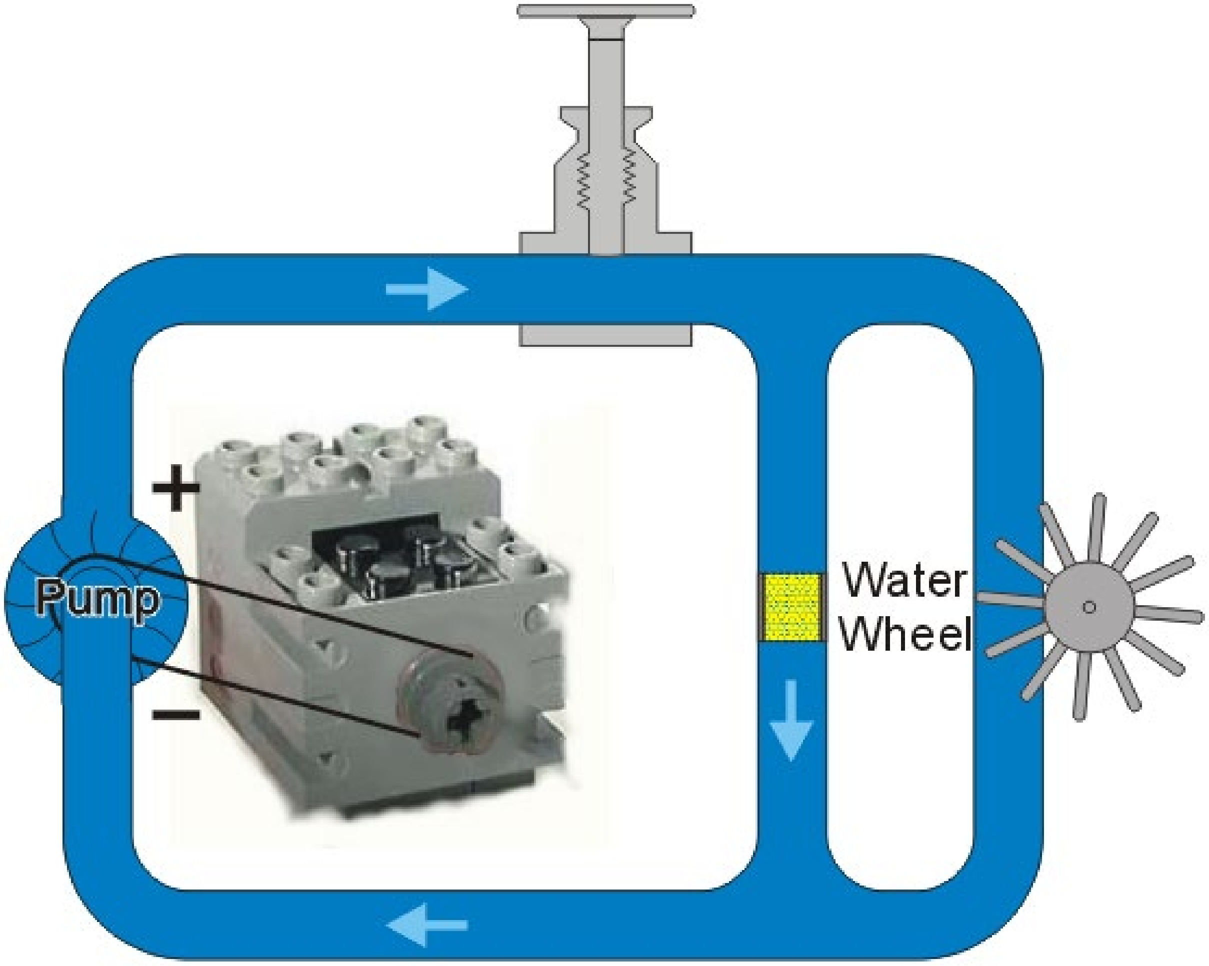

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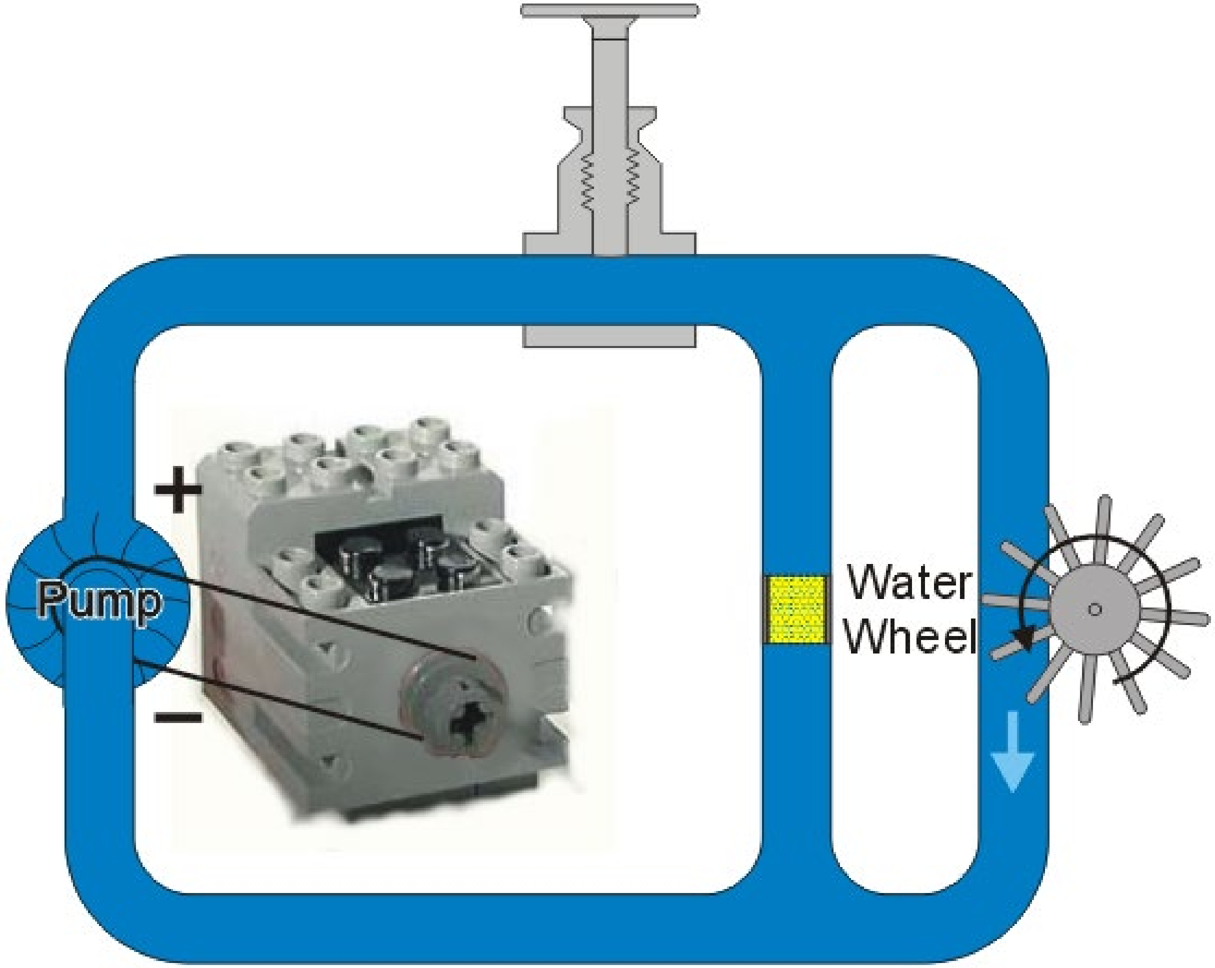

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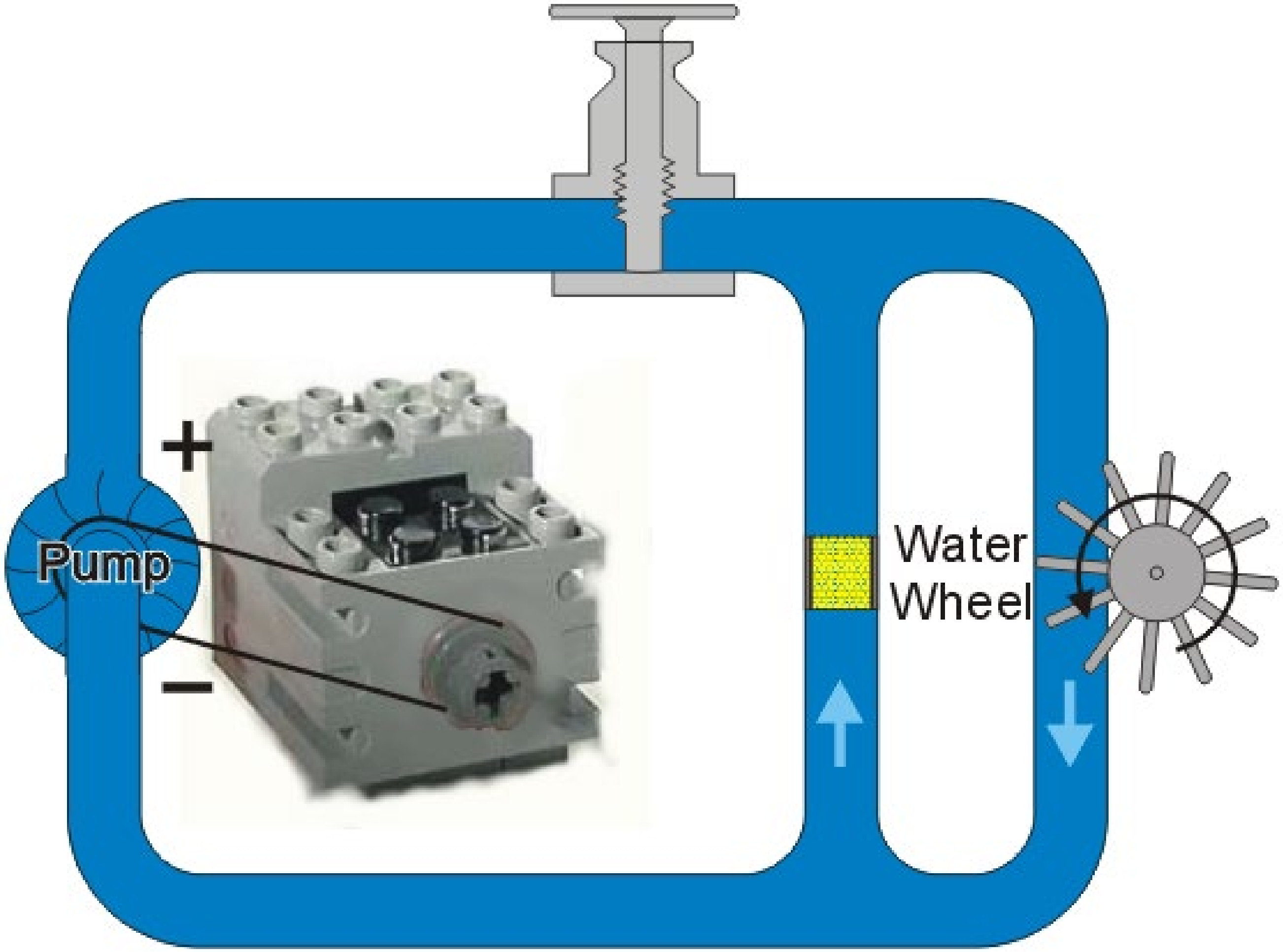

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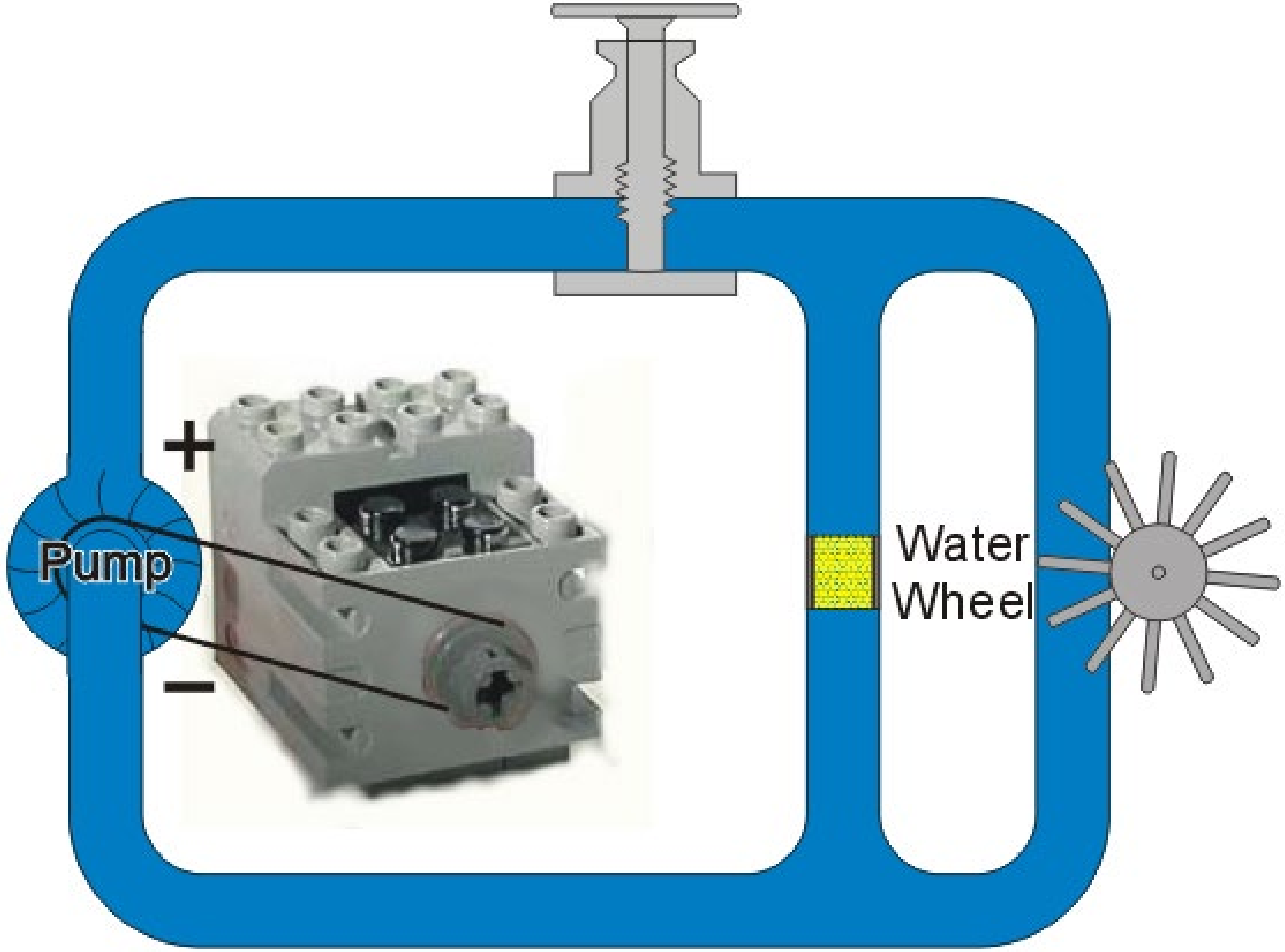

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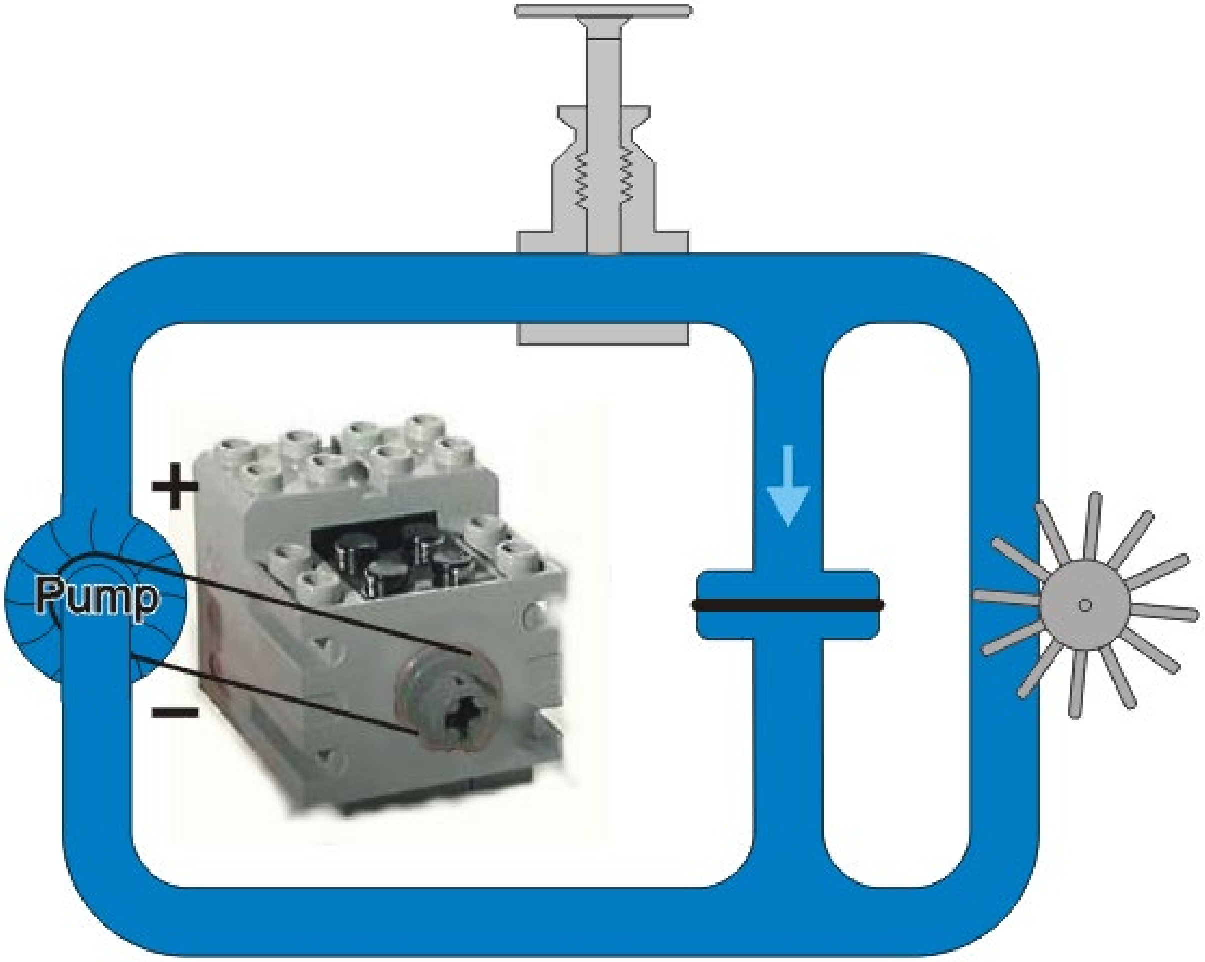

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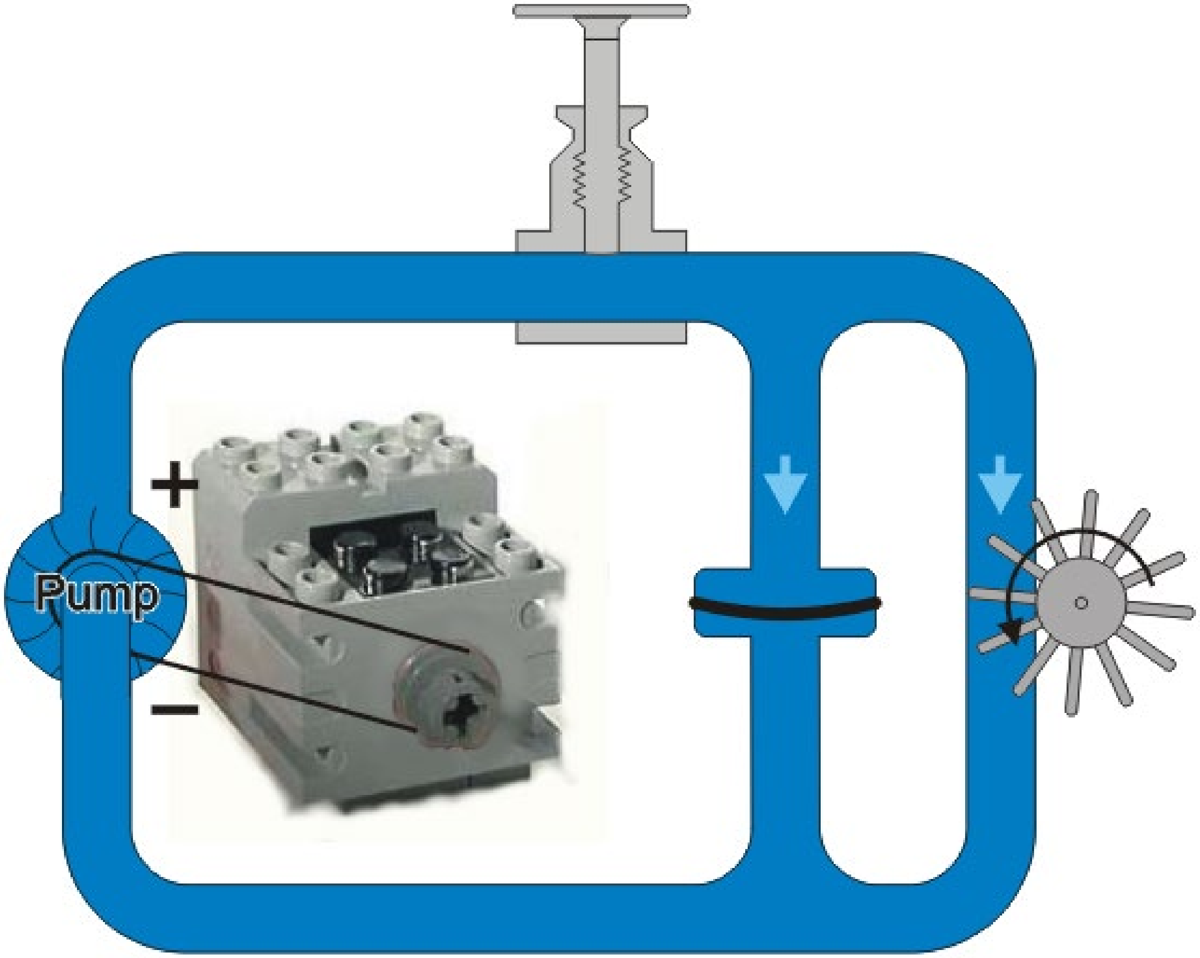

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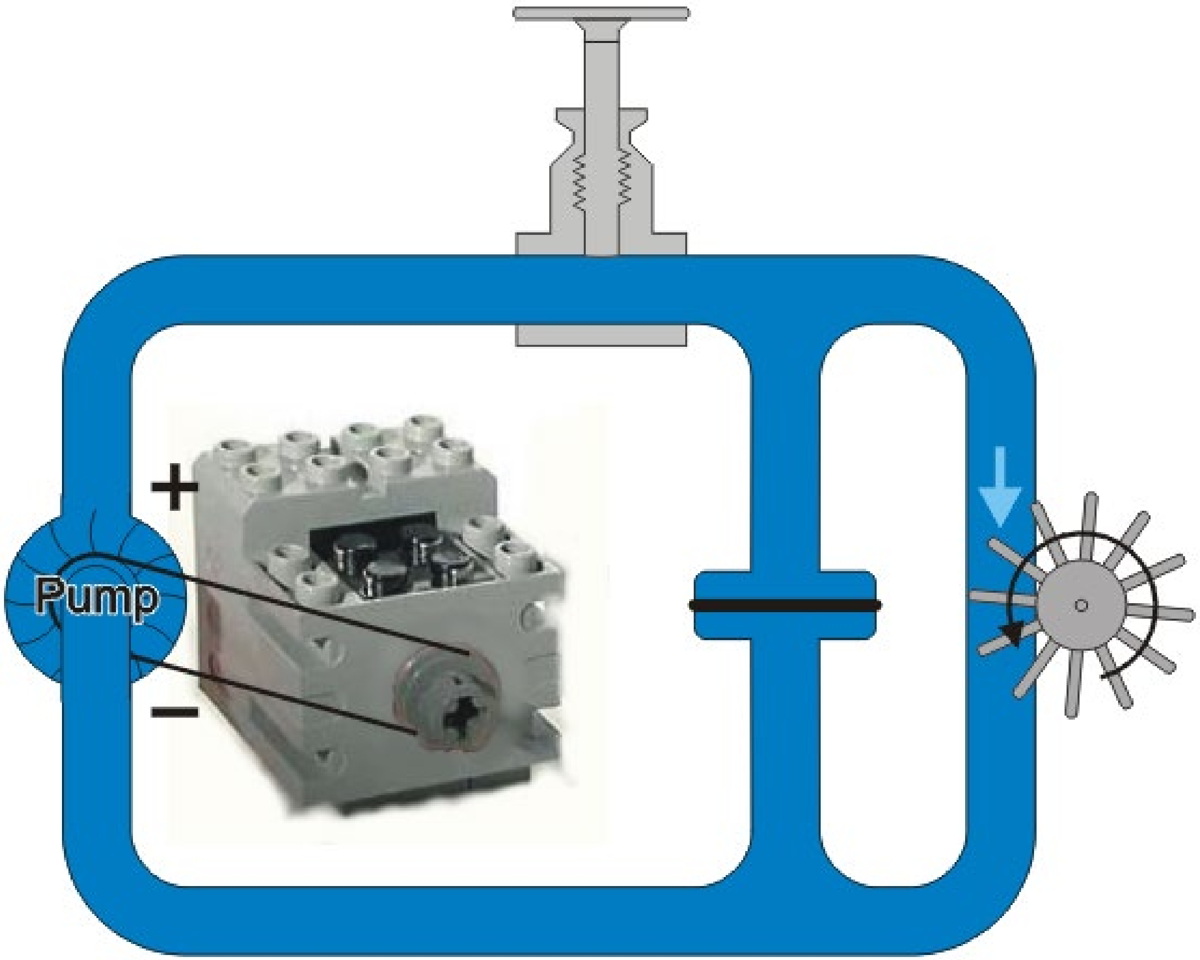

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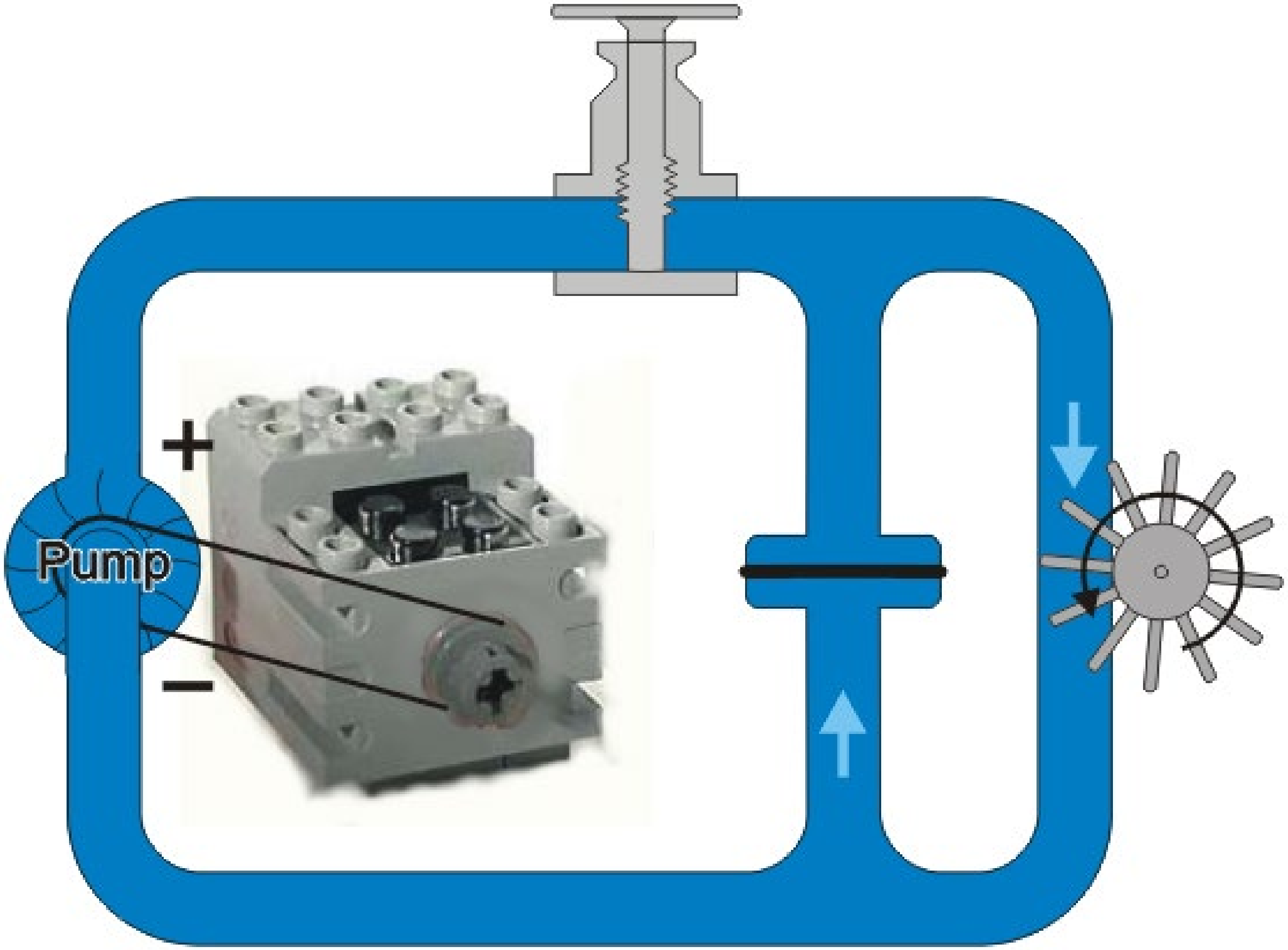

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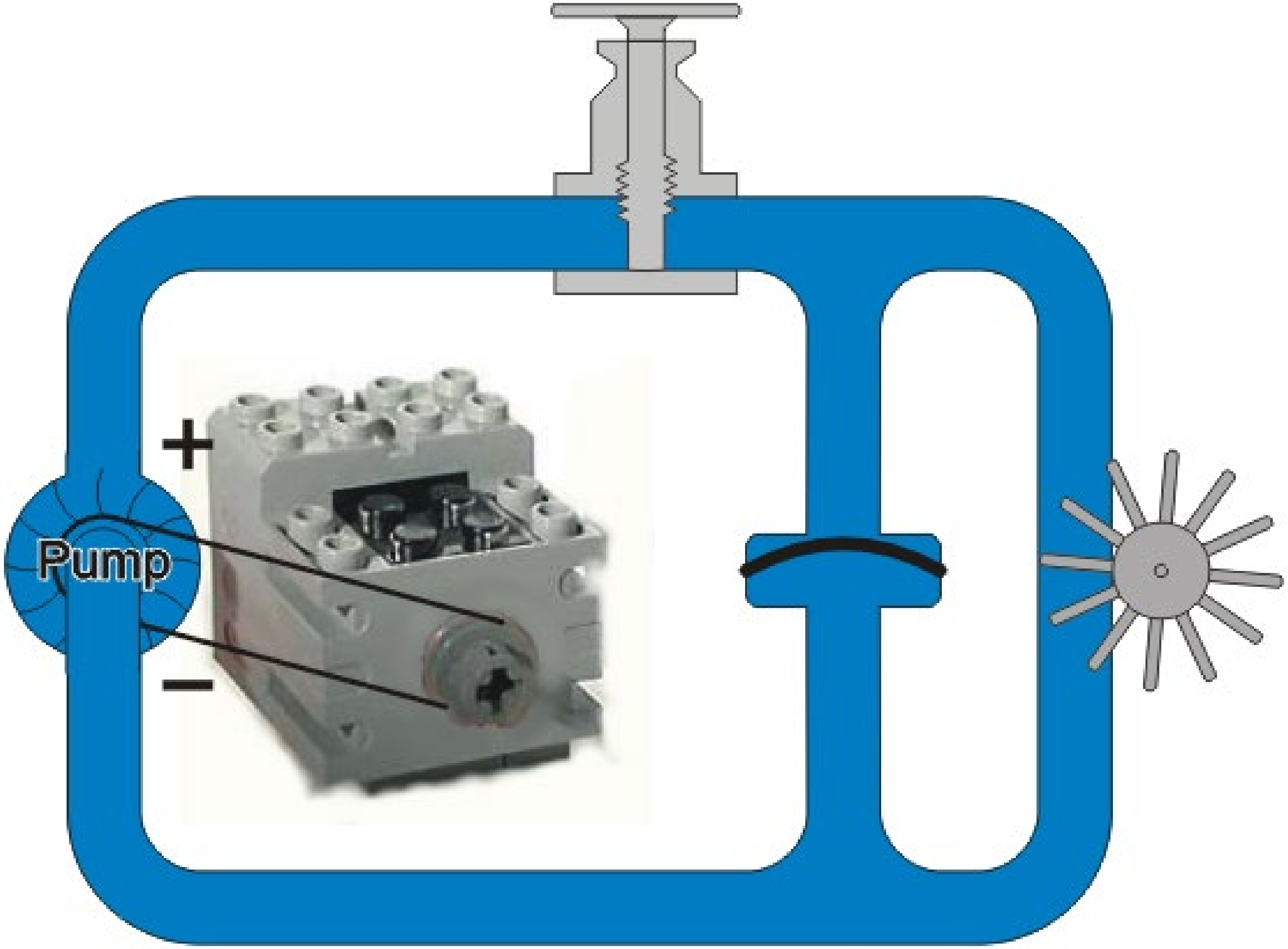

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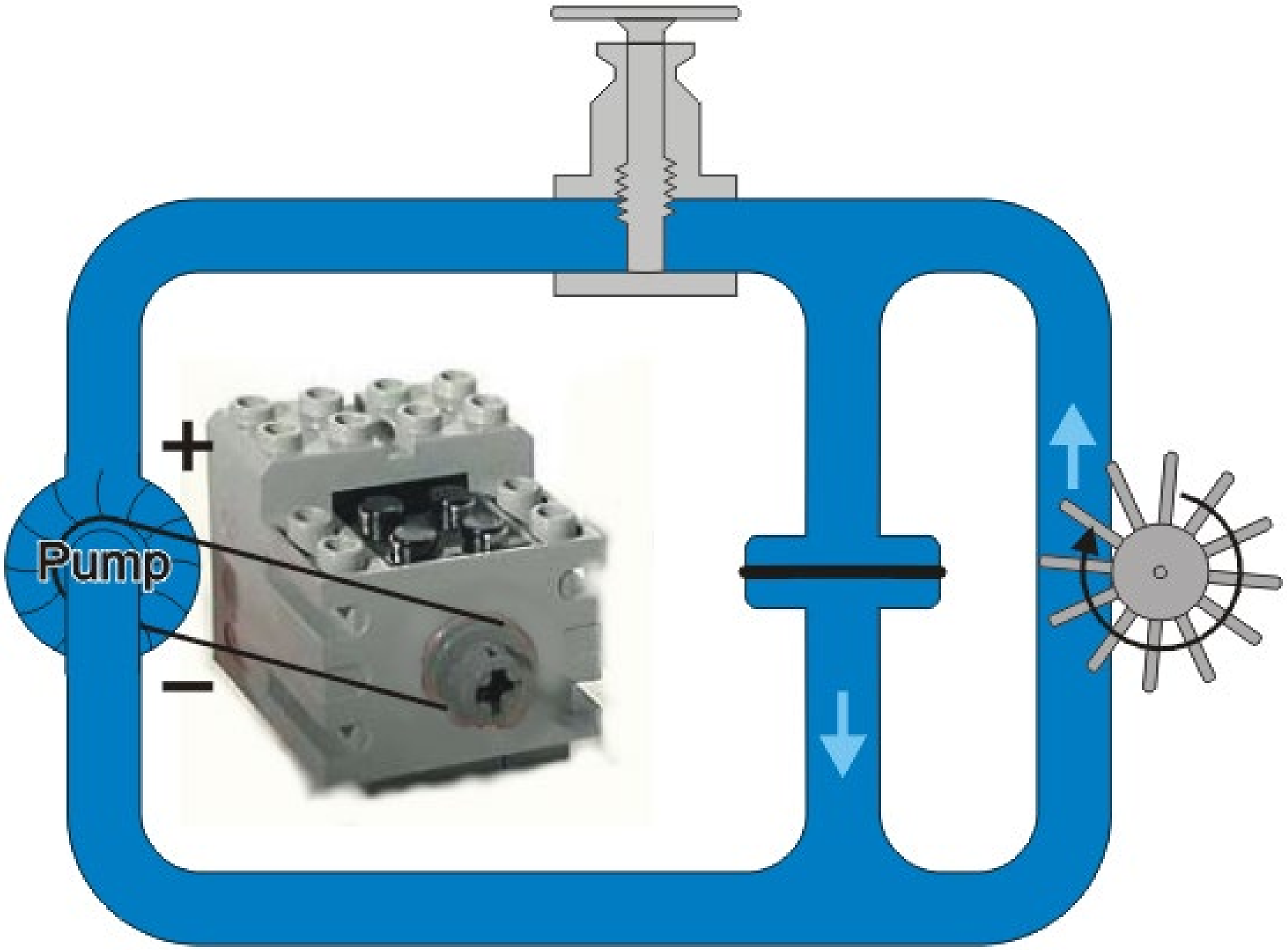

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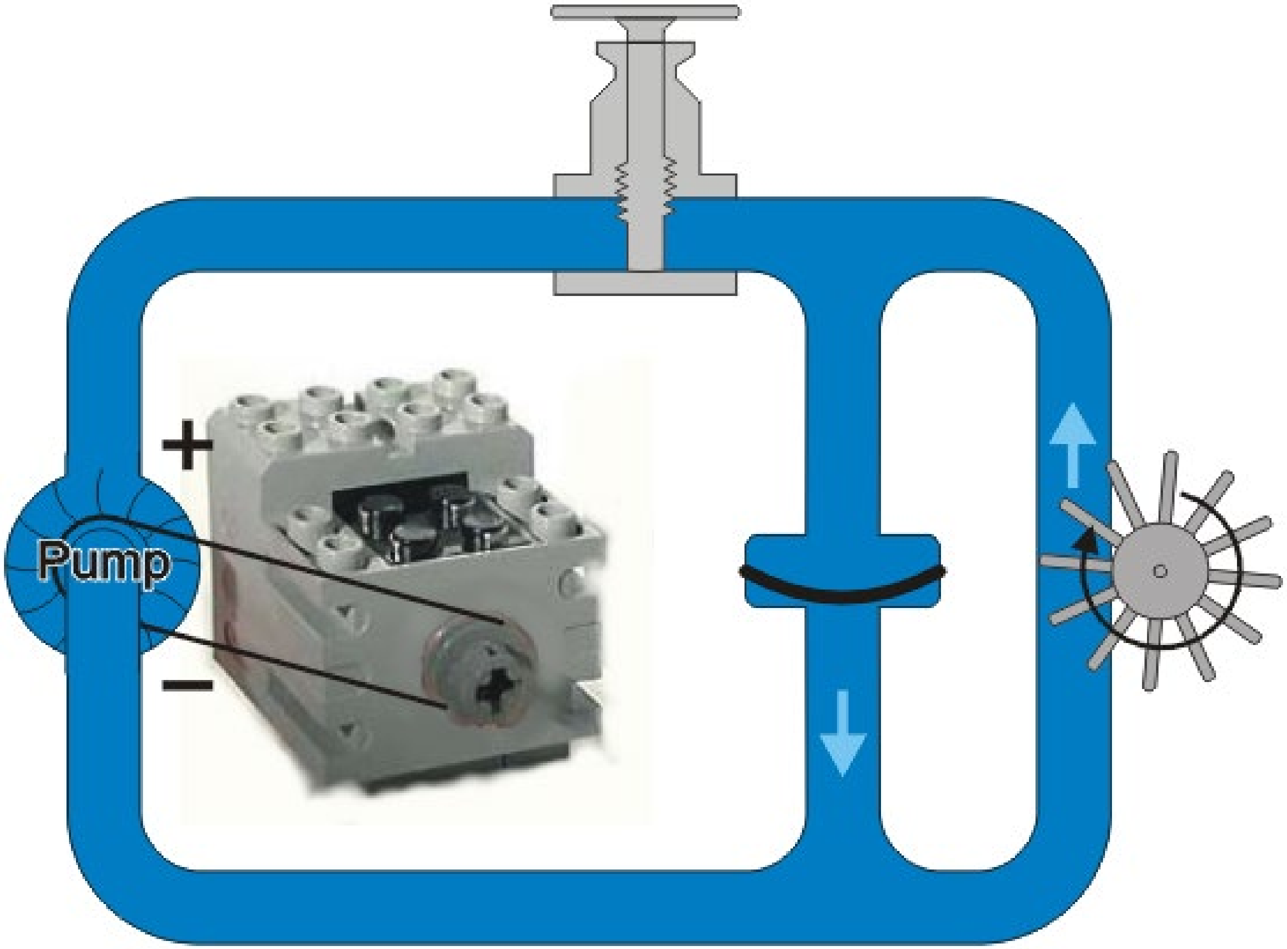

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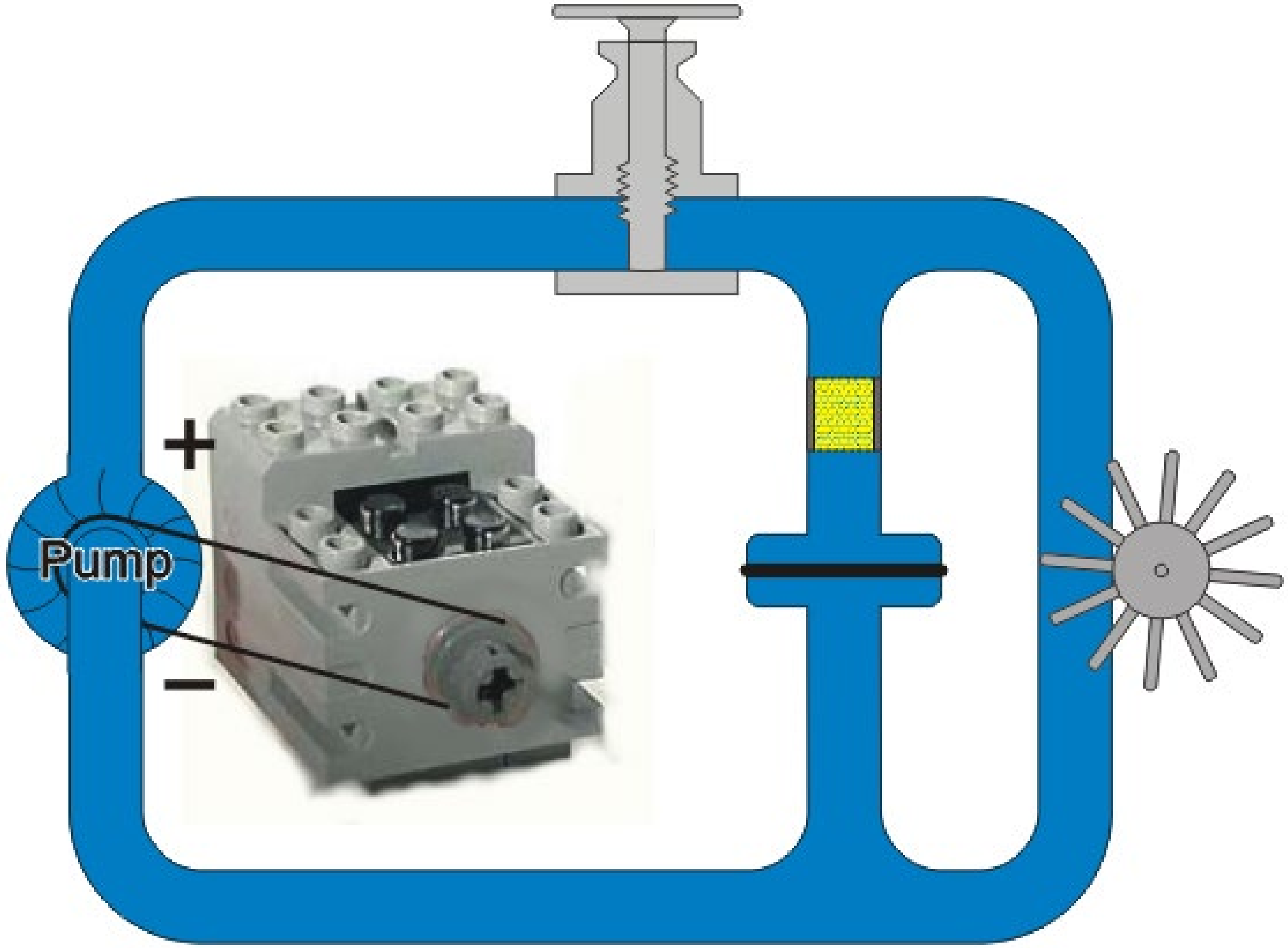

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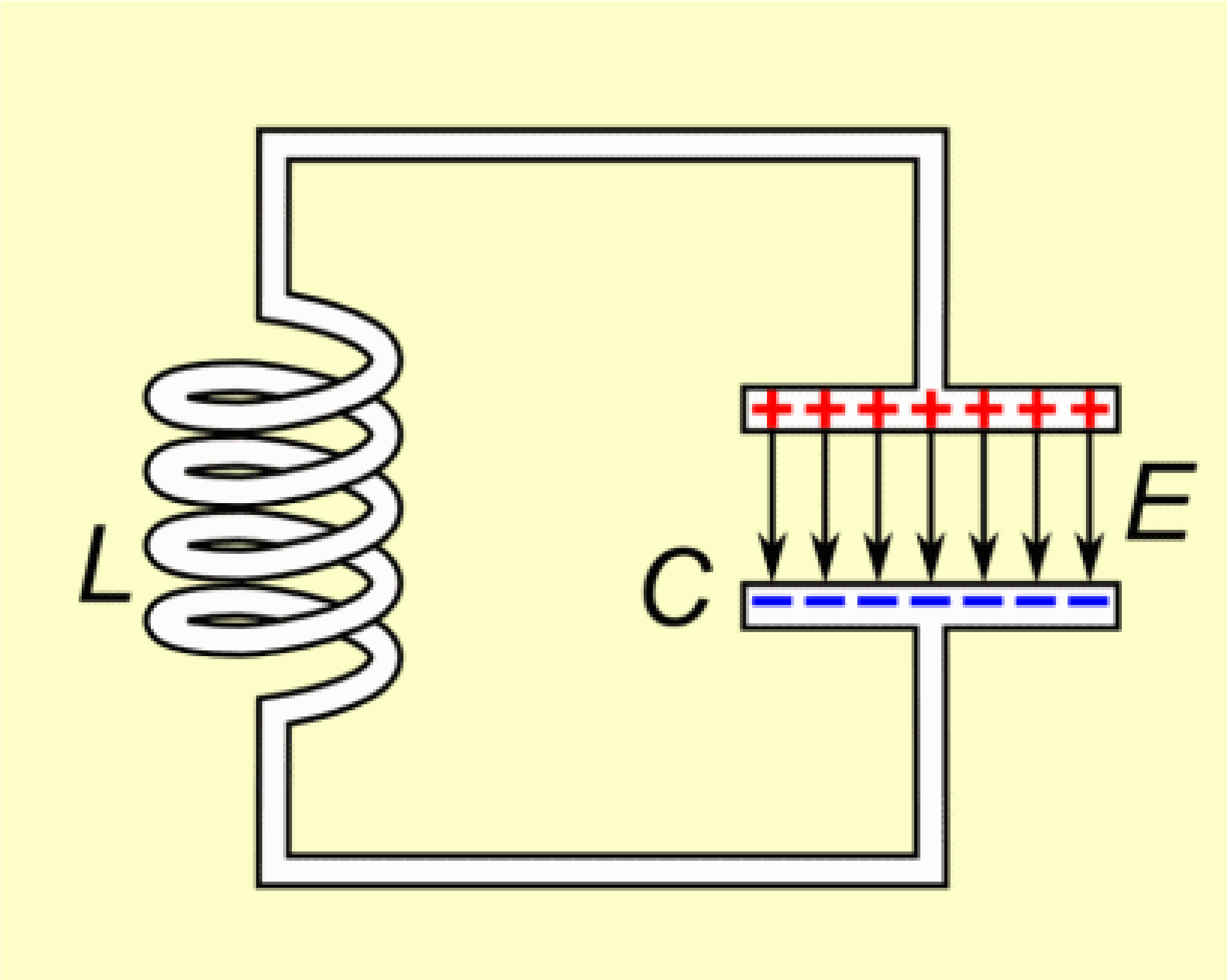
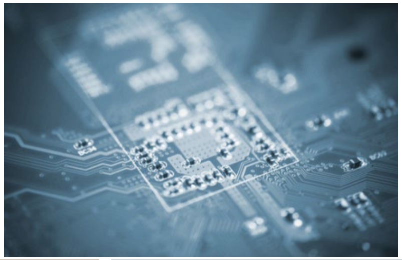


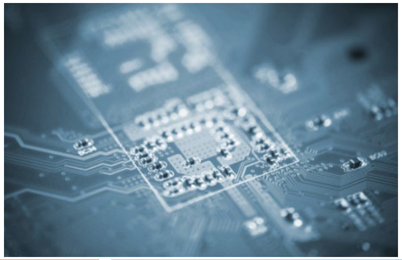
Analogiile complete le regasiti:
https://ece.uwaterloo.ca/~dwharder/Analogy/



Electronică- Scurtă Istorie

Andre Ampere

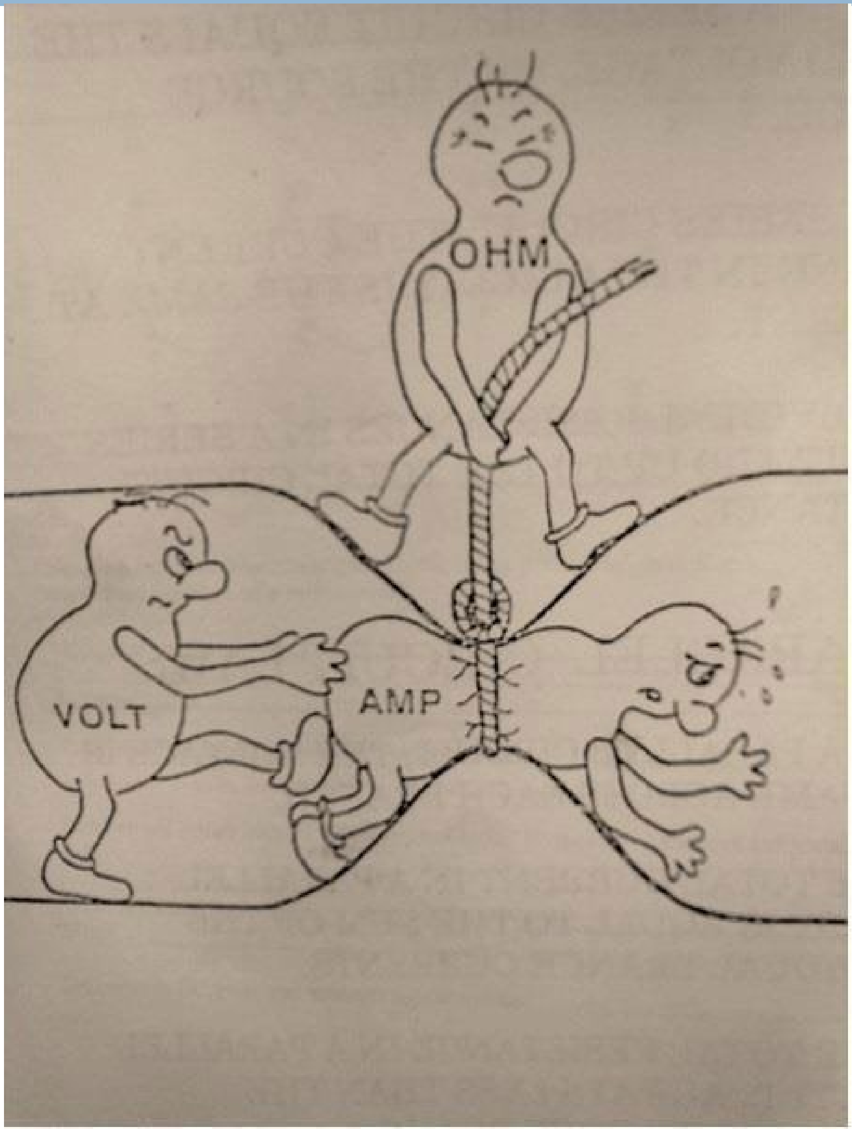
- 1775-1836
- Inventatorul solenoidului
- A studiat efectele curentului electric

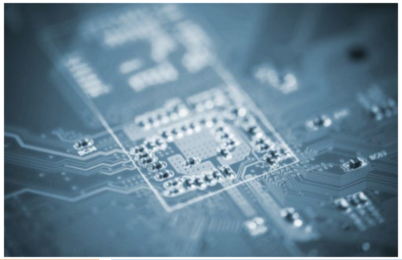


Electronică- Scurtă Istorie

Georg Simon Ohm

- 1789-1854
- Legea lui OHM





Electronică- Scurtă Istorie

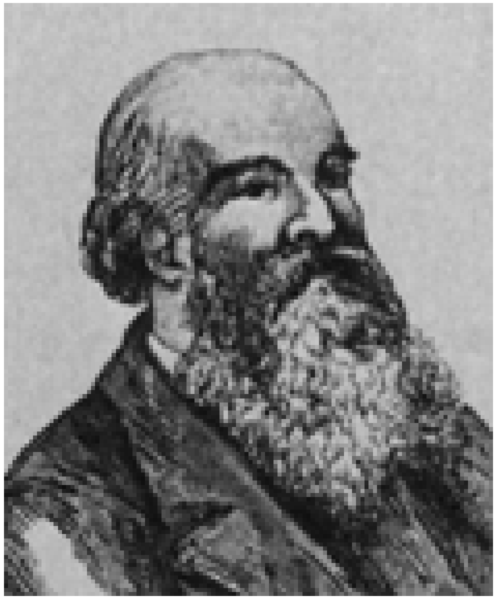
Michael Faraday

- 1791-1867
- Pionier in electricitate și magnetism
- A demonstrat inducția electromagnetică

Electronică- Scurtă Istorie

James Prescott Joule

- 1818-1889
- A descoperit Legea Conservării Energiei
- Unitatea de măsură pentru energie - Joule



Electronică- Scurtă Istorie

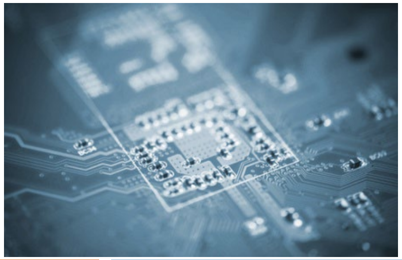
Gustav Robert Kirchhoff

- 1824-1887
- Spectroscopul
- Legile lui Kirchhoff

Electronică- Scurtă Istorie

James Clerk Maxwell

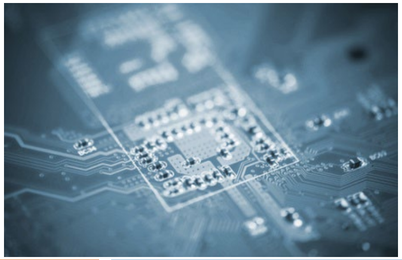
- 1831-1879
- *Treatise on Electricity and Magnetism*
- Ecuațiile lui Maxwell



Electronică- Scurtă Istorie

Heinrich Rudolph Hertz

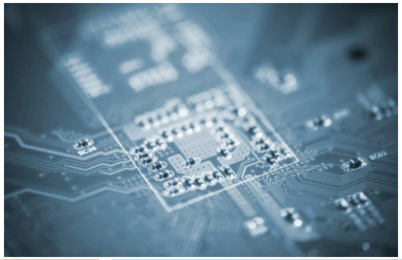
- 1857-1894
- A demonstrat radiația electromagnetică
- A demonstrat efectul fotoelectric



Electronică- Scurtă Istorie

Wilhelm Rontgen

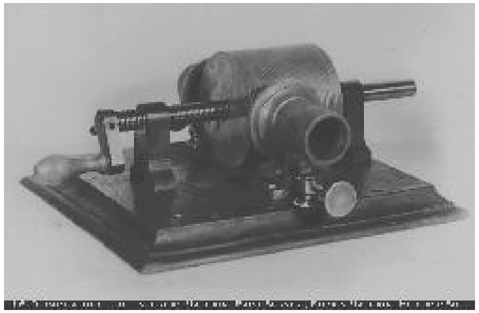
- 1845-1923
- Radiația X (*X-rays*) în 1895

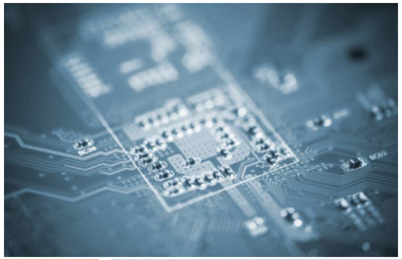


Electronică- Scurtă Istorie

Thomas Alva Edison

- 1847-1931
- 1093 brevete (lampa incandescentă, fonograf)

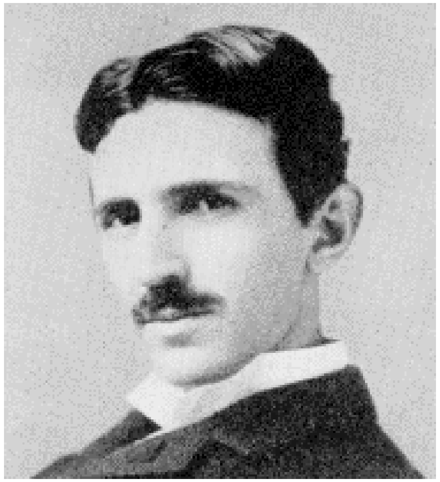


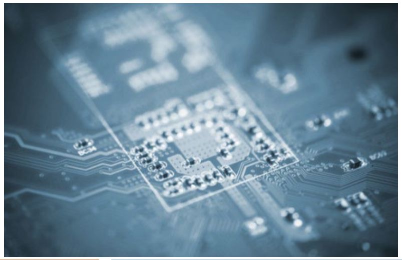


Electronică- Scurtă Istorie

Nikola Tesla

- 1856-1943
- Transformatorul
- Sistemele de distribuție de curent alternativ
- Motorul de inducție

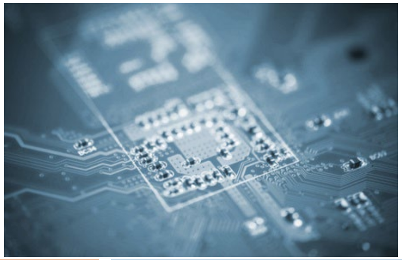




Electronică- Scurtă Istorie

Guglielmo Marconi

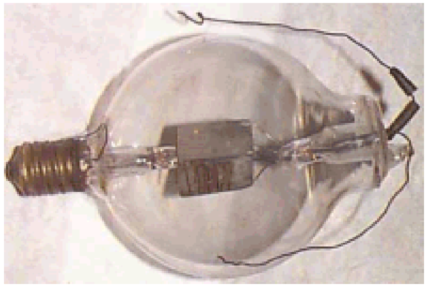
- 1874-1937
- Brevet Telegrafia Radio (1896)
- Premiul Nobel in Fizică (1909)



Electronică- Scurtă Istorie

John Ambrose Fleming

- 1849-1945
- Valva Fleming -primul redresor sau **diodă** (1904)



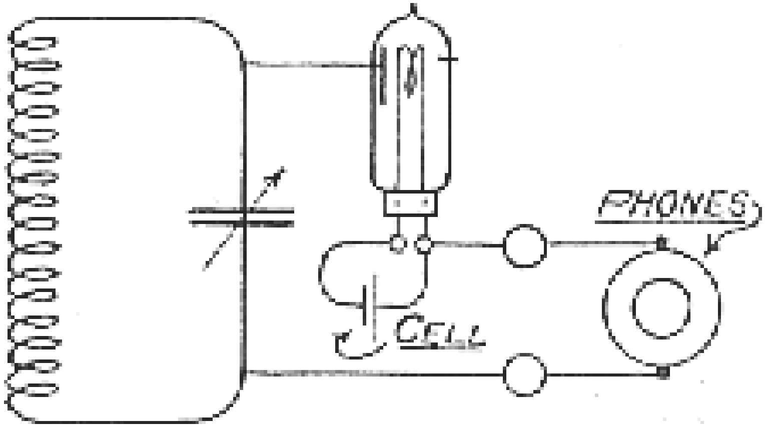
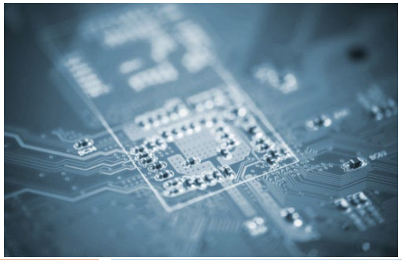


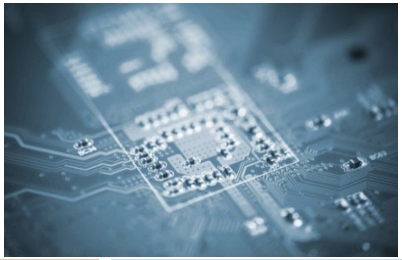
FIG. 47
Fleming valve



Electronică- Scurtă Istorie

Lee De Forest

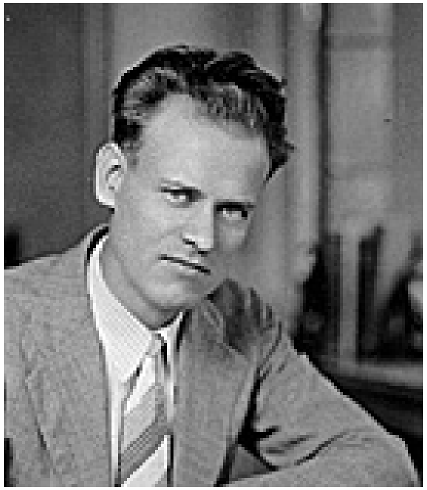
- 1873-1961
- Tubul Audion (1906)- **Trioda** – (Tub vidat de amplificare electronică)

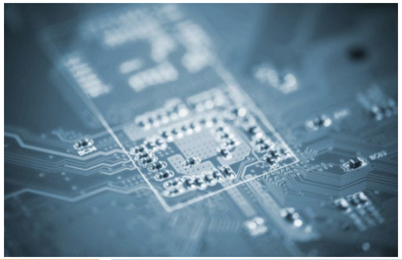


Electronică- Scurtă Istorie

Philo Taylor Farnsworth

- 1906-1971
- A dezvoltat Sistemul TV (1922- la 14 ani!!!)
- In 1927 l-a brevetat





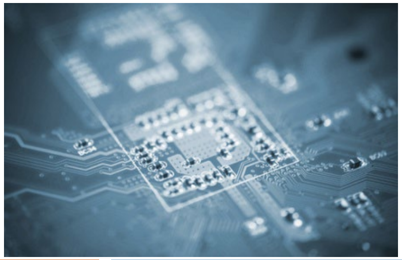
Electronică- Scurtă Istorie

William Bradford Shockley (1910-1989)

Walter H. Brattain (1902-1987)

John Bardeen (1908-1991)

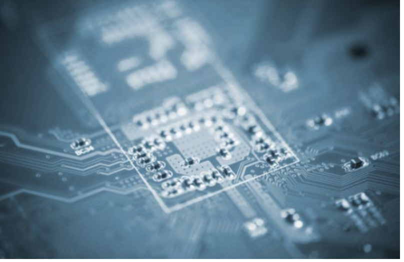
- Premiul Nobel (1956) pentru invenția **tranzistorului**



Electronică- Scurtă Istorie

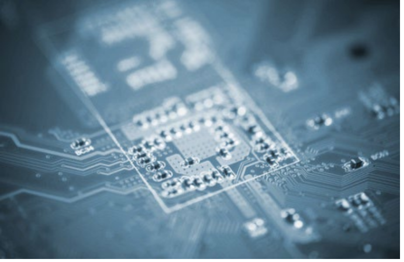
- Ce a urmat după?

- Circuite cu diode și tranzistoare…..
- Alte dispozitive electronice



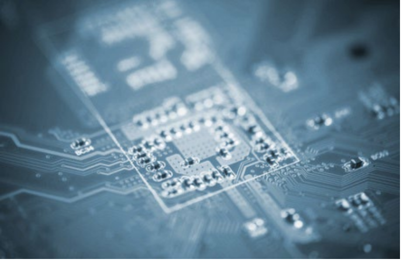
Electronica- Definiție

- **Electronica** reprezintă o disciplină din domeniul fizicii aplicate care se ocupă cu **studiul dispozitive electronice** și al circuitelor care includ aceste elemente (**circuite electronice**), folosite în procese de comandă, reglare, măsurare etc.
- **Electronica de putere** este știința care se ocupă cu teoria generală a **conversiei statice** a energiei electrice, cu principiile de funcționare, analiza și sinteza **convertoarelor electronice** de putere precum și cu circuitele de comandă și reglare a acestora.



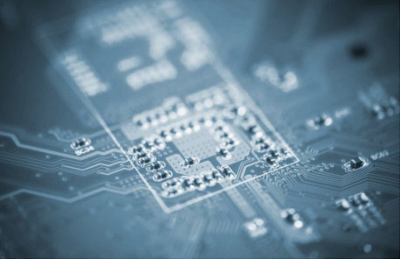
Electronica

- Ce sunt circuitele electronice ?
- Sunt circuite electrice care contin **cel putin un dispozitiv electronic**.
- Ce este dispozitivul electronic?
- Este acea componenta speciala a unui circuit electric a carui comportare se bazeaza pe **controlul miscarii purtatorilor de sarcina** in corpul solid, in gaze, in vid sau in lichide.
- In prezent majoritatea absoluta a dispozitivelor electronice se bazeaza pe controlul miscarii purtatorilor de sarcina in corpul solid, in speta in **materialele semiconductoare.**



Dispozitive electronice.Generalitati

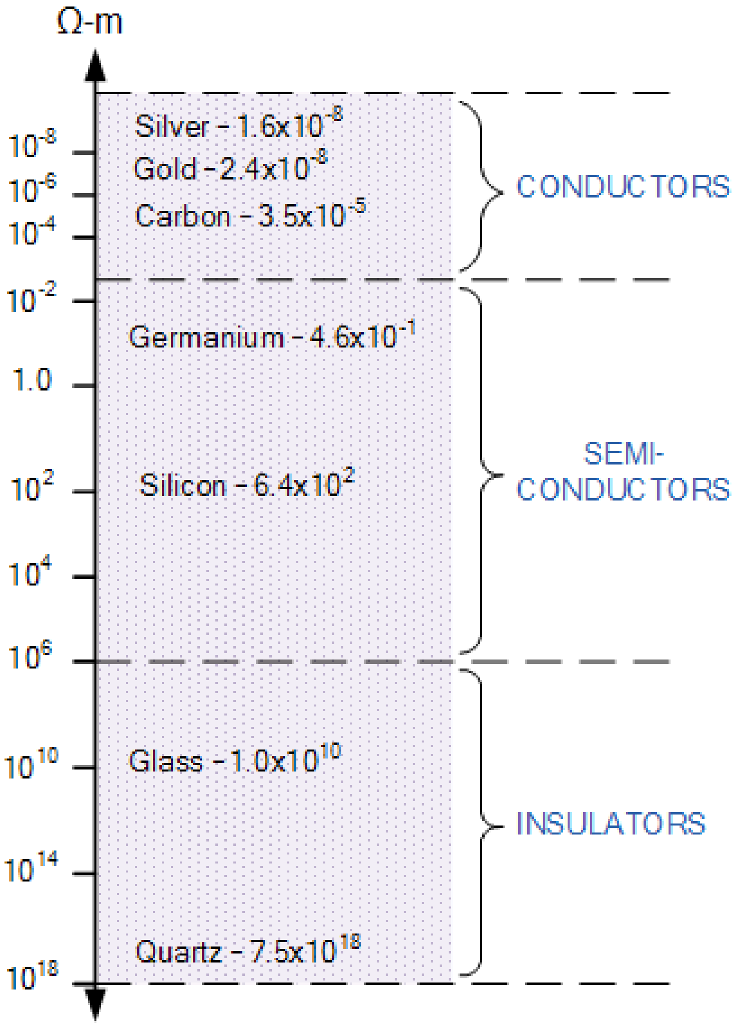
- Conductia in dispozitivul electronic se bazeaza pe **controlul miscarii sau concentratiei** de purtatori de sarcina;
- Prezenta unui dispozitiv electronic intr-un circuit electric il transforma in circuit electronic;
- Datele de catalog sunt orientative si se refera la exemplare cu performante medii;
- Marimile care apar la interfata dintre dispozitivul electronic si celelalte elemente de circuit **sunt tot tensiuni si curenti electrici.**



Dispozitive electronice.Generalitati

- Dispozitivele electronice pot avea doua, trei sau mai multe borne.
- Dispozitivele electronice prezinta caracteristici statice si dinamice.
- Caracteristicile statice sunt **neliniare**.

Dispozitive electronice.Generalitati



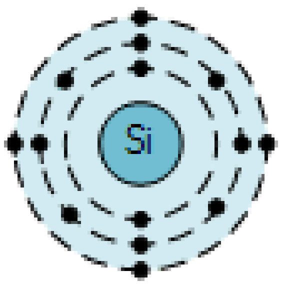
Electronica

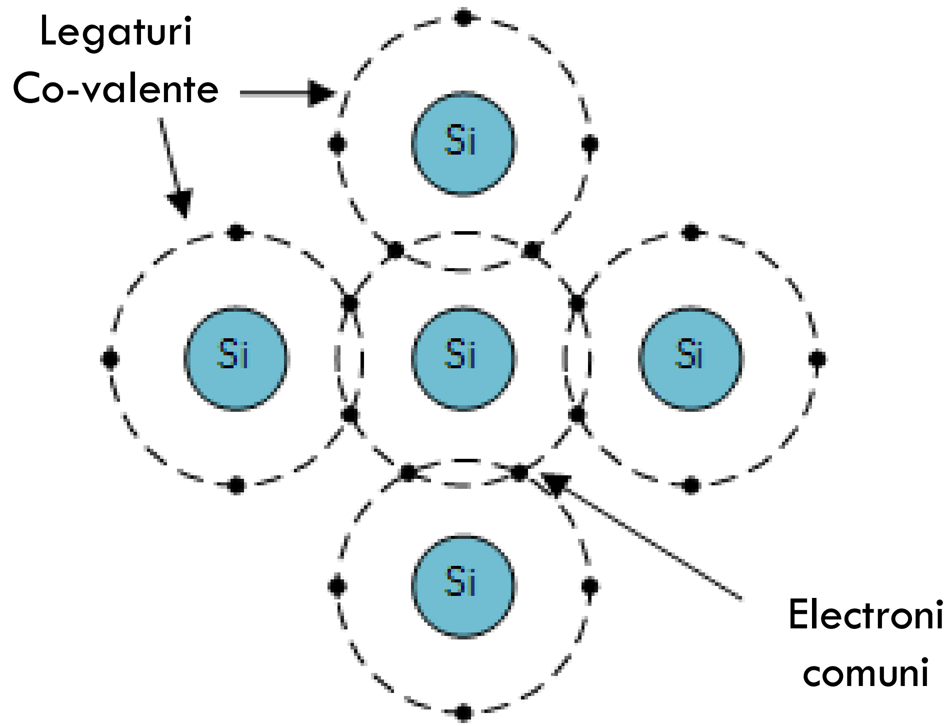
- Electric vs Electronic

- Controlabilitate = controlam numarul de electroni dintr-un circuit electric
- Circuit electric + disp. Electronic= circuit electronic= electronica
- Electronica:
  - Transfer de informatie (digitala si analogica)
  - Transfer de energie electrica – Electronica de Putere
    - 6litri vs 20kW (100km) ; 36lei vs 20lei (3kwh PV+ Statii de incarcare gratuite)
    - Randamentul 50% (3 litri deplasare; 3 litri – caldura)
    - EV – Randament 80-90% (10-20% - caldura)
    - Tesla - EV

Dispozitive electronice.Generalitati

Atomul de Siliciu. Nr. Atomic "14"

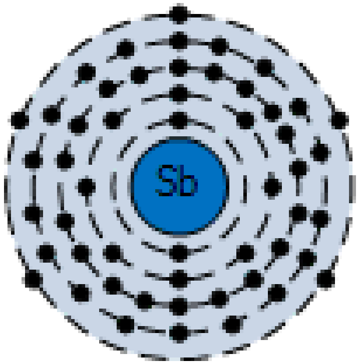


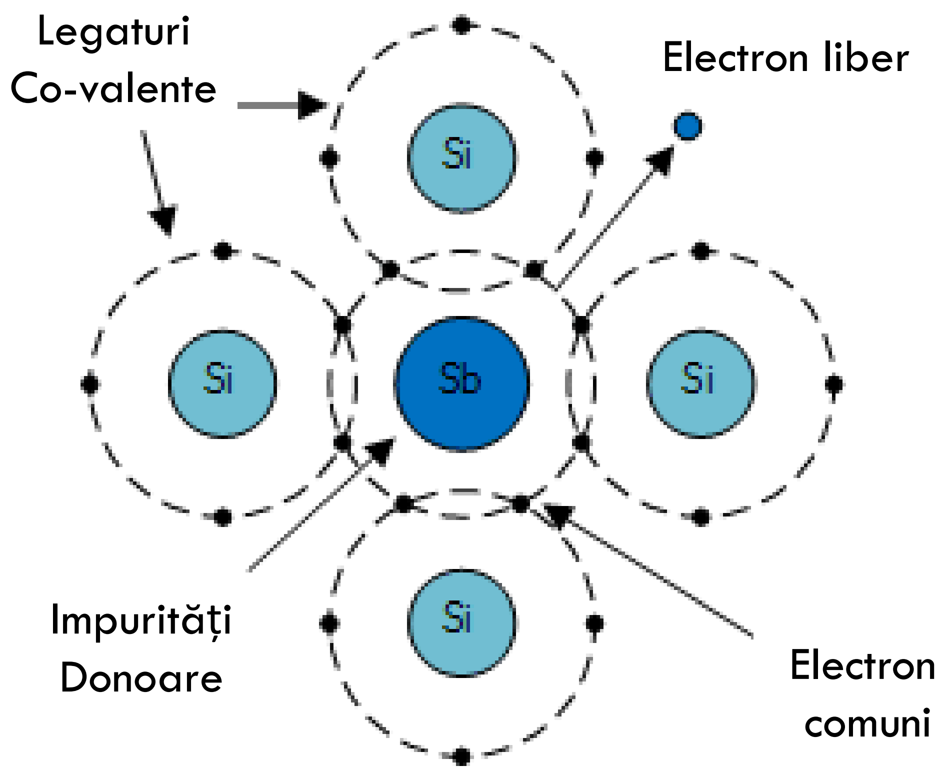


Semiconductor pe bază de Siliciu

Dispozitive electronice.Generalitati

Atomul de Antimoniu.
Nr. Atomic "51"

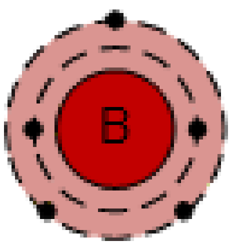


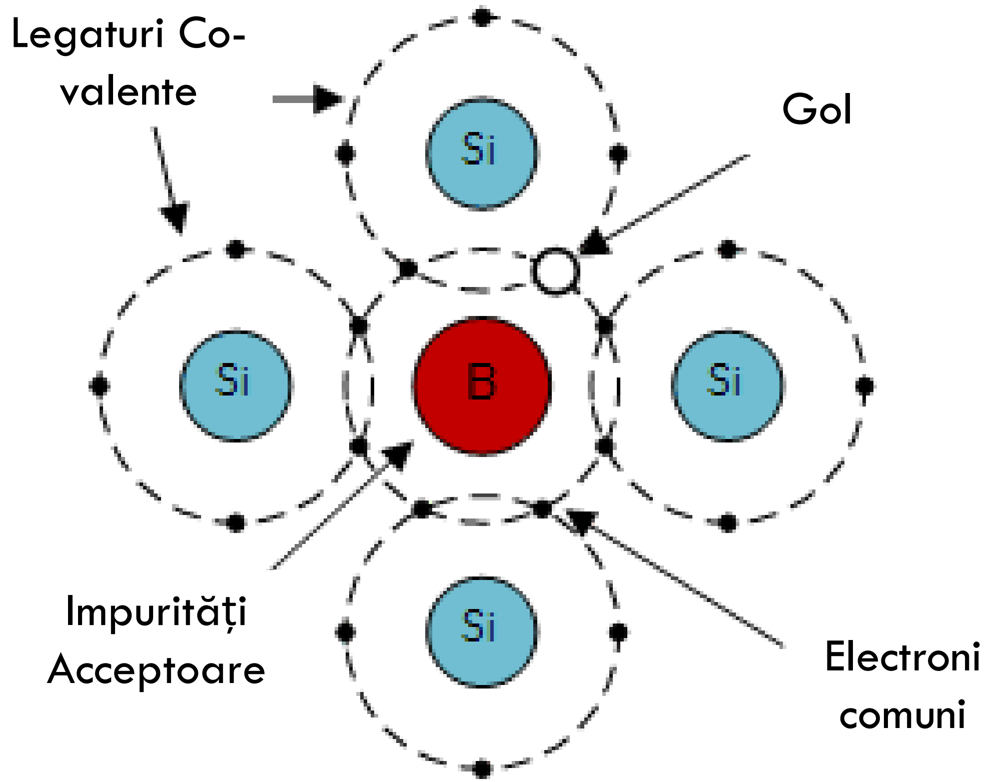


Semiconductor de
tip N

Dispozitive electronice.Generalitati

Atomul de Bor
Nr. Atomic "5"



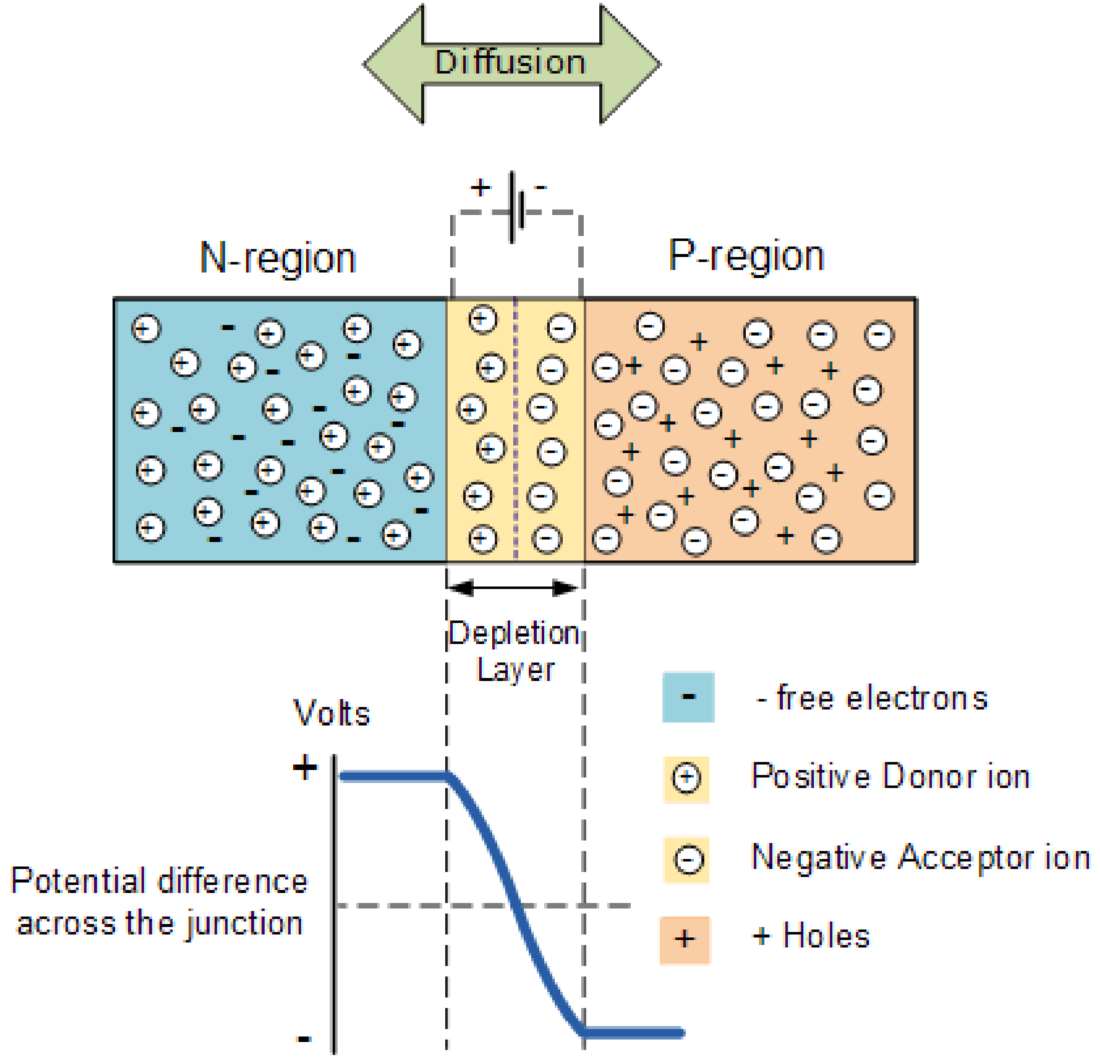


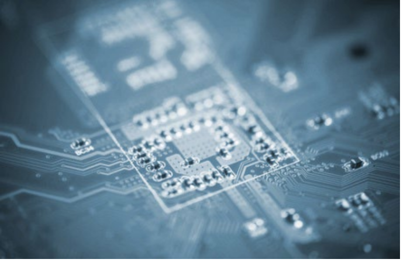
Semiconductor de tip P

Dispozitive semiconductoare

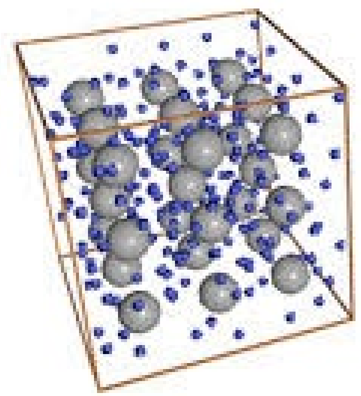
- Jonctiunea

semiconductoare pn



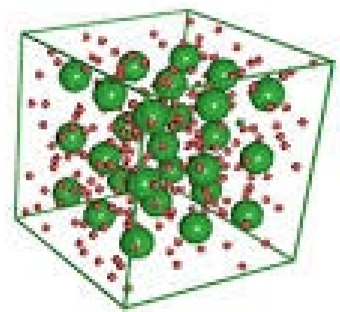


Dispozitive semiconductoare



P

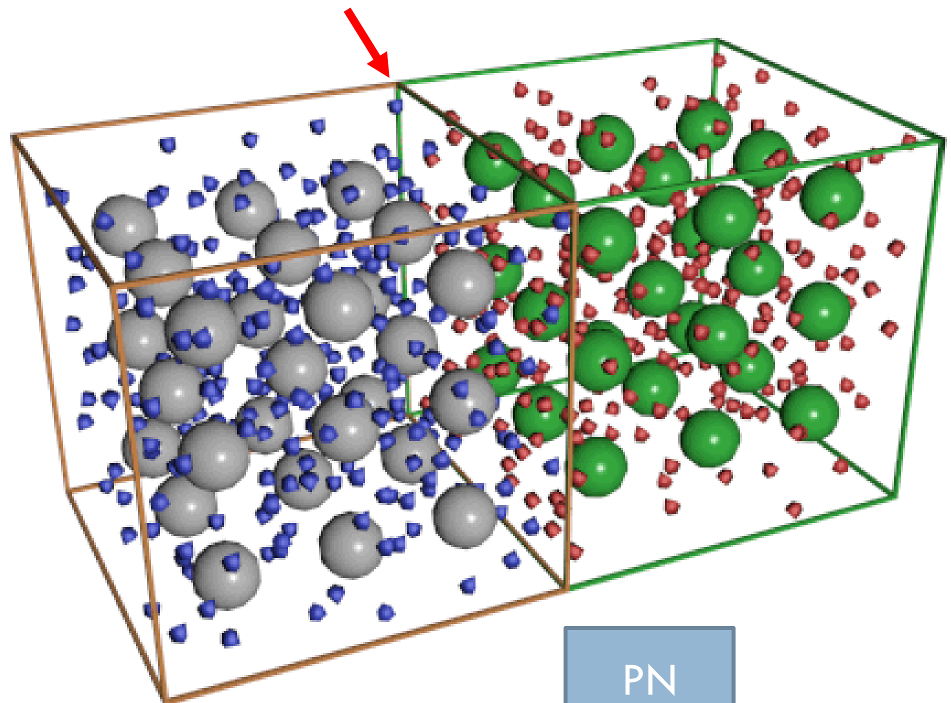
Acceptor +
Sarcini pozitive
(Goluri)



N

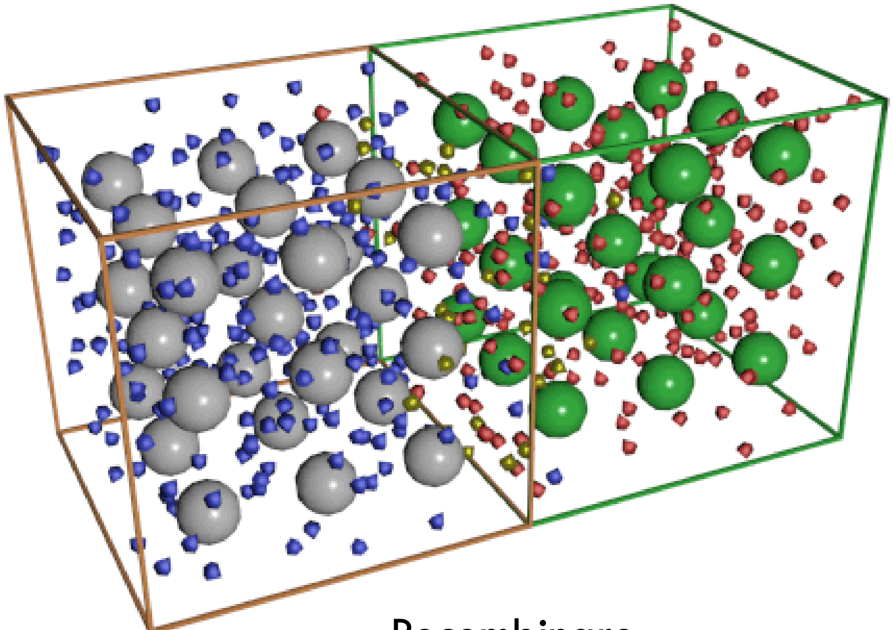
Donor + Sarcini
Negative
(Electroni)

Jonctiune PN



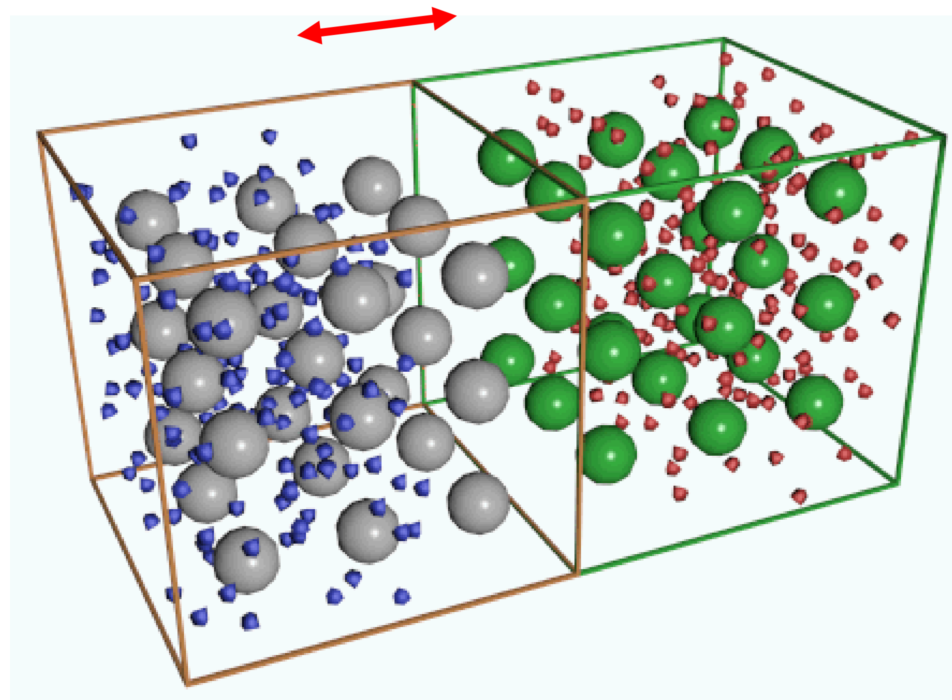
PN

Dispozitive semiconductoare

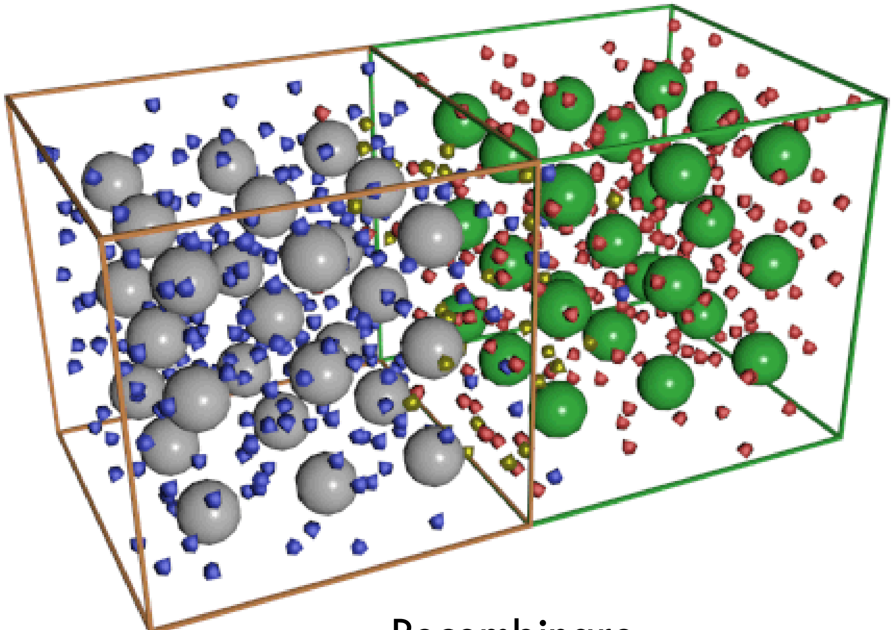


Recombinare
Goluri/Electroni

Zonă neutră, Crearea
Barierei de Potențial

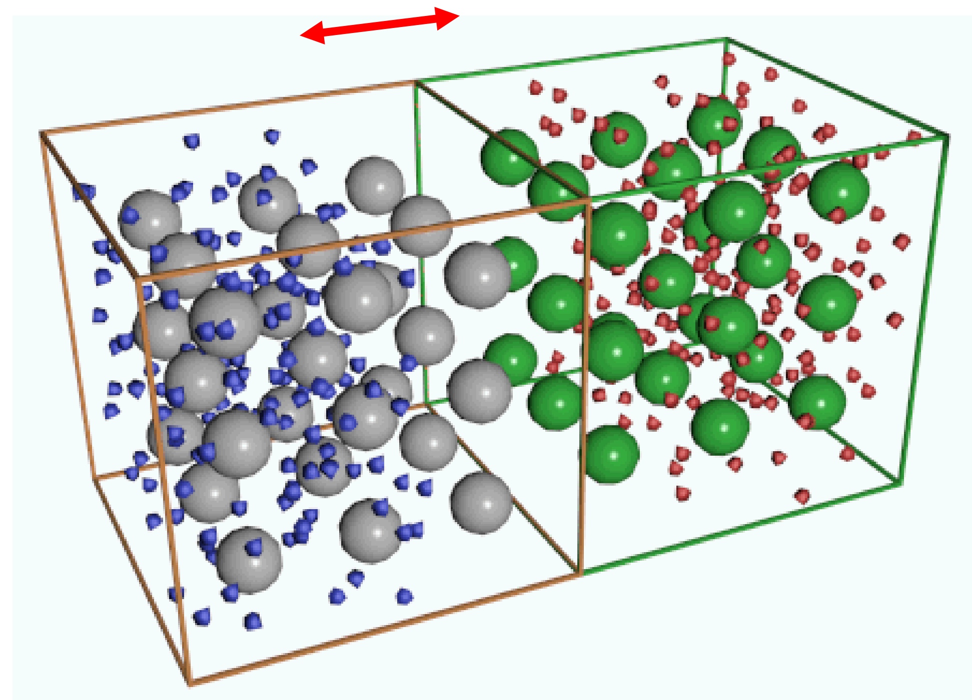


Dispozitive semiconductoare

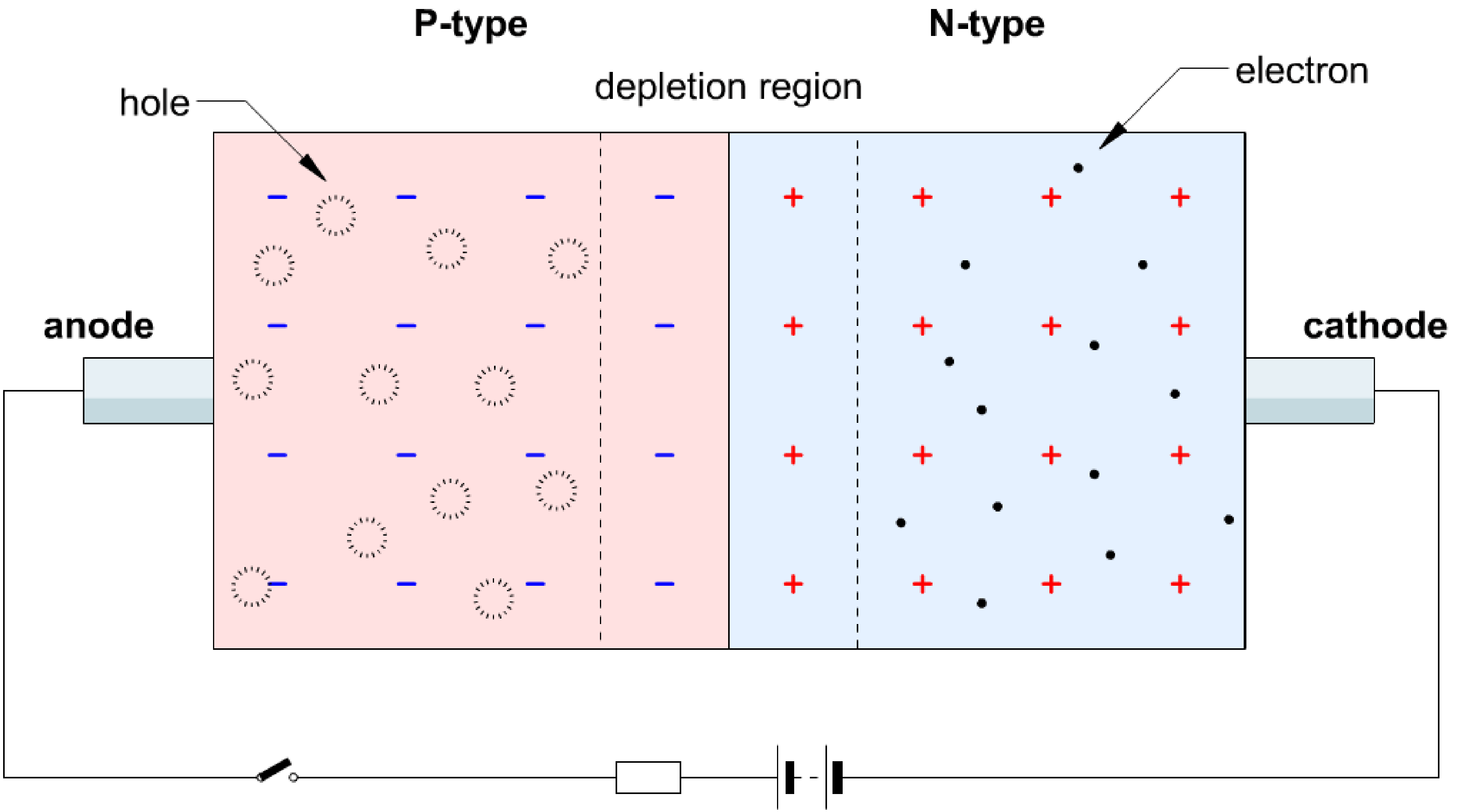


Recombinare
Goluri/Electroni

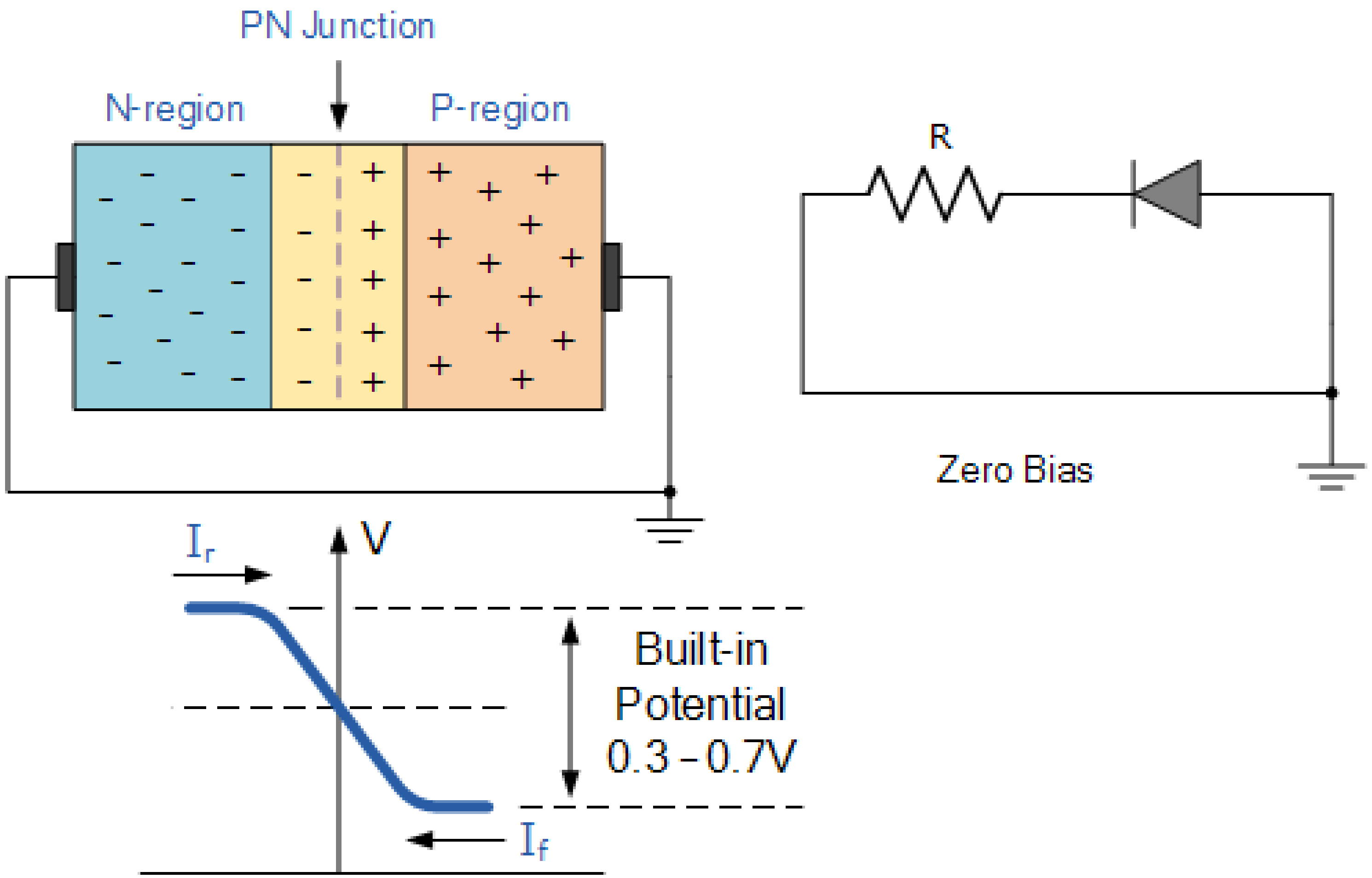
Zonă neutră, Crearea
Barierei de Potențial



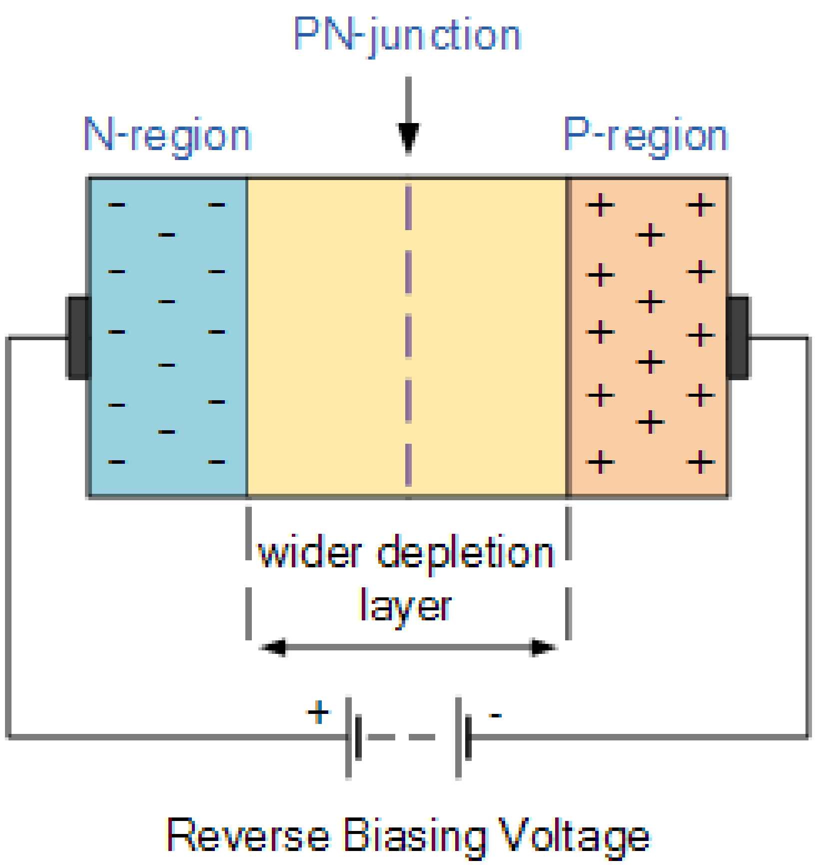
Dispozitive semiconductoare

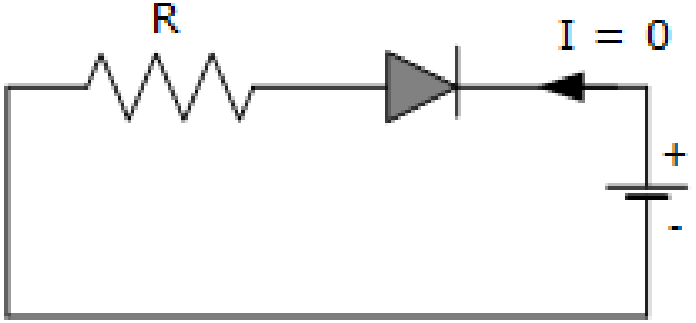


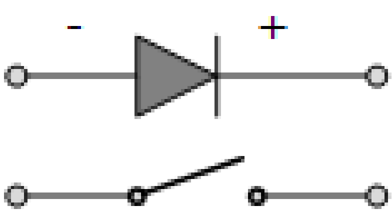
Dispozitive semiconductoare

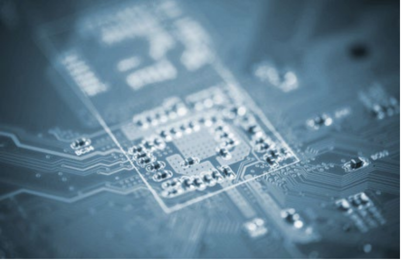


Dispozitive semiconductoare

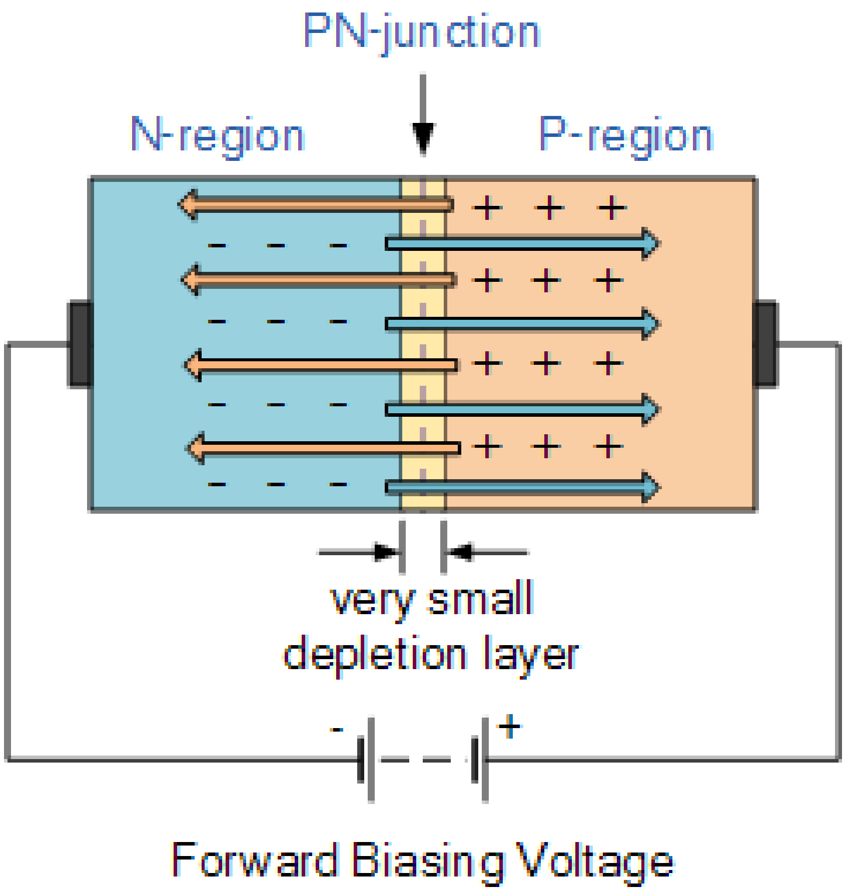


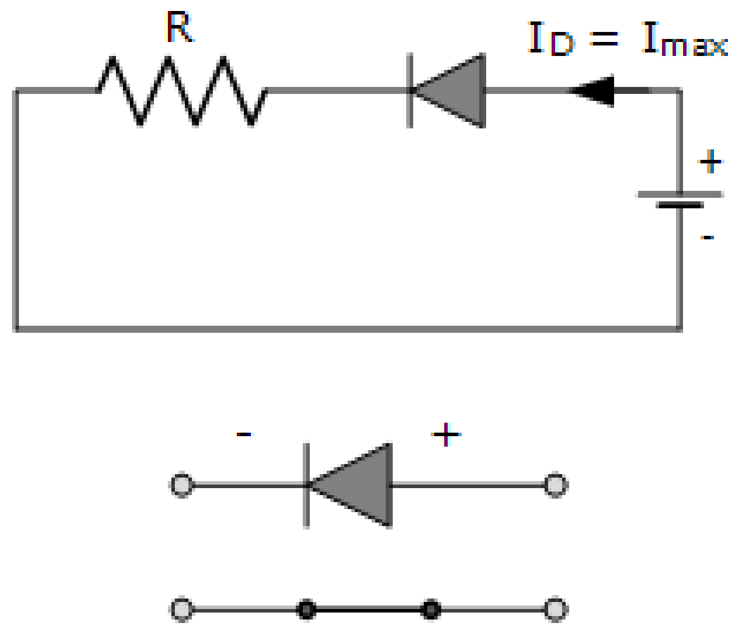


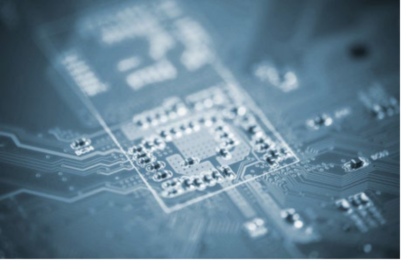




Dispozitive semiconductoare

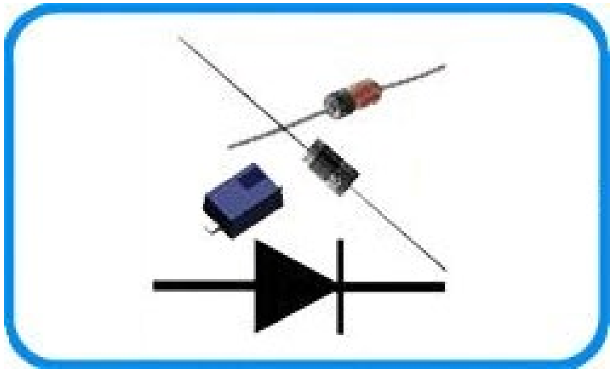




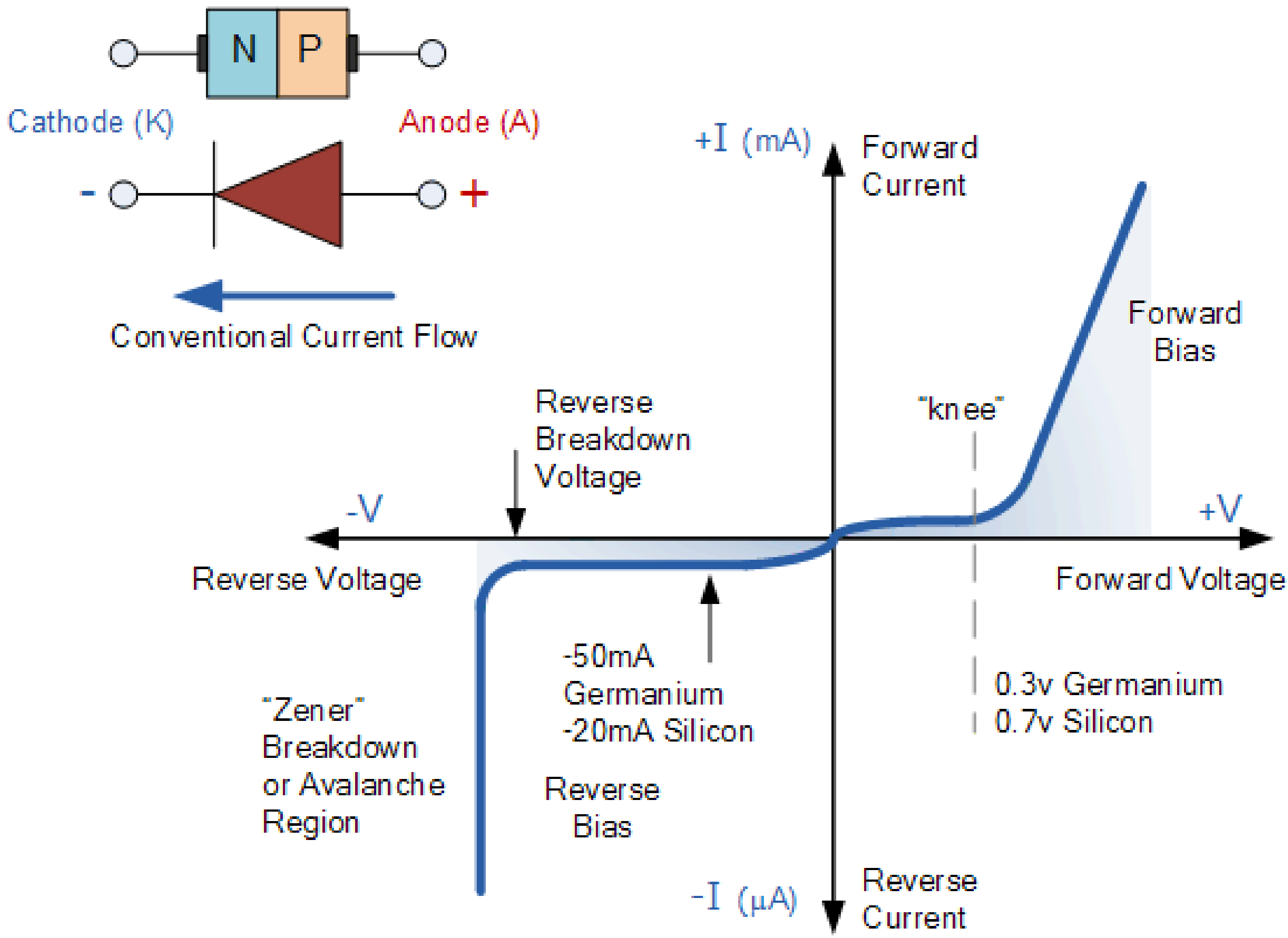


Diode semiconductoare

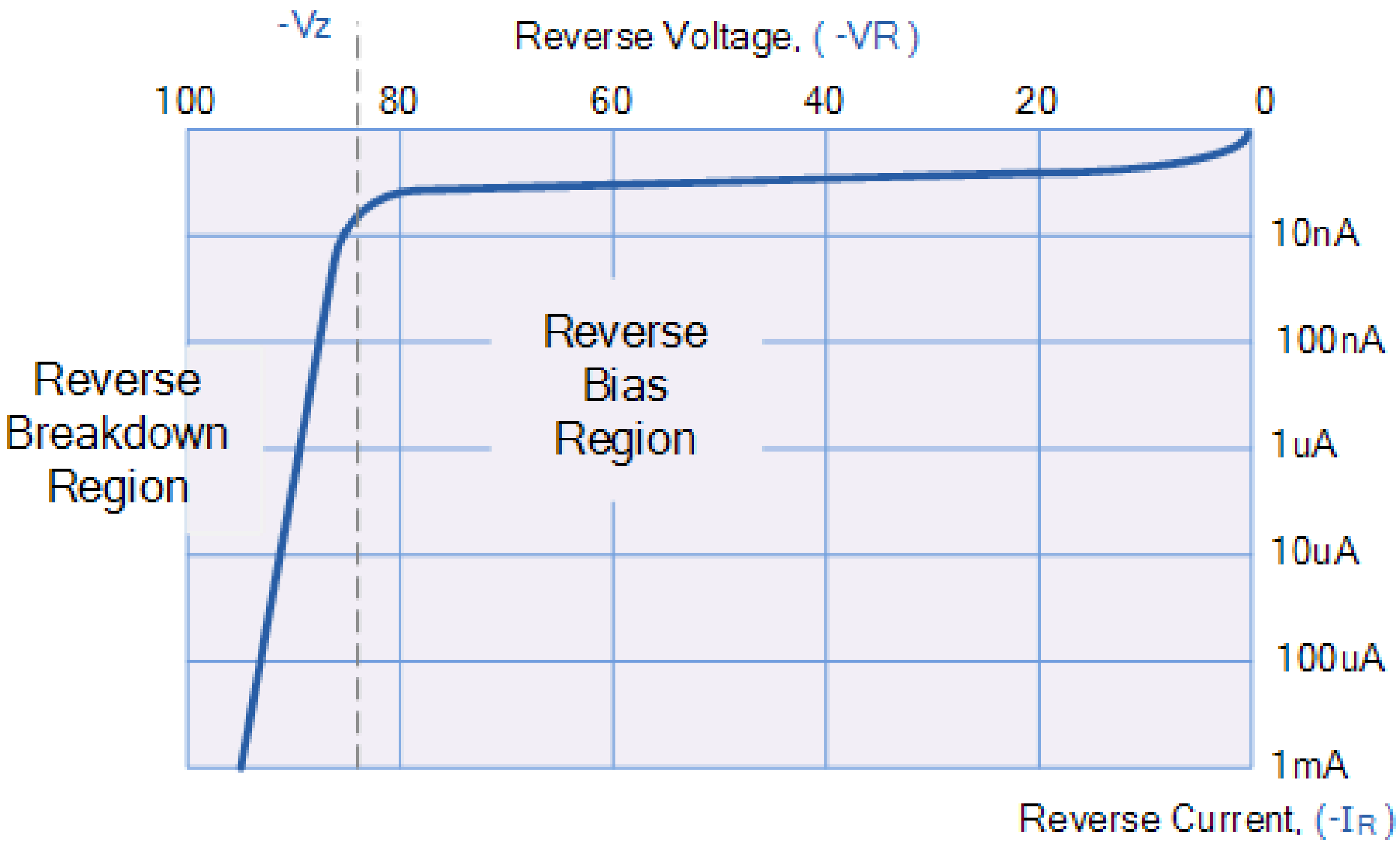
- **Tipuri de diode:**
  - diode redresoare
  - diode de detectie
  - diode de comutatie
  - diode varicap
  - diode stabilizatoare
  - diode tunel
  - diode Schottky
  - diode LED
  - fotodiode



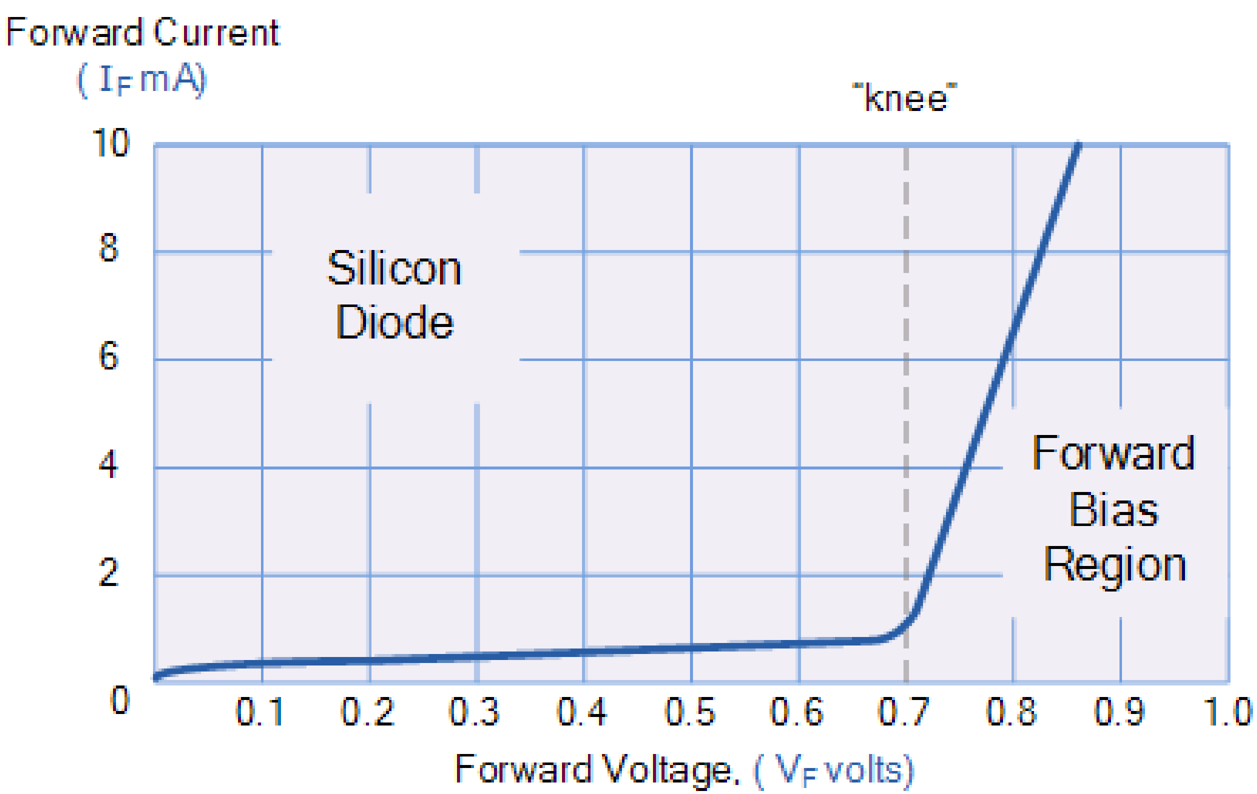
Dispozitive semiconductoare

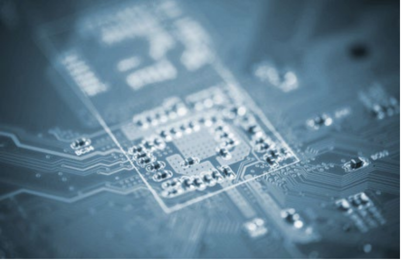


Dispozitive semiconductoare



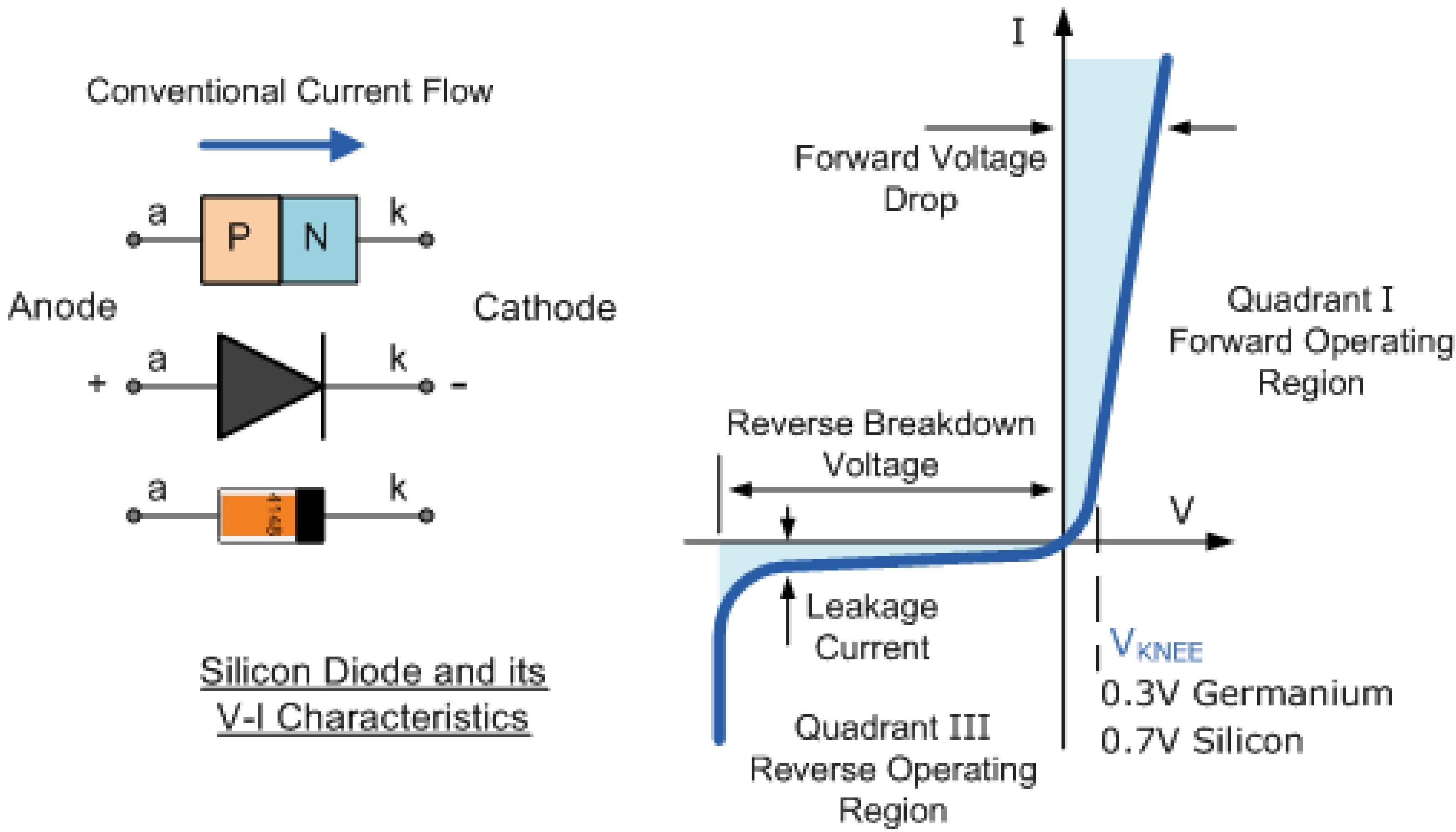
Dispozitive semiconductoare





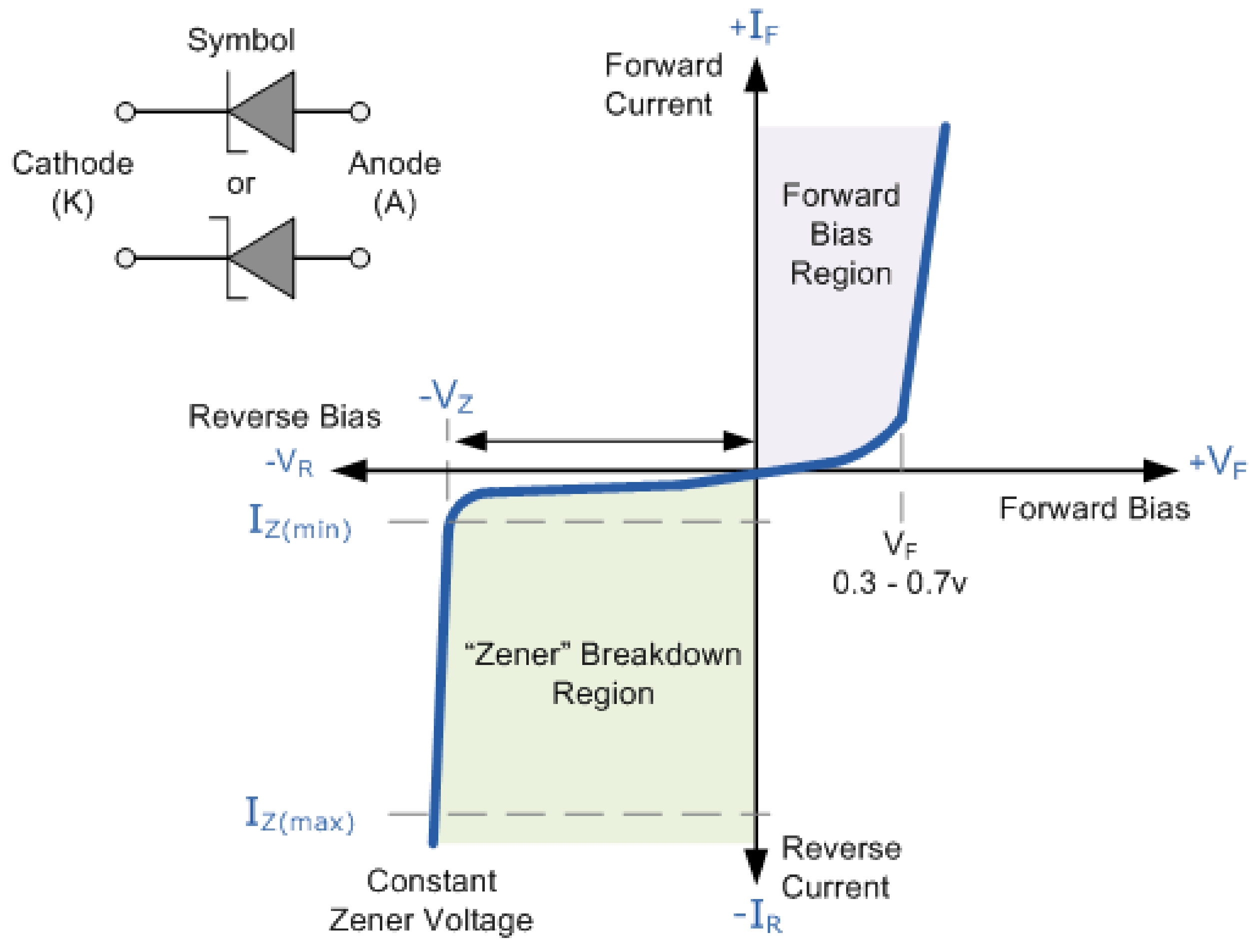
Dispozitive semiconductoare

- Diodă de semnal



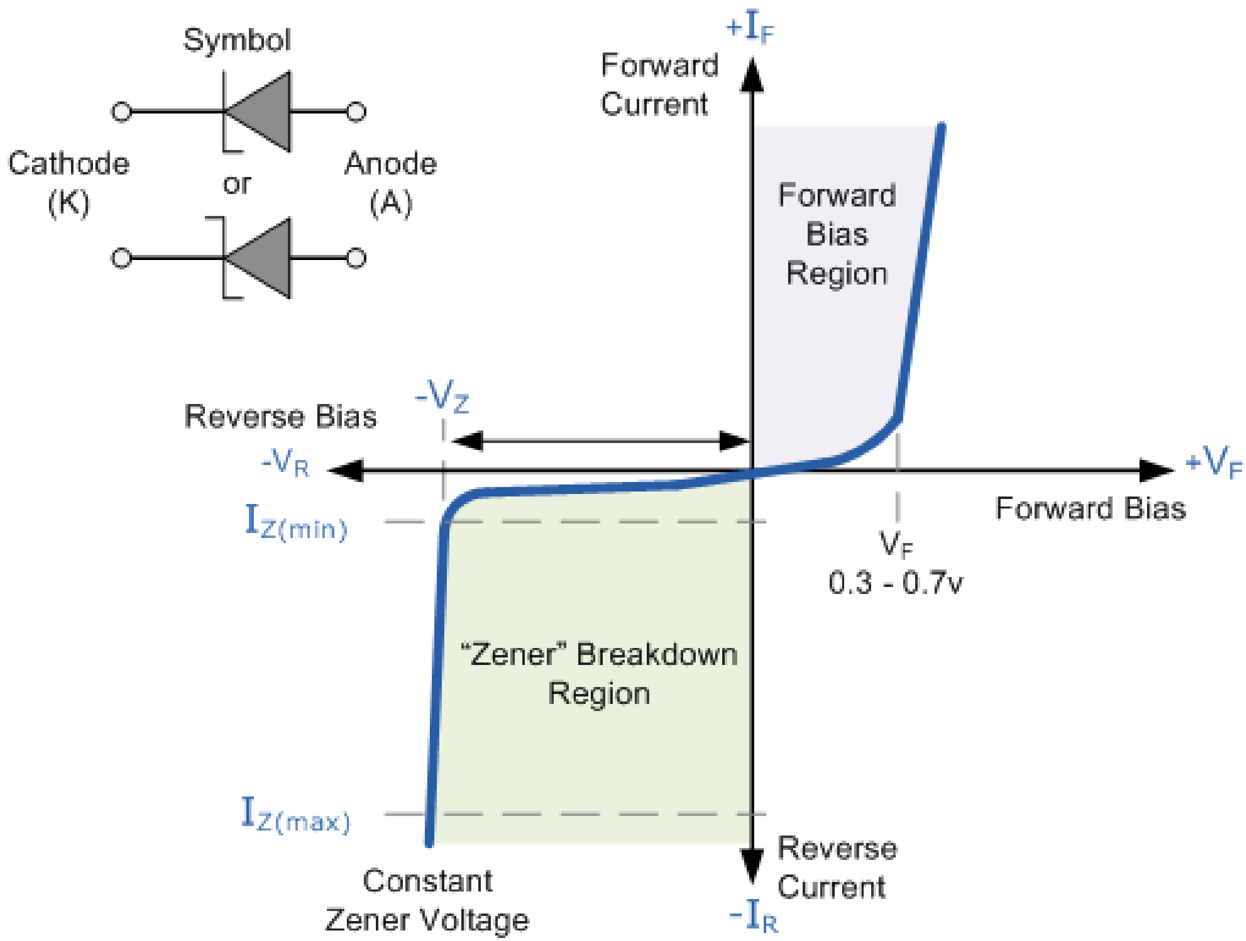
Dispozitive semiconductoare

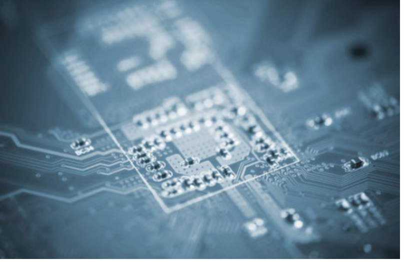
- Dioda Zener – Demonstatie functionare cadran III



Dispozitive semiconductoare

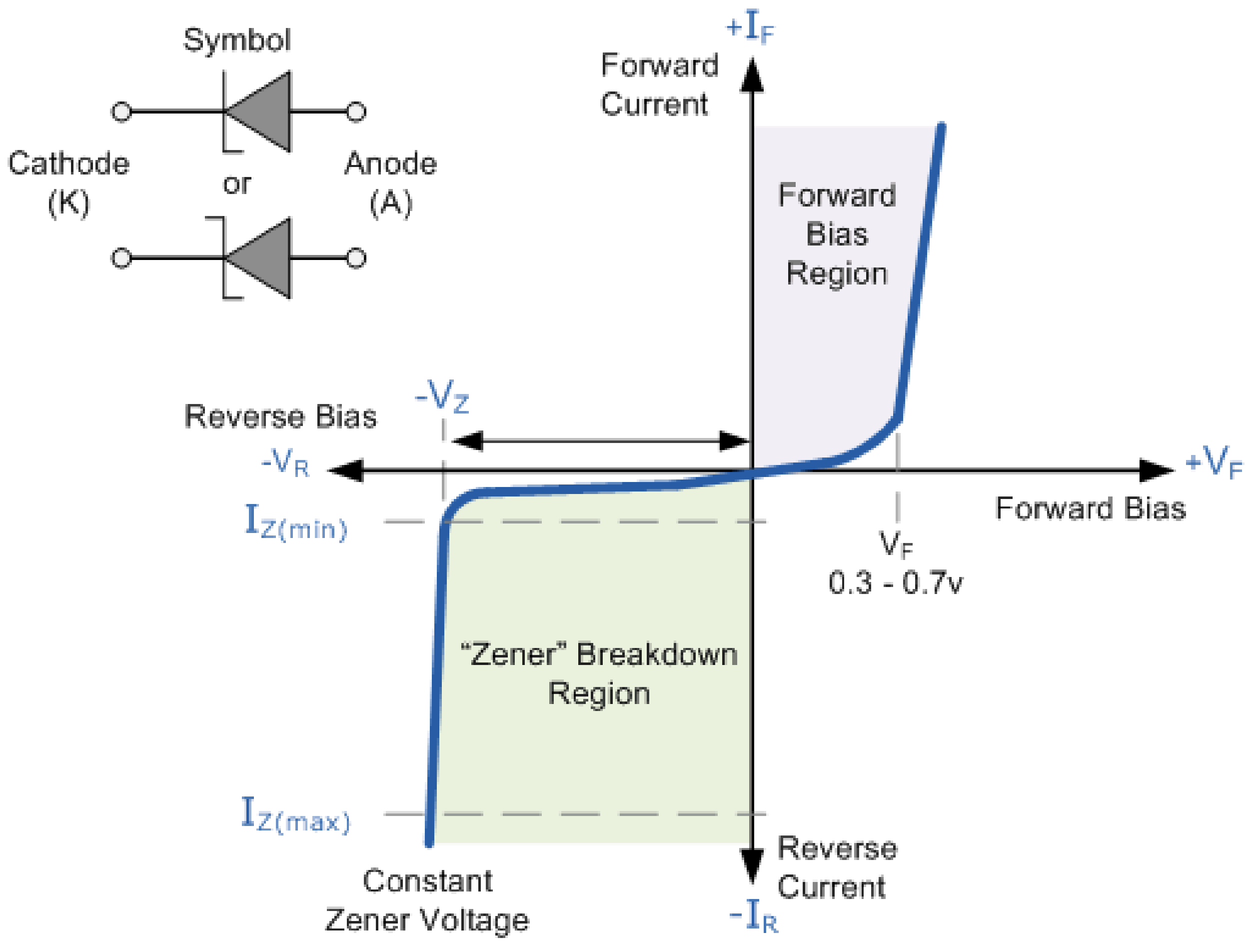
- Dioda Zener – Demonstatie functionare cadran III





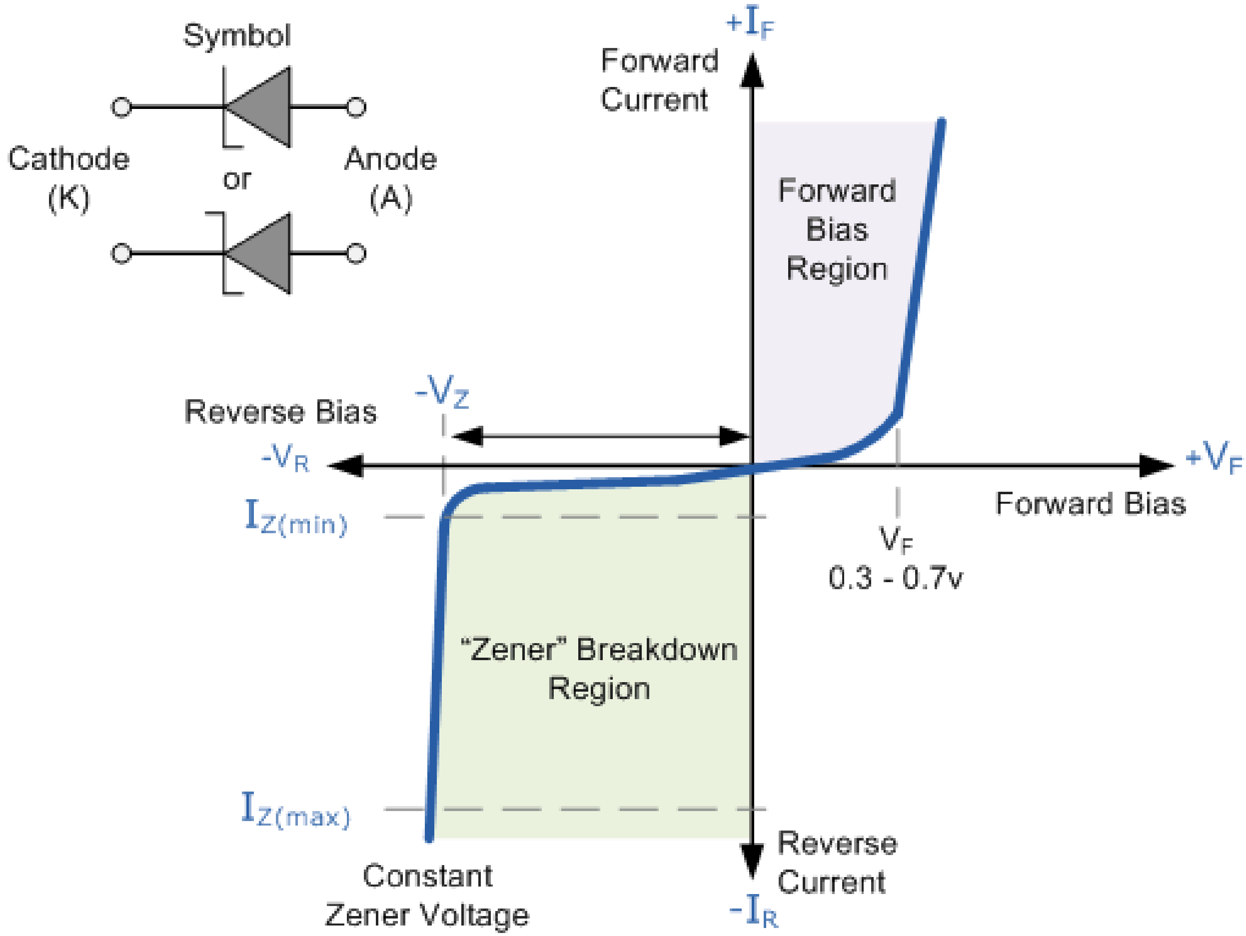
Dispozitive semiconductoare

- Dioda Zener – Demonstatie functionare cadran III



Dispozitive semiconductoare

- Dioda Zener – Demonstatie functionare cadran III

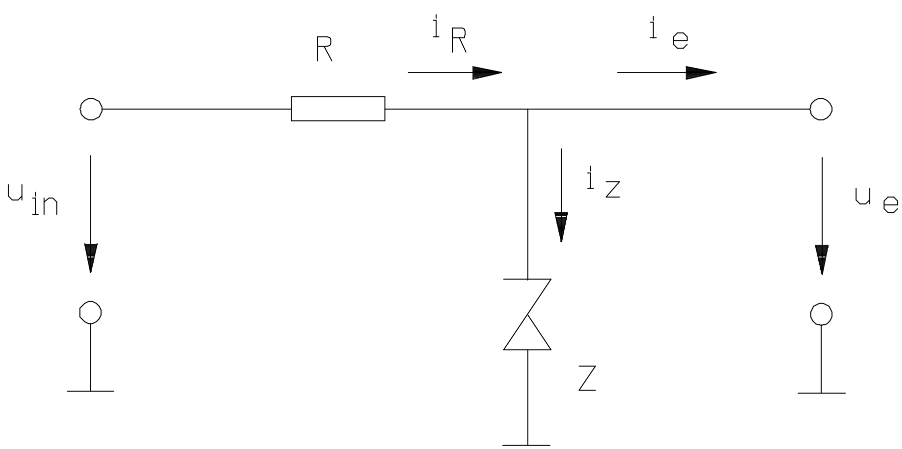


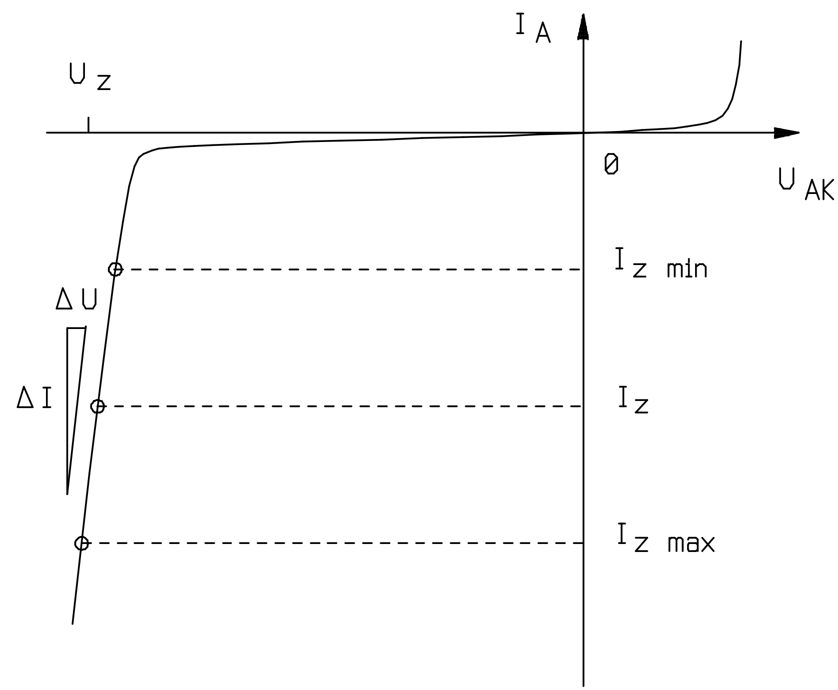
Circuite simple cu diode

- Circuite de prestabilizare
- Redresoare simple
- Circuite de multiplicare a tensiunii
- etc

Circuite simple cu diode

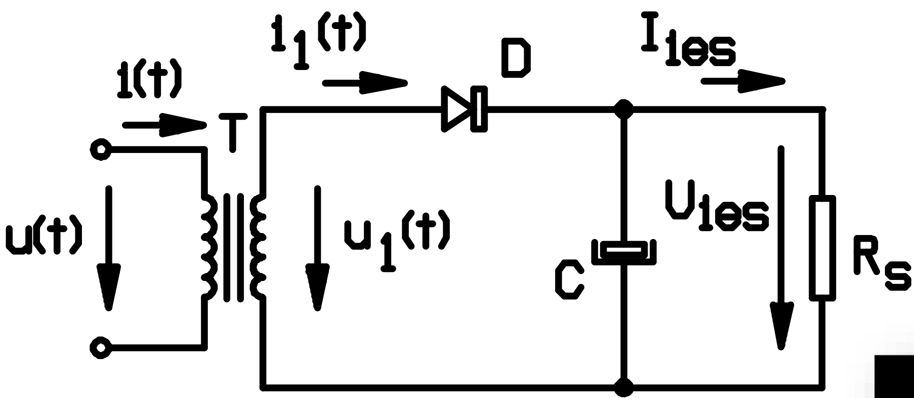
- Prestabilizator simplu cu dioda Zener

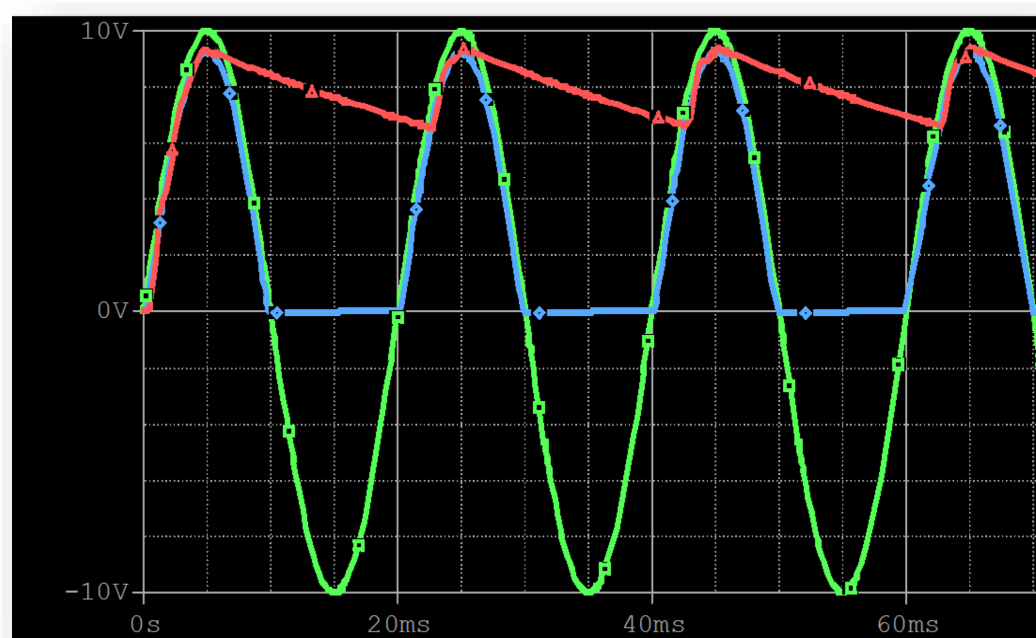




Circuite simple cu diode

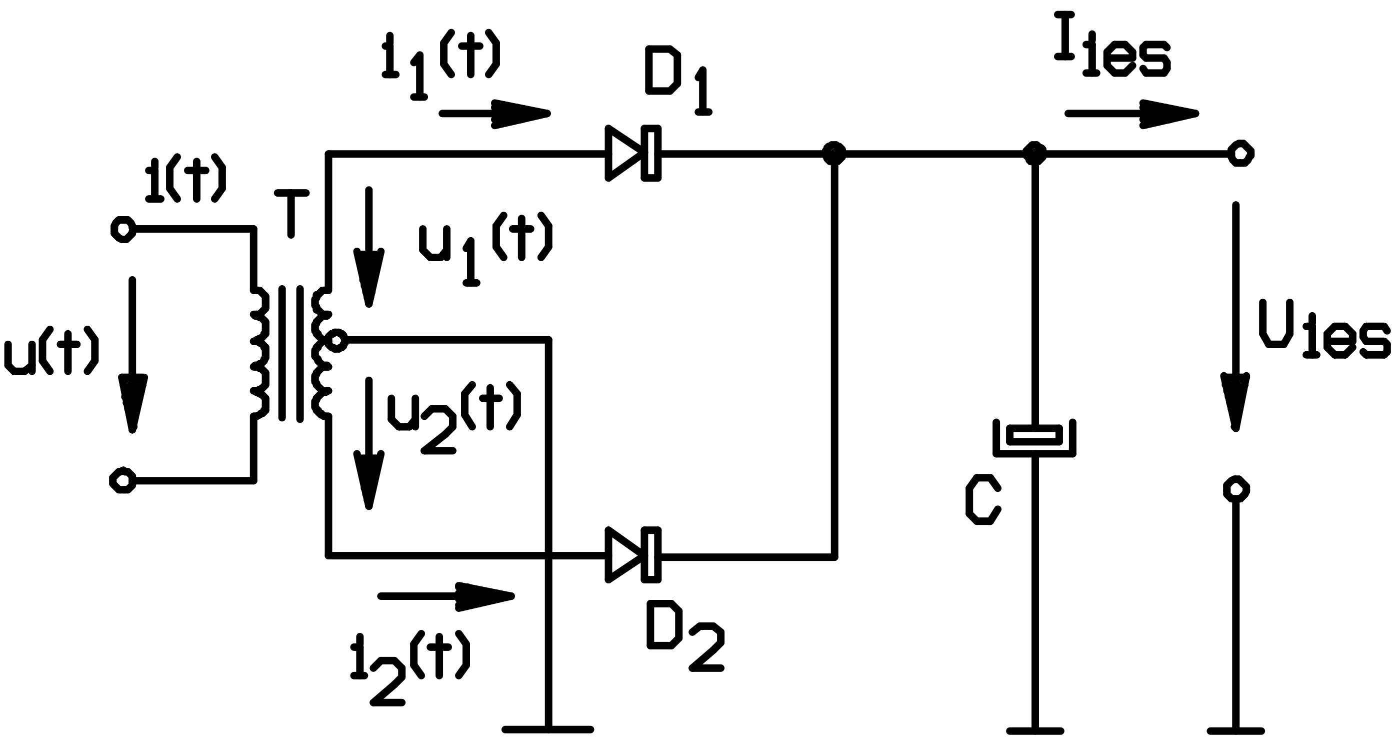
- Redresorul monofazat monoalternanta





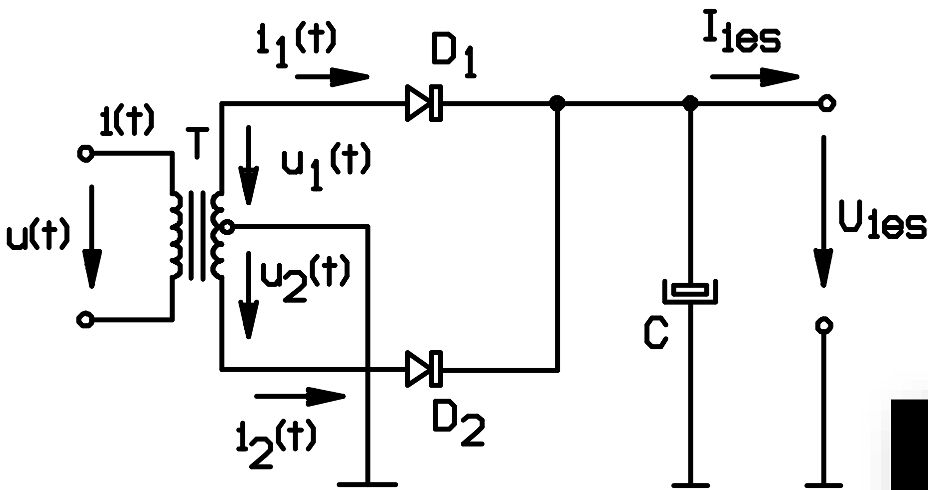
Circuite simple cu diode

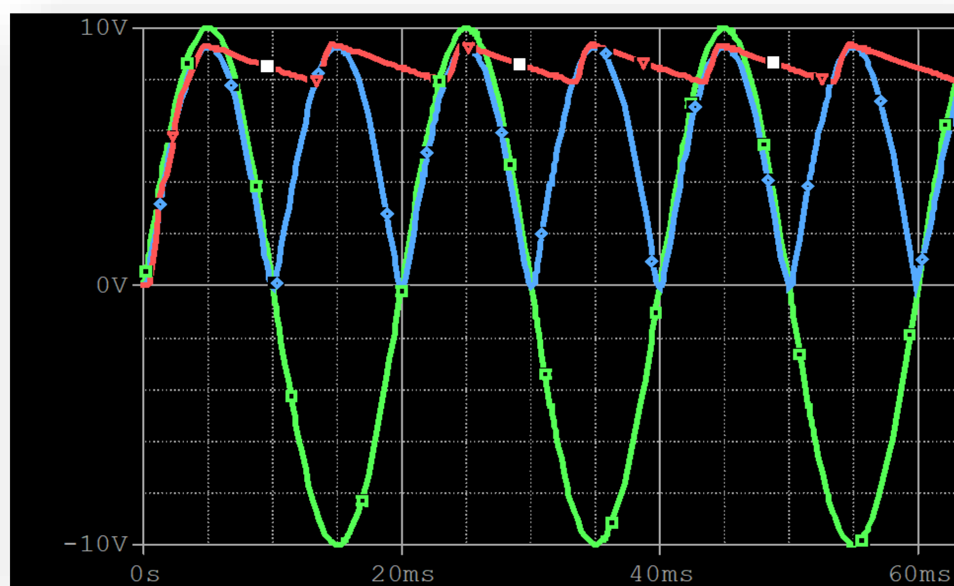
- Redresorul monofazat cu nul. Redresor dubla alternanta



Circuite simple cu diode

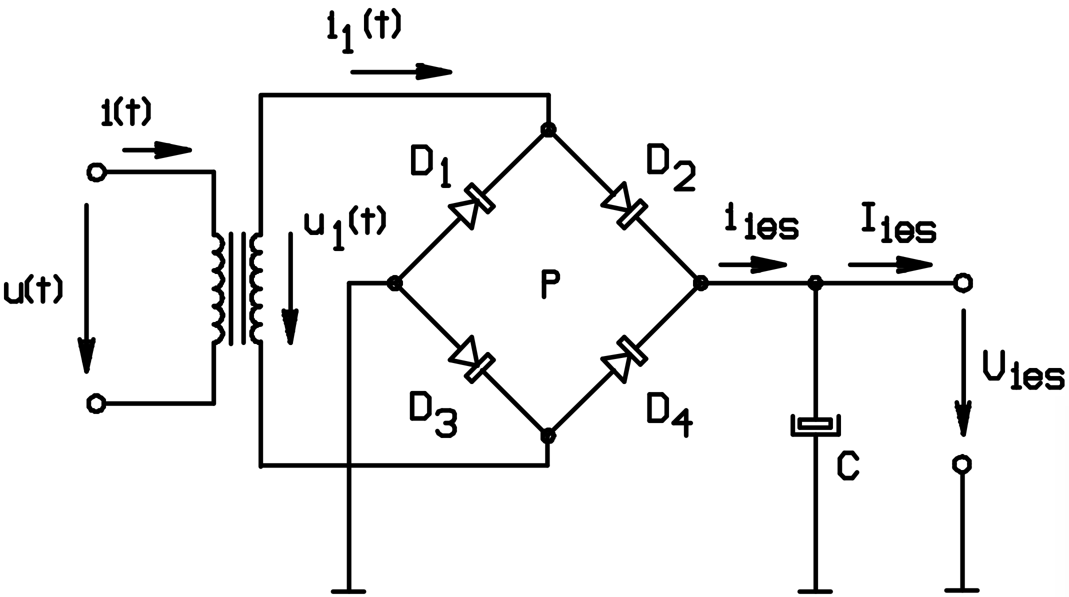
- Redresorul monofazat cu nul. Redresor dubla alternanta

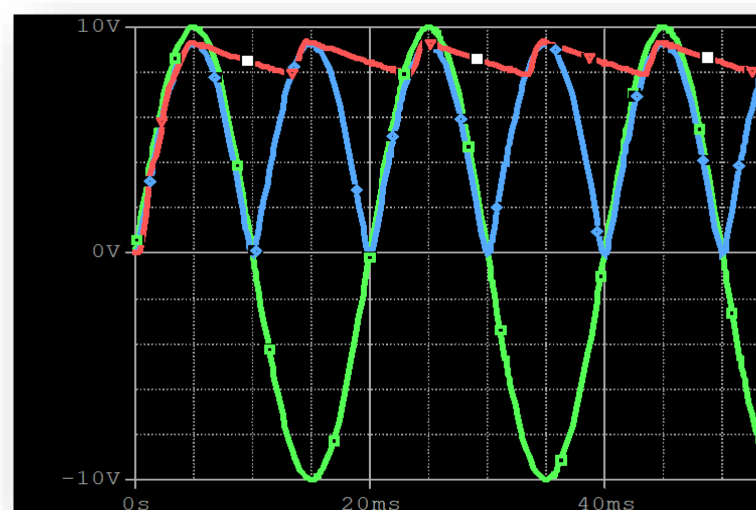




Circuite simple cu diode

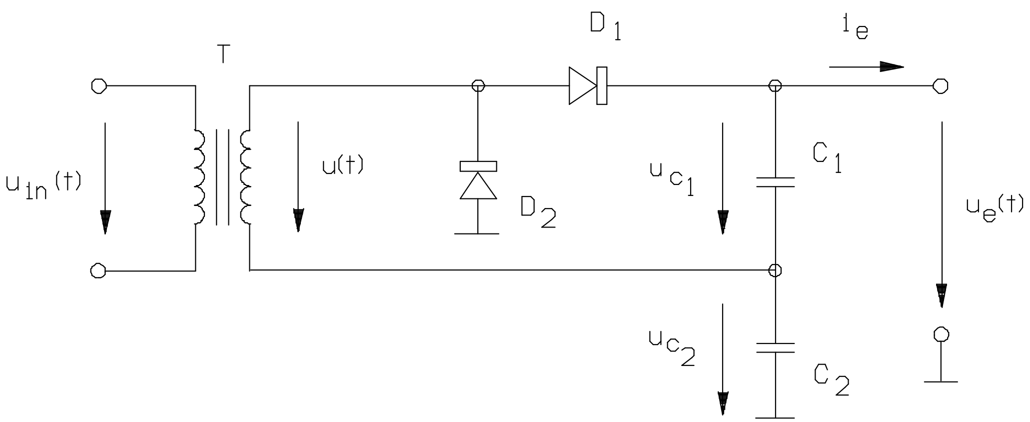
- Redresorul monofazat in punte. Puntea Graetz. Redresor dubla alternanta.

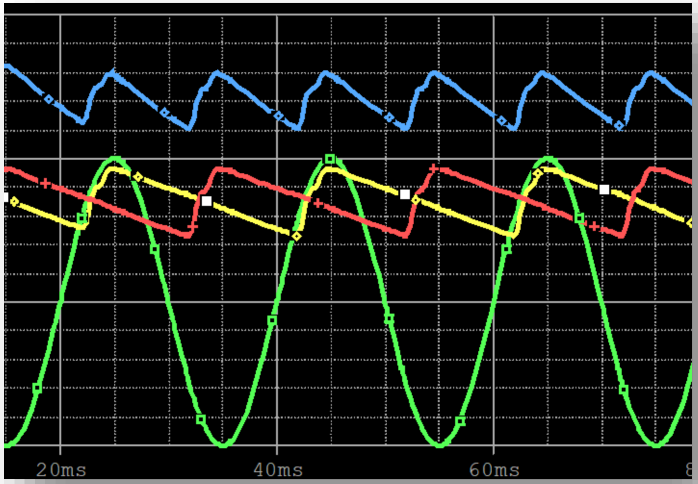




Circuite simple cu diode

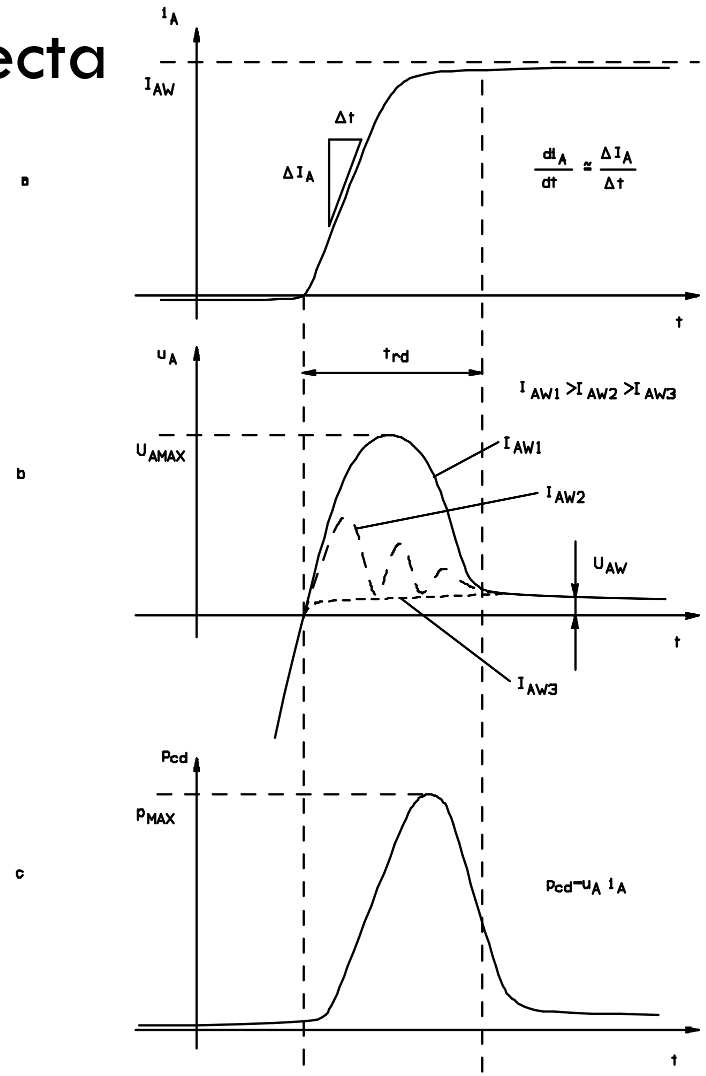
- Circuitul dublor de tensiune de tip Greinacher-Delon





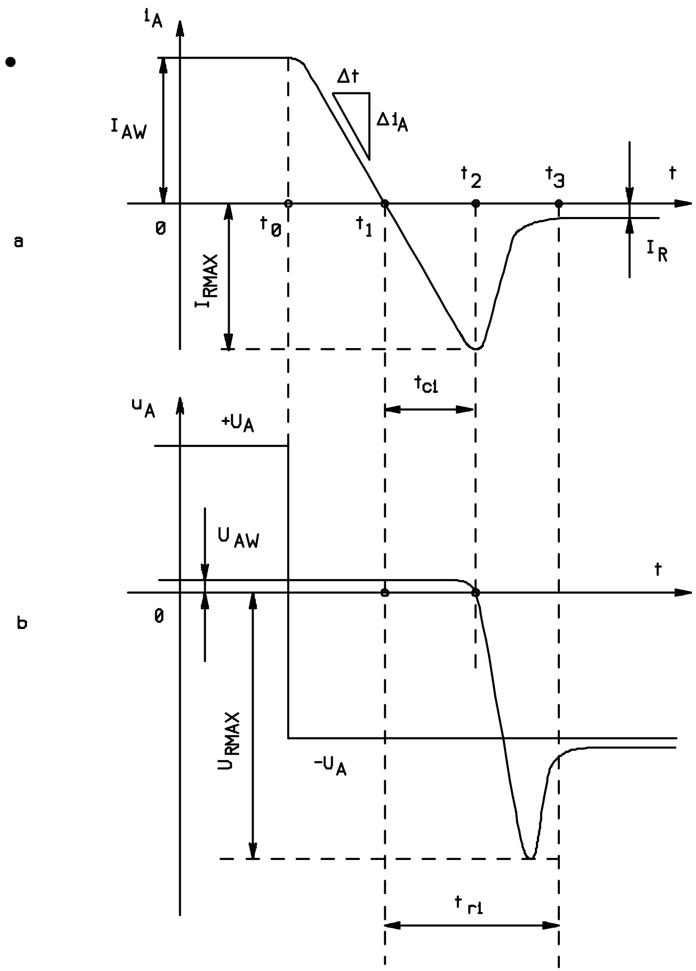
Comutatia la diode

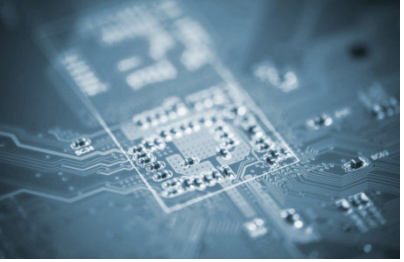
- Comutatia directa



Comutatia la diode

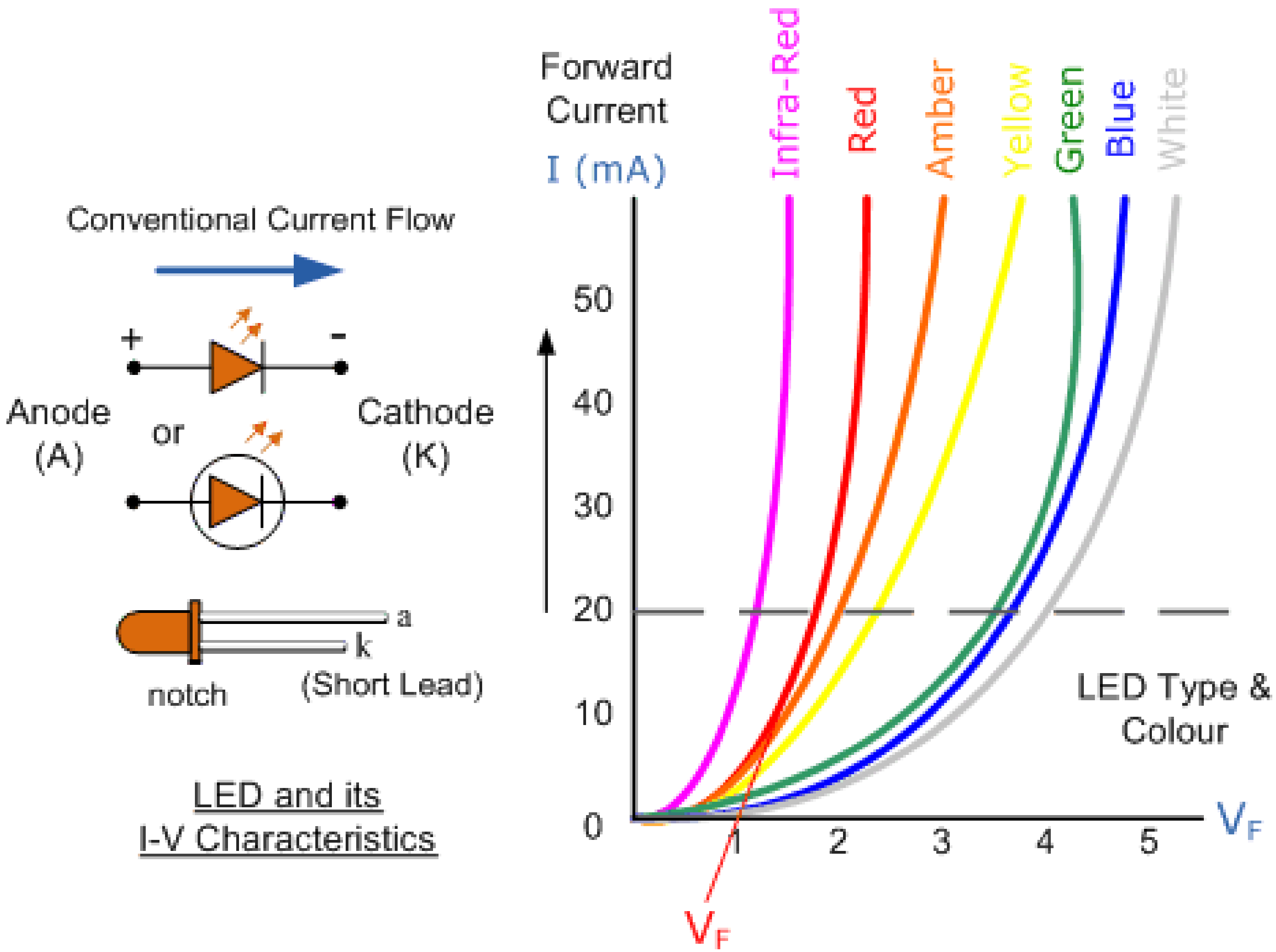
- Caracteristicile dinamice la revenirea inversa a diodelor redresoare.

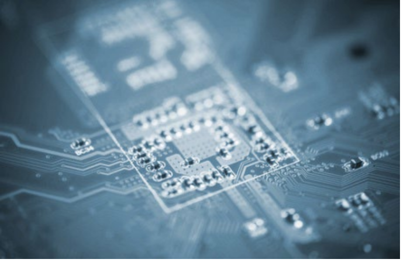




Dispozitive semiconductoare

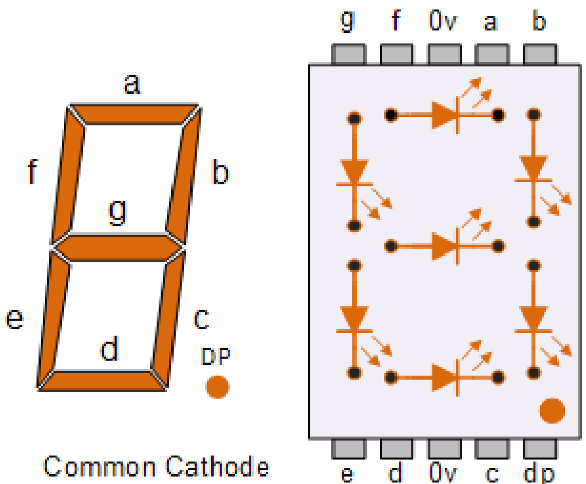
- LED



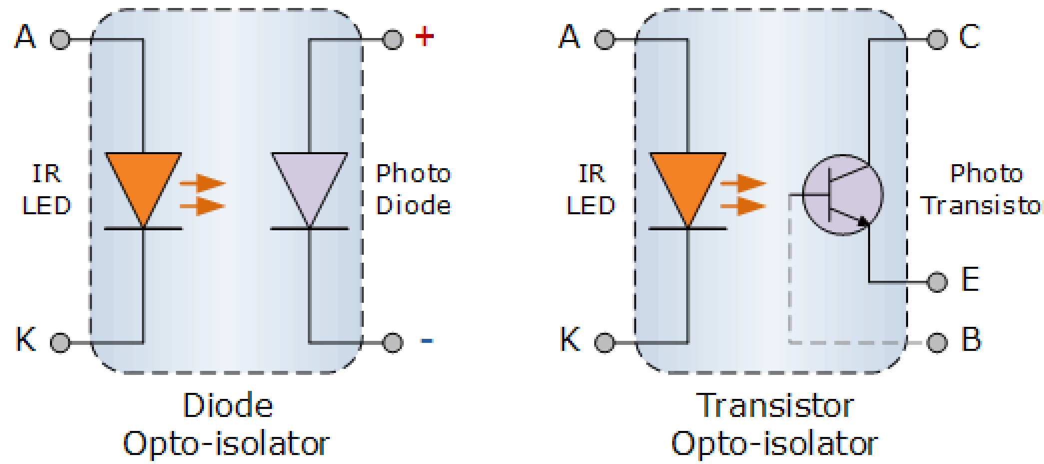


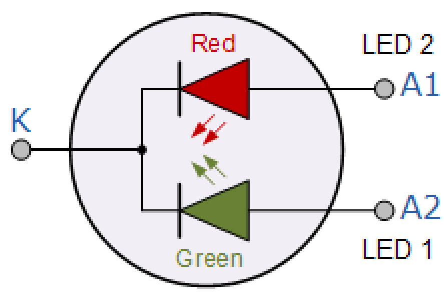
Dispozitive semiconductoare

- LED

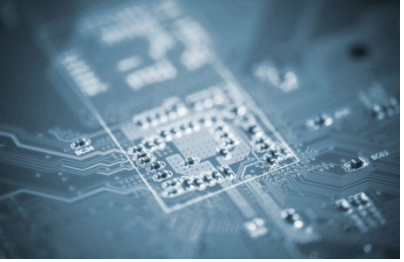


Common Cathode Display



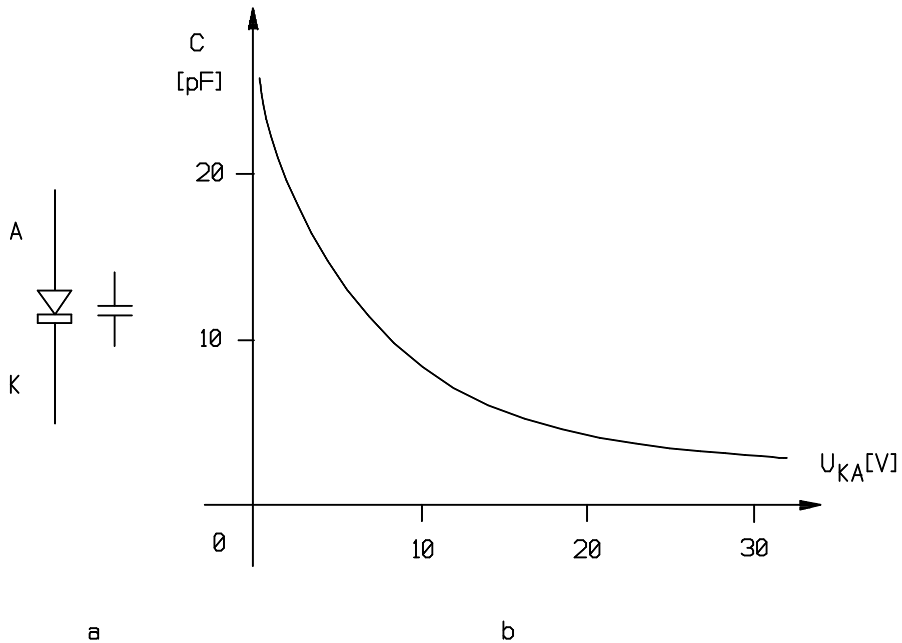


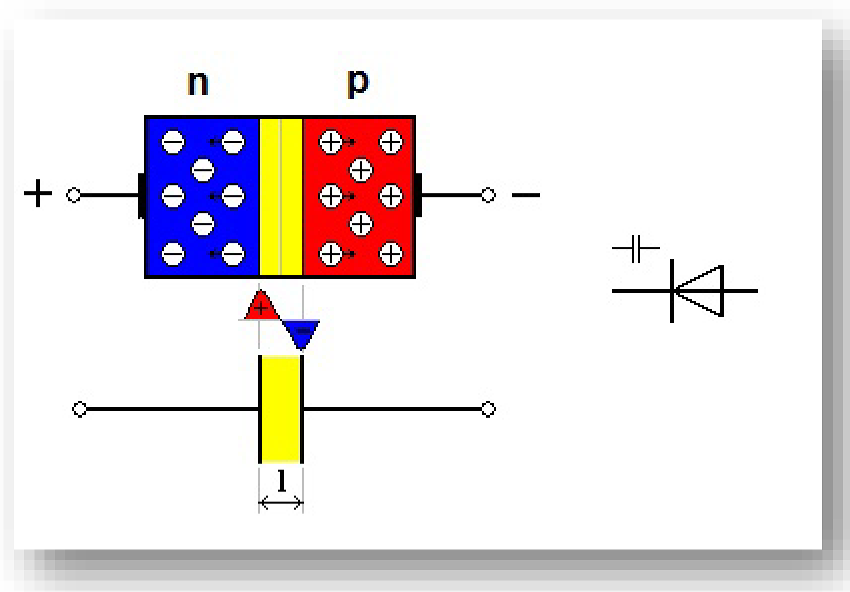
utput Colour	Red	Orange	Yellow	Green
LED 1 Current	0	5mA	9.5mA	15mA
LED 2 Current	10mA	6.5mA	3.5mA	0

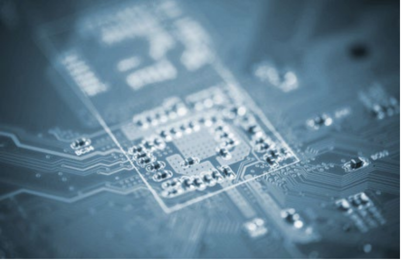


Diode semiconductoare

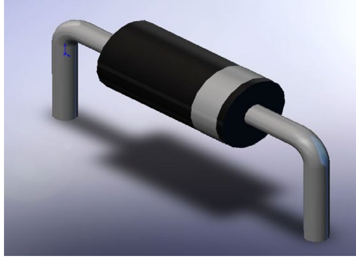
- Diode varicap. Simbolizare si caracteristica de iesire,
  - C = C(Ur). Aplicatie a jonctiunii p+n

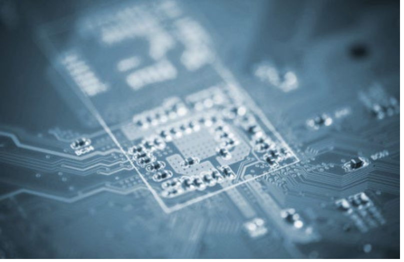






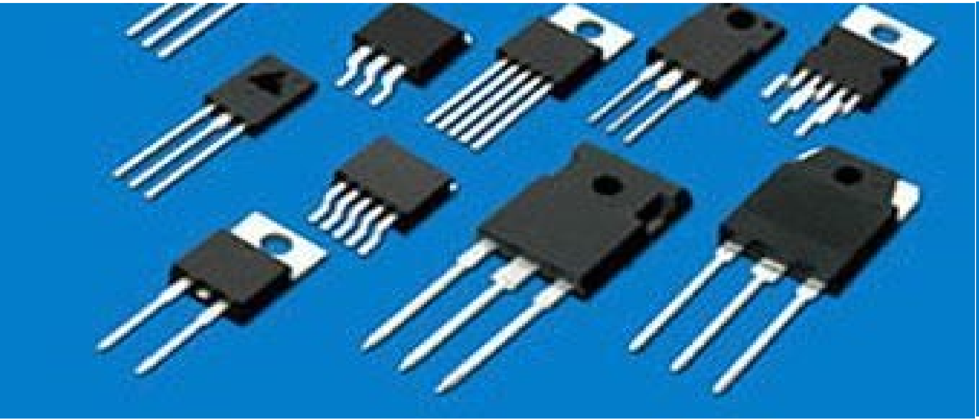
Diode semiconductoare

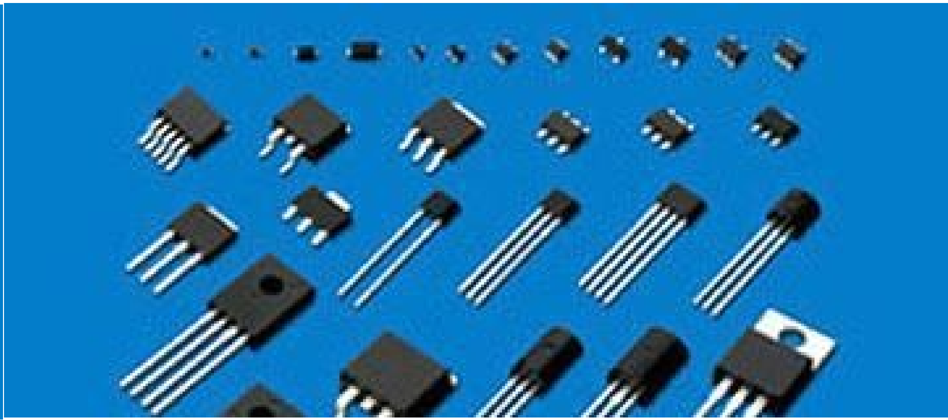


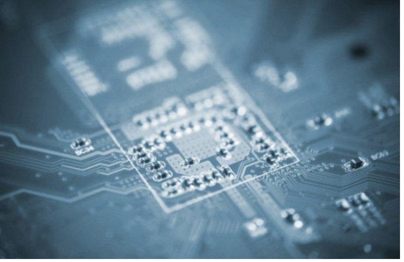


Tranzitoare bipolare

- Ce este un tranzistor ?
  - Un dispozitiv electronic cu care se pot amplifica sau conecta semnale electrice.
- Ce fel de tranzistoare gasim ?
  - Pe substrat de germaniu sau de siliciu. De tip NPN sau PNP !
- De ce bipolare?
  - Pentru ca conductia curentului electric in diferitele zone ale dispozitivului se face, respectiv, cu electroni sau goluri !

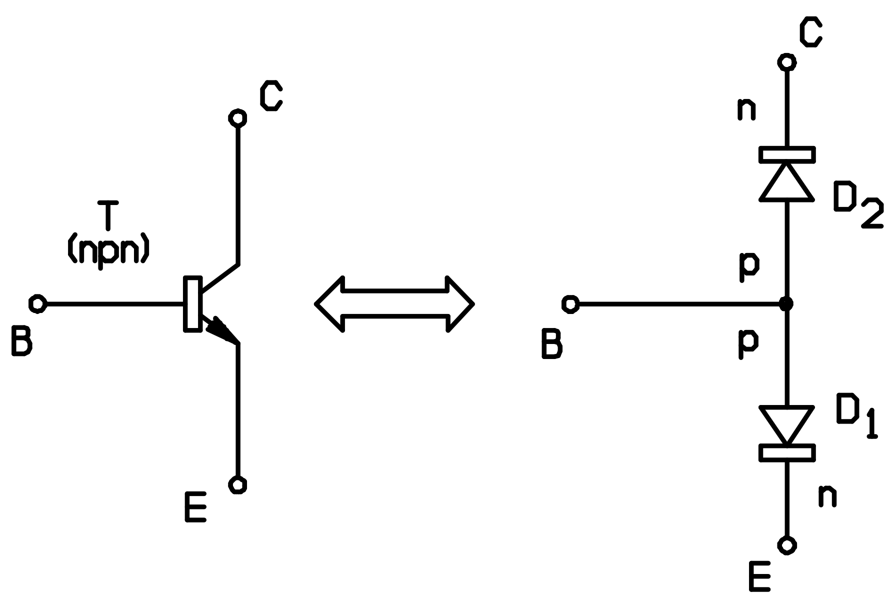






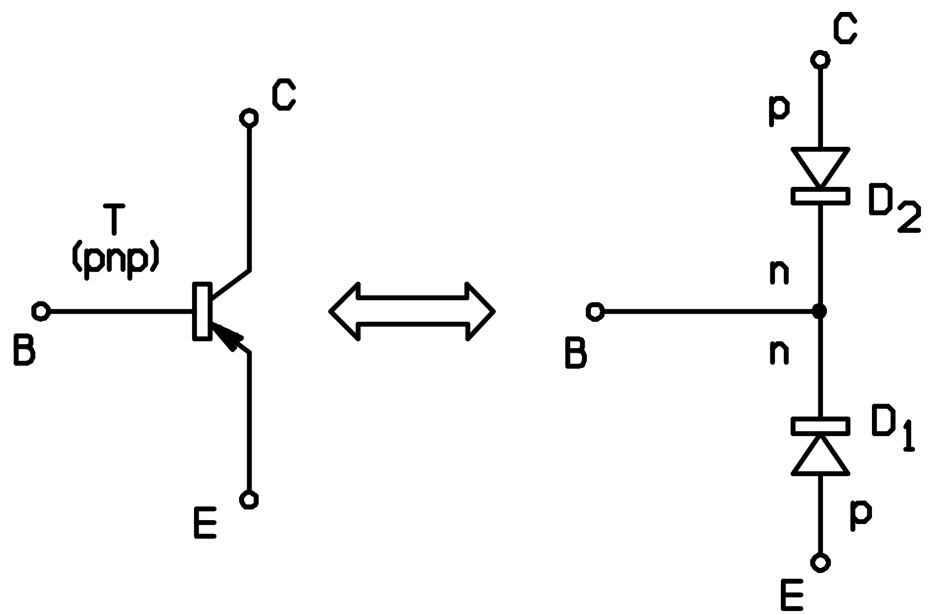
Tranzitoare bipolare

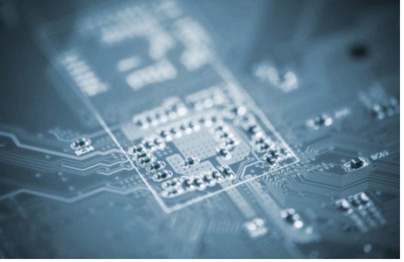
- Simbolul si schema echivalenta cu diode pentru tranzistorul de tip NPN.
- Atentie: schema echivalenta serveste numai pentru retinerea modului de polarizare corecta !



Tranzitoare bipolare

- Simbolul si schema echivalenta pentru tranzistoarele PNP.
- Observatia ramine valabila: schema echivalenta numai pentru intelegerea polarizarii corecte.



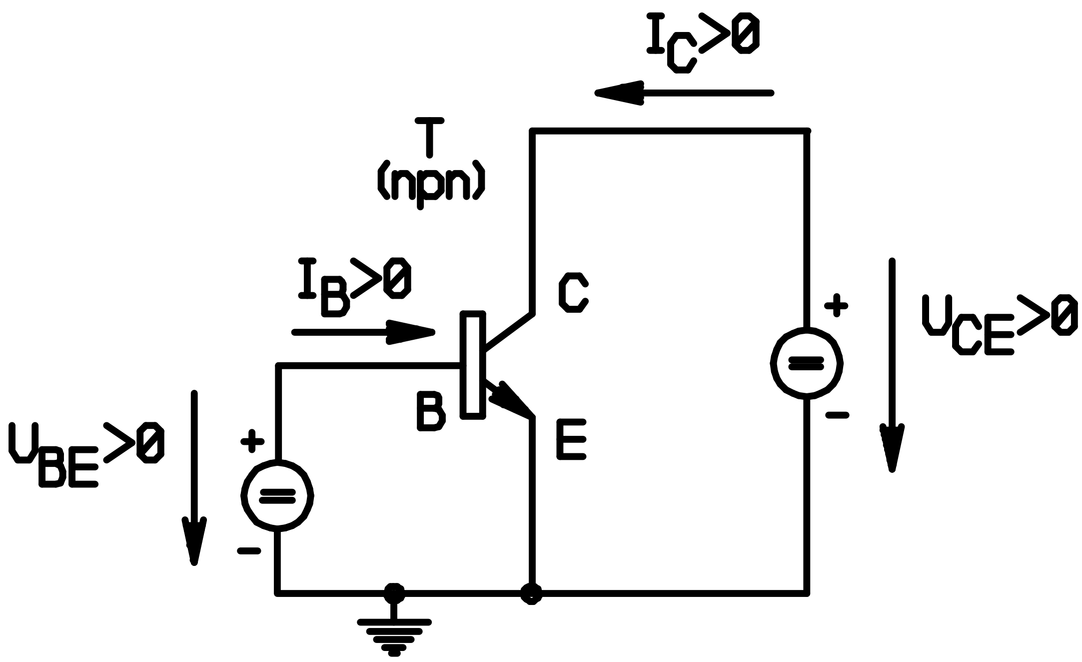


Tranzitoare bipolare

- Ce inseamna polarizare ?
  - Alegerea corecta a semnului si nivelului tensiunilor continue din circuitul de intrare si de iesire !
- Cum se face?
  - Din punctul de vedere al semnului trebuie retinut ca circuitul de intrare, BE, lucreaza la polarizare directa a jonctiunii iar circuitul de iesire, de obicei CE, lucreaza la polarizare inversa a jonctiunii colector-baza.
- Din punctul de vedere al nivelelor: conform catalogului asociat cu dorintele proiectantului
- **CA URMARE:**

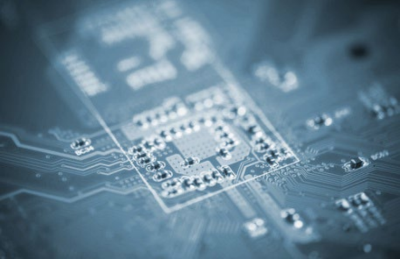
Tranzitoare bipolare

- Polarizarea corecta a unui tranzistor PNP.



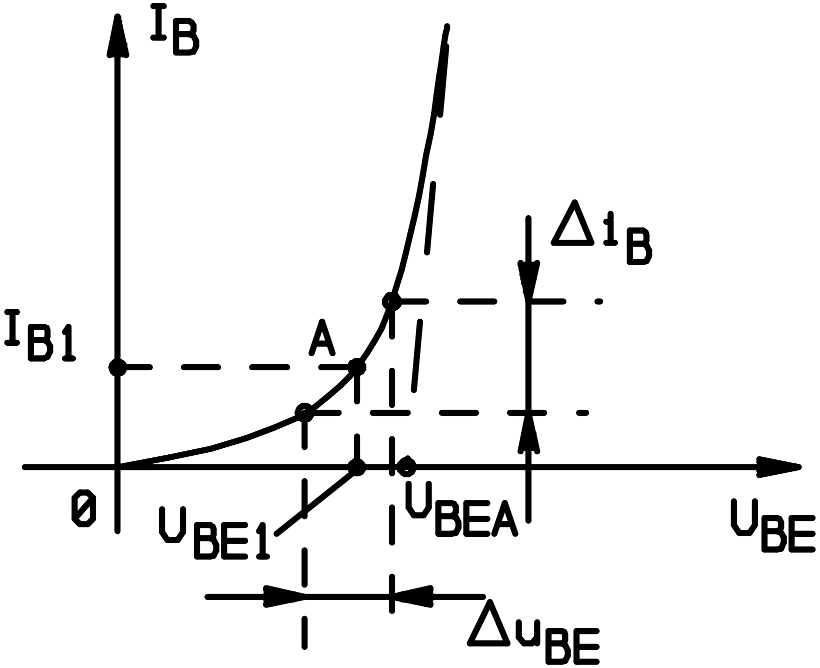
Tranzitoare bipolare

- Dar ce putem face un tranzistor ?
  - **Deocamdata nimic !**
- **Atunci cel putin sa aflam ce proprietate fundamentala are !**
  - **Una singura:**
    - Curentul de colector este un multiplu bine determinat al curentului din circuitul de baza**:** $I_C = \beta I_B$
    - Si sa mai vedem ce caracteristici statice si dinamice are si ce parametri specifici putem defini.



Tranzitoare bipolare

- Caracteristica de intrare a tranzistorului bipolar. Fata de o simpla jonctiune, tensiunea baza-emitor, la curent de baza constant depinde si de tensiunea colector-emitor prin factorul v_r, neglijabil in aplicatiile practice !

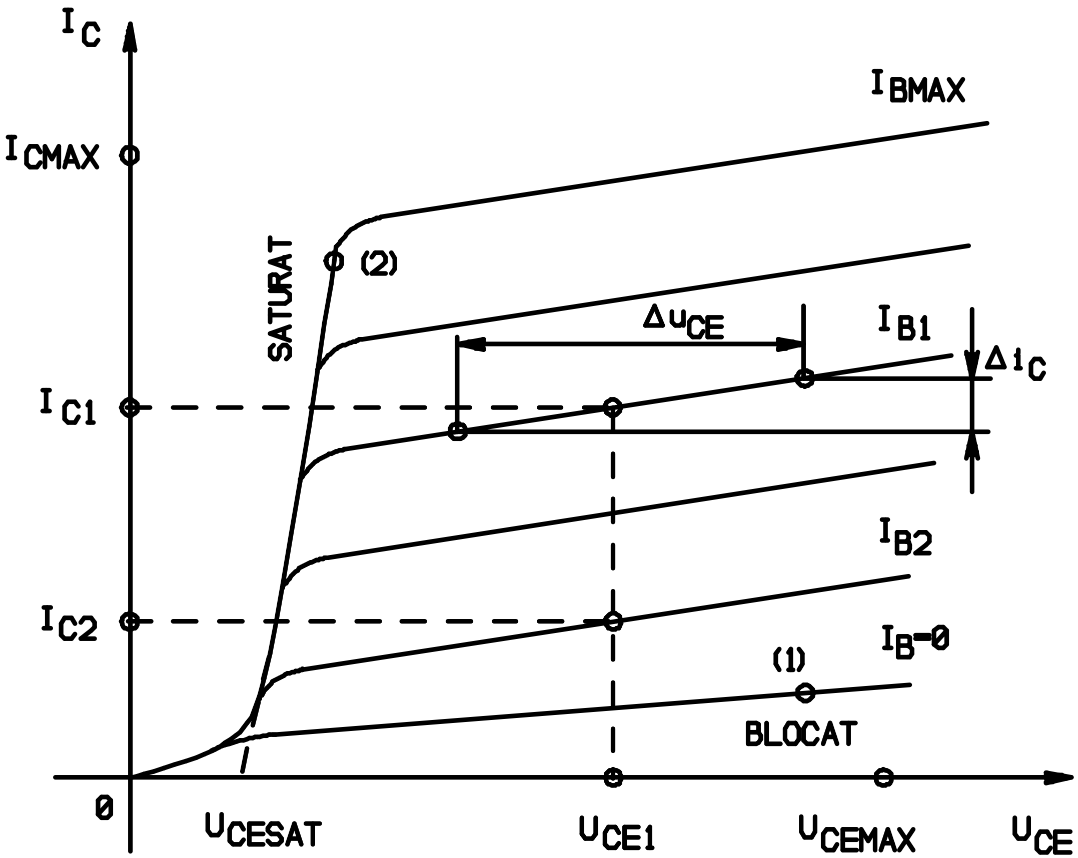


$$R_{BE} = \frac{U_{BE1}}{I_{B1}}$$

$$r_{BE} = \frac{\Delta u_{BE}}{\Delta i_B} = \left[\frac{\partial u_{BE}}{\partial i_B}\right]_{U_{CE} = cst}$$

Tranzitoare bipolare

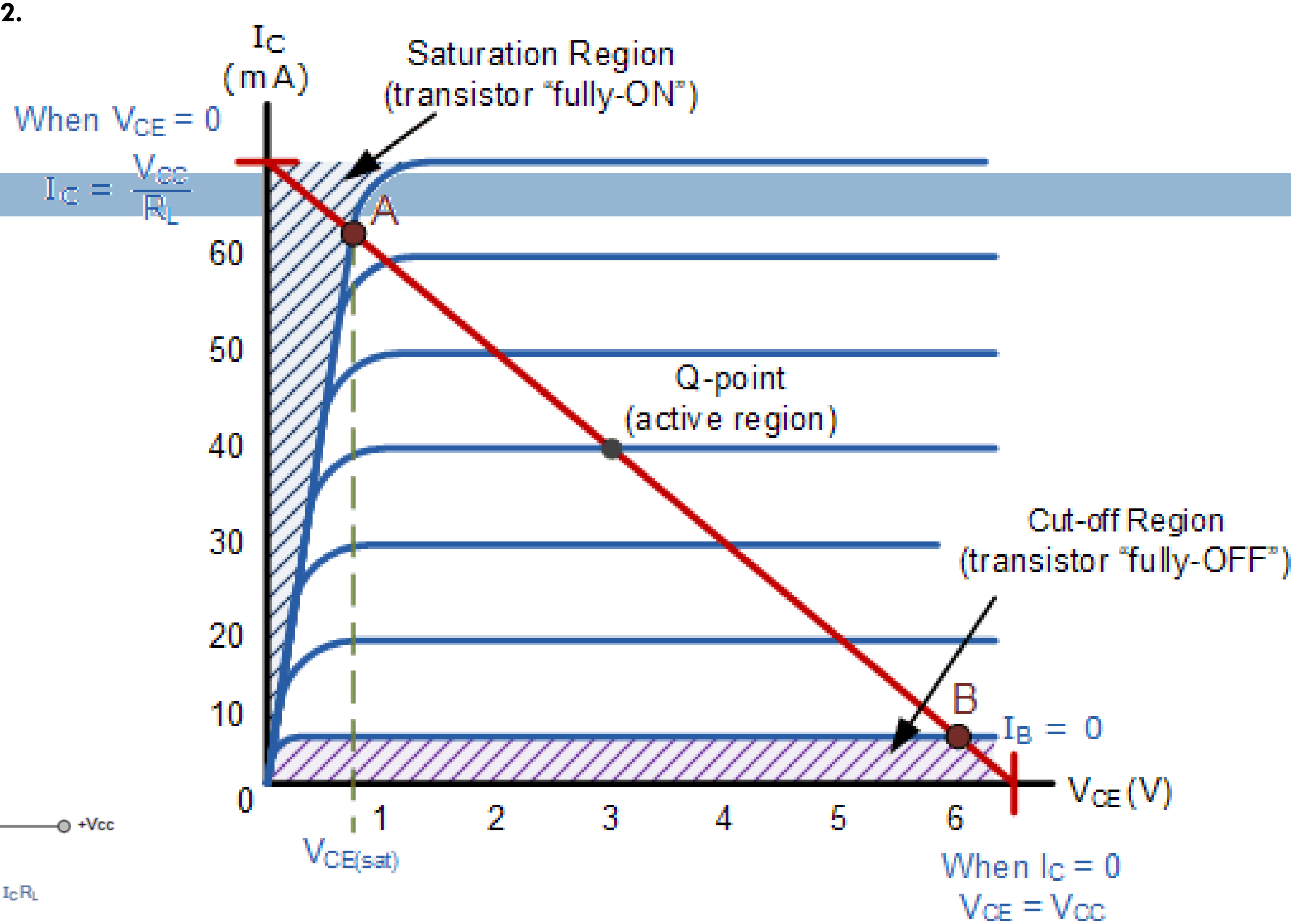
- Familia de caracteristici de iesire a tranzistorului bipolar.

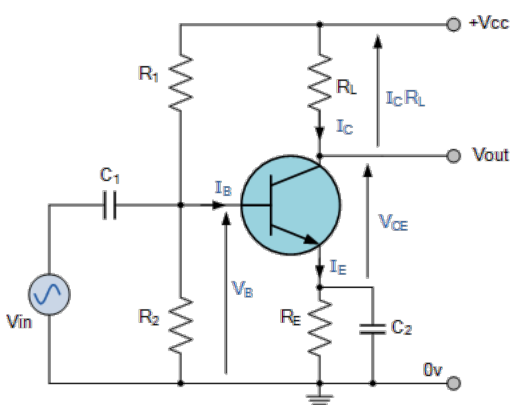


$$r_{CE} = \frac{\Delta u_{CE}}{\Delta i_C} = \left[\frac{\partial u_{CE}}{\partial i_C}\right]_{I_B = cst}$$

$$\beta = \frac{\Delta i_C}{\Delta i_B} = \left[\frac{\partial i_C}{\partial i_B}\right]_{U_{CE} = cst}$$

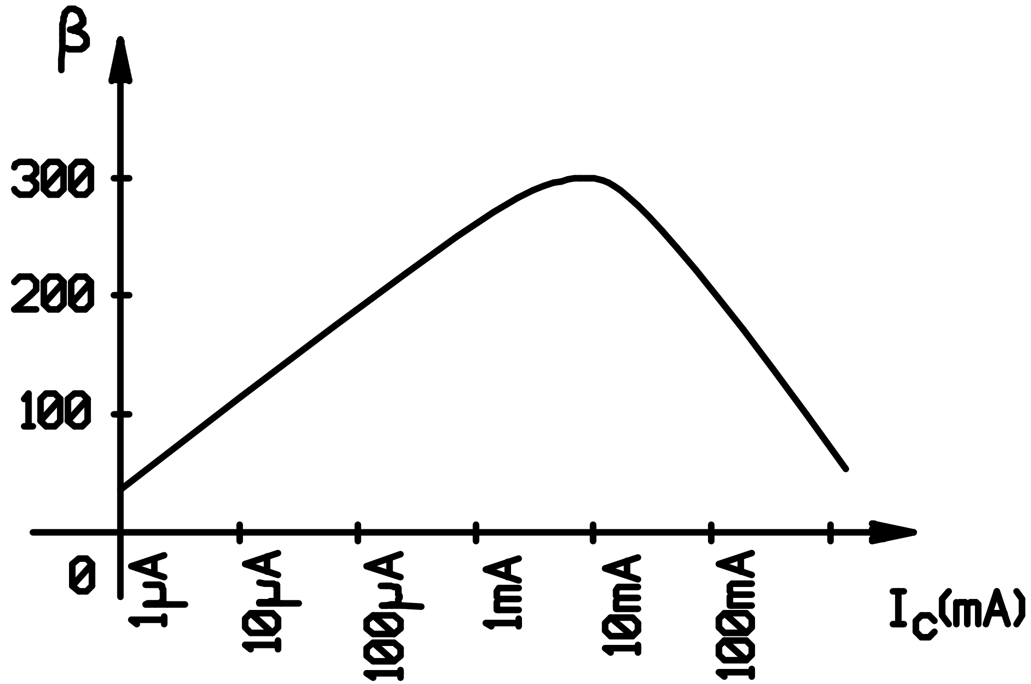
http://www.electronics-tutorials.ws/amplifier/amp_2.html

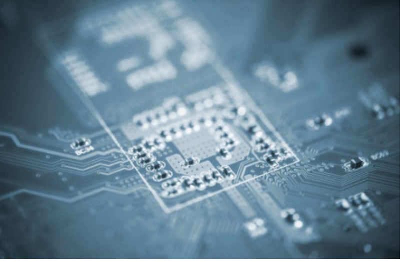




Tranzitoare bipolare

- Important: factorul de amplificare in curent, de semnal mic, depinde de valoarea curentului de colector !



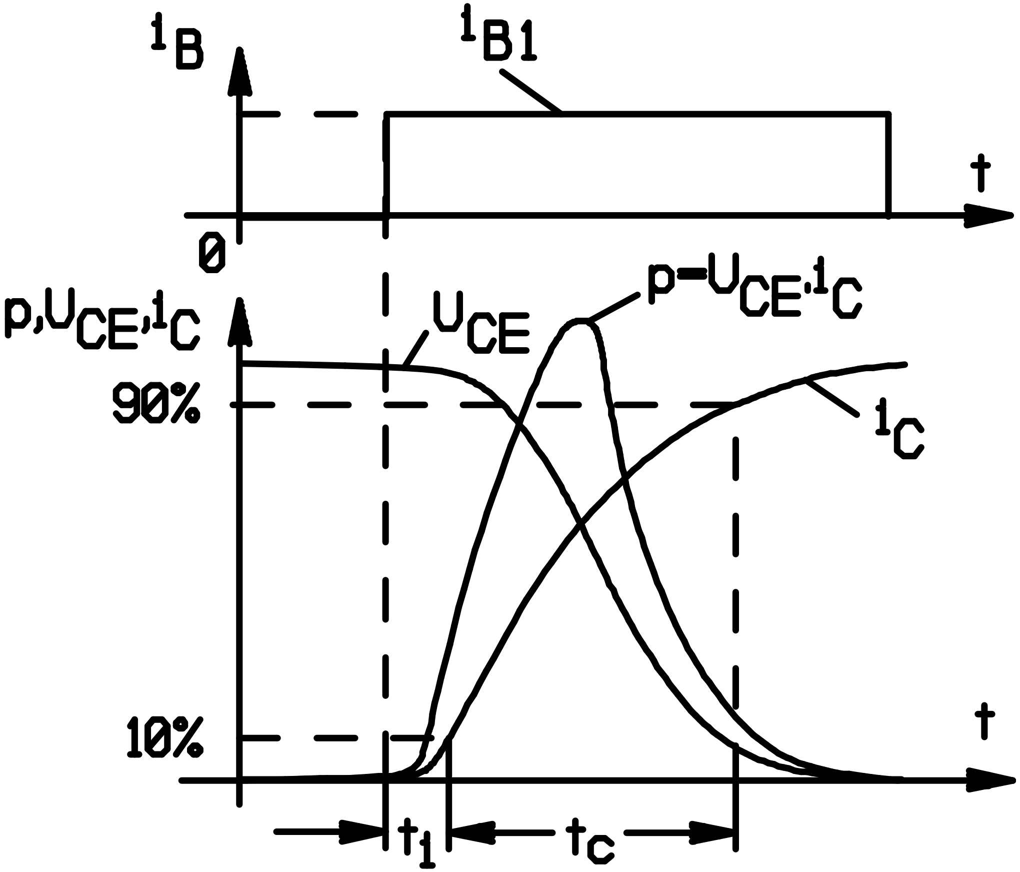


Tranzitoare bipolare

- Pentru a putea amplifica sau comuta semnale electrice cu ajutorul tranzistorului bipolar trebuie sa stim a deplasa controlat punctele de functionare pe caracteristicile de intrare si iesire, exploatind proprietatea dispozitivului de a amplifica curentul din circuitul de baza.
- Din pacate caracteristicile sunt **neliniare.** Deci efectul controlului depinde de zona in care il facem. Trebuie, prin urmare sa liniarizam caracteristicile si sa lucram cu “semnale mici”, in zona liniarizata. Rezulta **modelul de semnal mic** al tranzistorului bipolar:
- $du_{BE} = r_{BE}\, di_B + v_r\, du_{CE}$
- $di_C = \beta\, di_B + (1 / r_{CE})\, du_{CE}$
- Acest lucru nu este necesar cand lucram in comutatie:

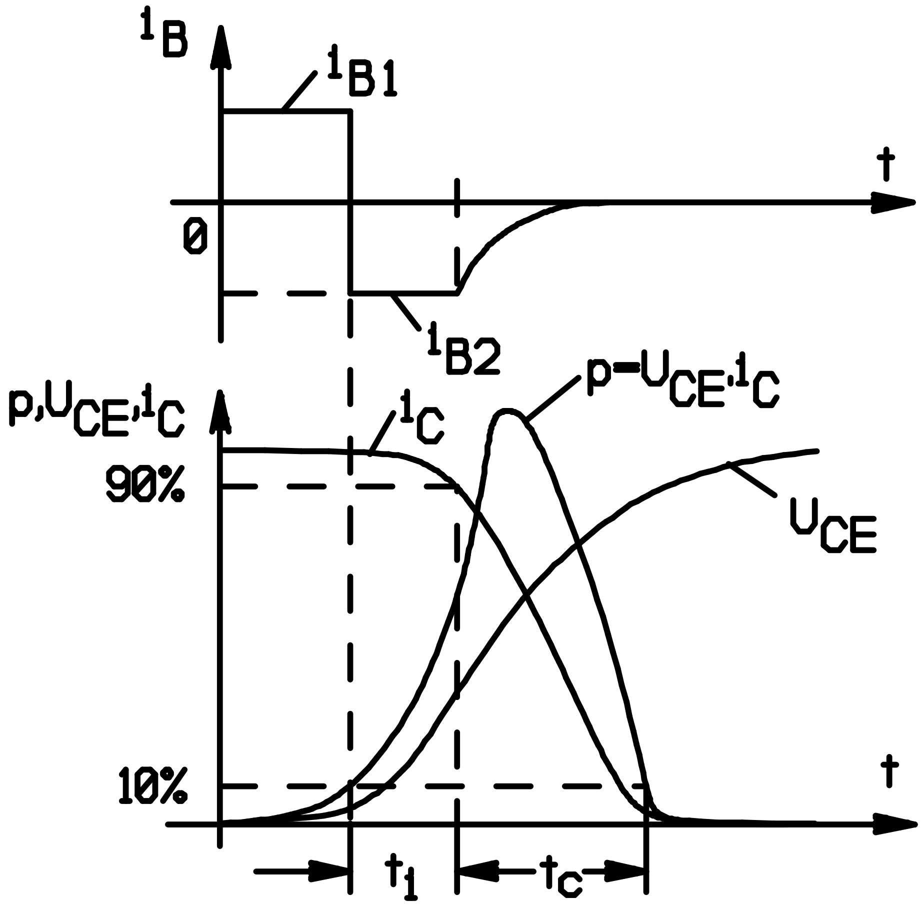
Tranzitoare bipolare

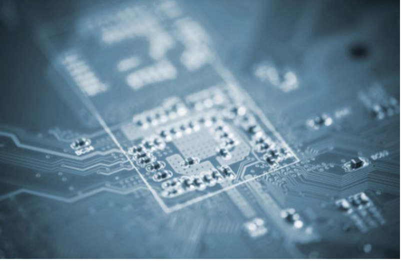
- Comutatia directa la tranzistoarele bipolare.



Tranzitoare bipolare

- Comutatia inversa la tranzistoarele bipolare.





Tranzitoare bipolare. Concluzii

- De un mare ajutor ne este aici stabilirea **conexiunii in care opereaza tranzistorul:**
  - EC - emitor comun
  - CC - colector comun
  - BC - baza comuna
- Conexiunea este determinata de acel electrod al dispozitivului care este conectat la potential electric constant, in particular la potentialul masei circuitului.

Circuite simple cu tranzitoare bipolare

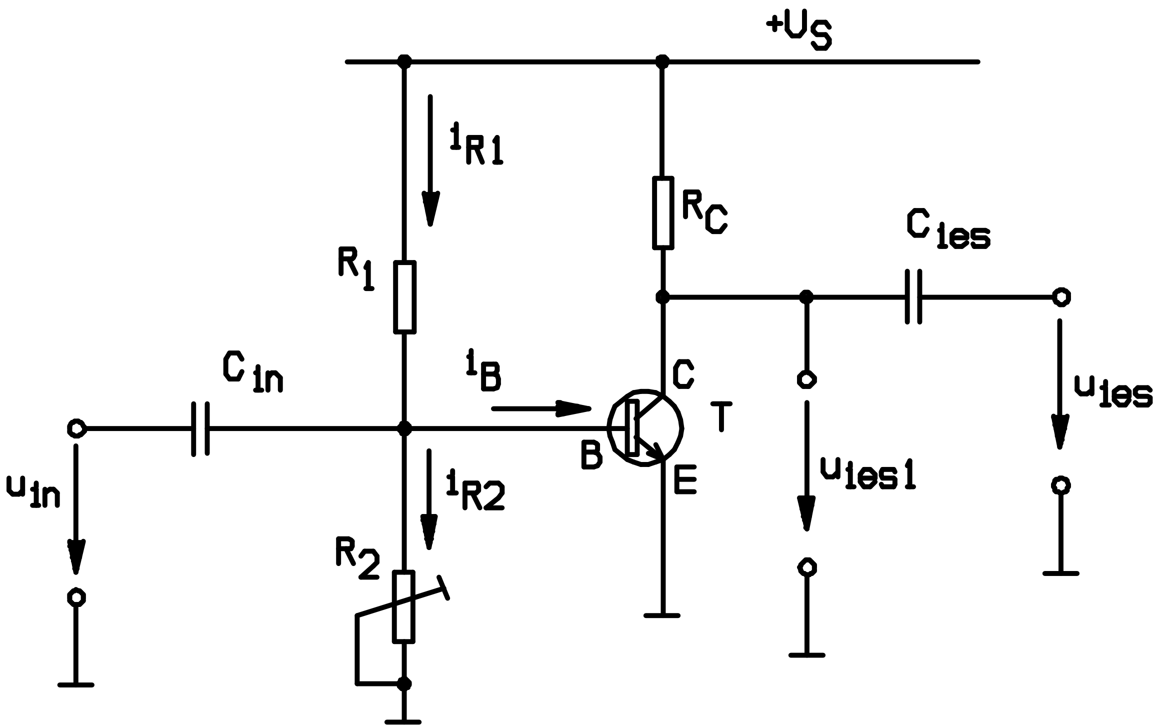
- Problema electronica secundara = polarizare = stabilire a punctului static de functionare.

- Analiza o vom face pe cazul celor mai simple circuite, fara a apela mult la reactii, acestea urmind a fi introduse in a doua parte a acestui curs, la studiul circuitelor ce indeplinesc functiile electronice fundamentale principale.

- Ca urmare acest capitol impune studiul atent al bibliografiei recomandate.

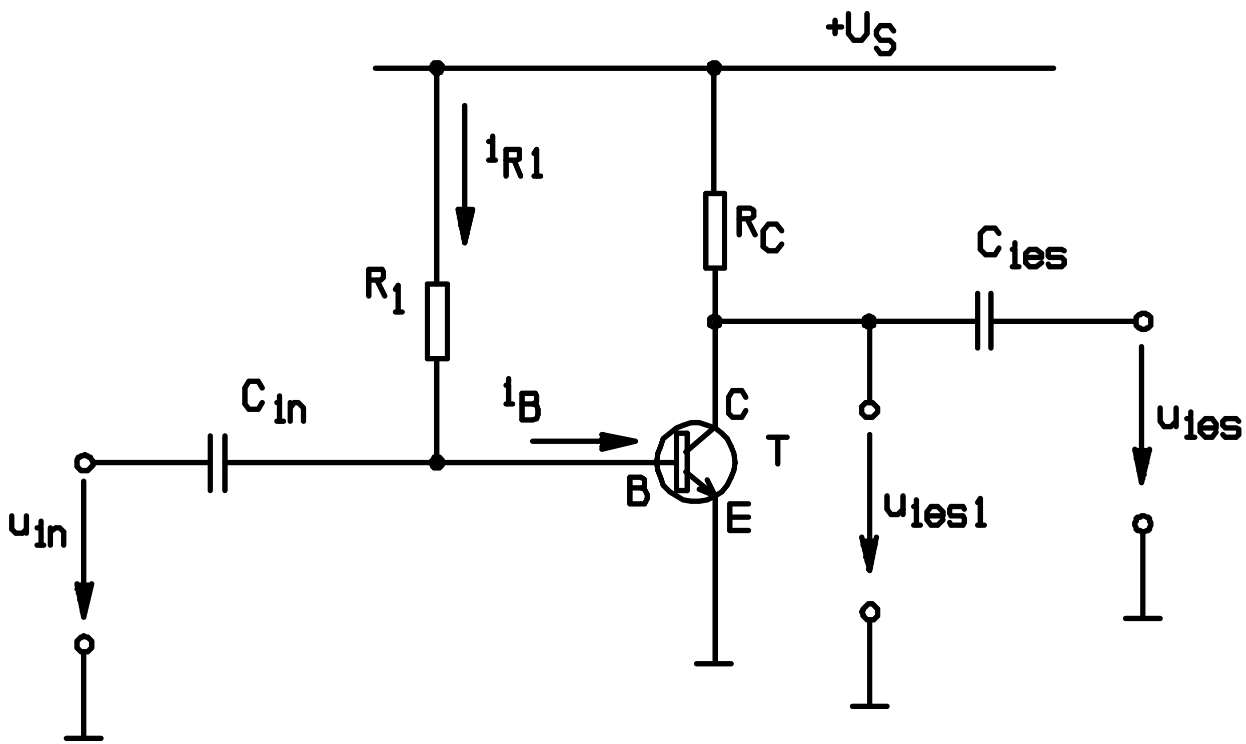
Circuite simple cu tranzitoare bipolare

- Polarizarea tranzistorului bipolar in conexiune emitor-comun, cu divizor rezistiv de tensiune continua.
- Atentie: lucram in curent continuu si notam totul cu litere mari !



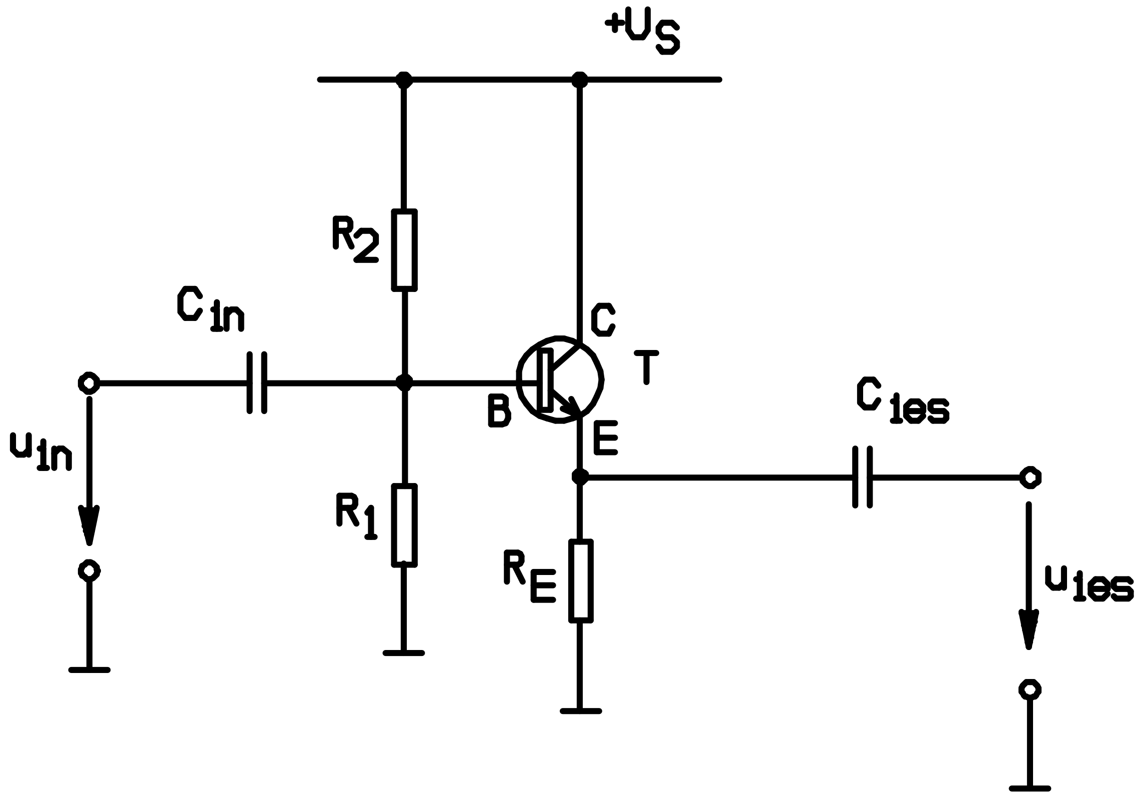
Circuite simple cu tranzitoare bipolare

- Stabilirea punctului static de functionare prin injectare de curent de baza. Tot conexiune EC. Generator simplu de curent constant.



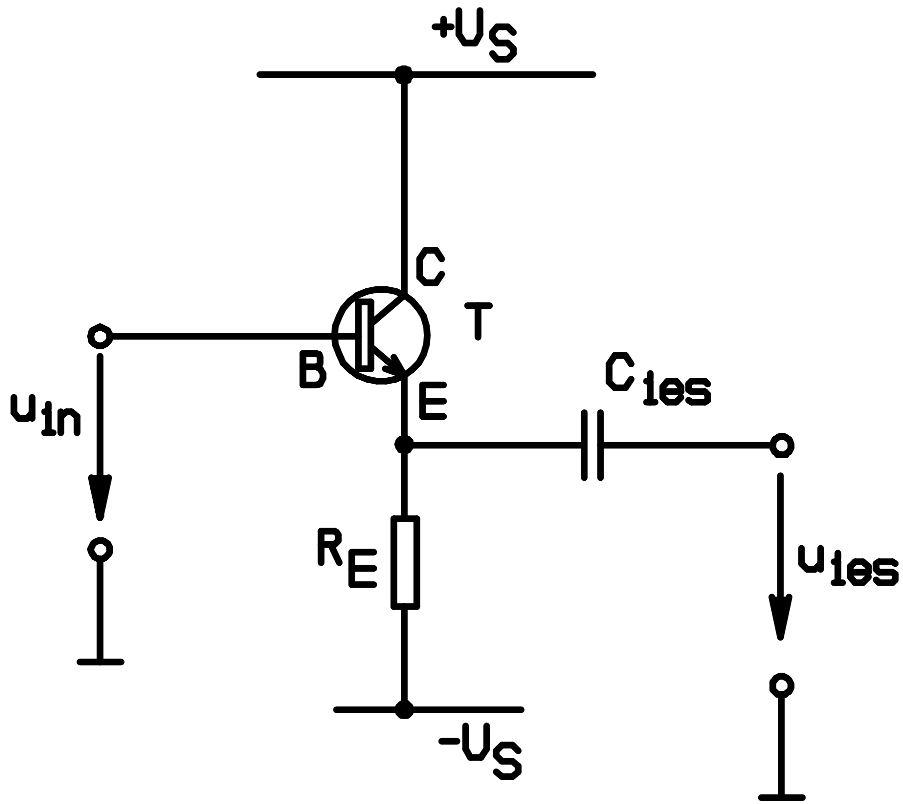
Circuite simple cu tranzitoare bipolare

- Polarizare prin divizor rezistiv de tensiune continua pentru tranzistoare functionind in conexiune colector comun.



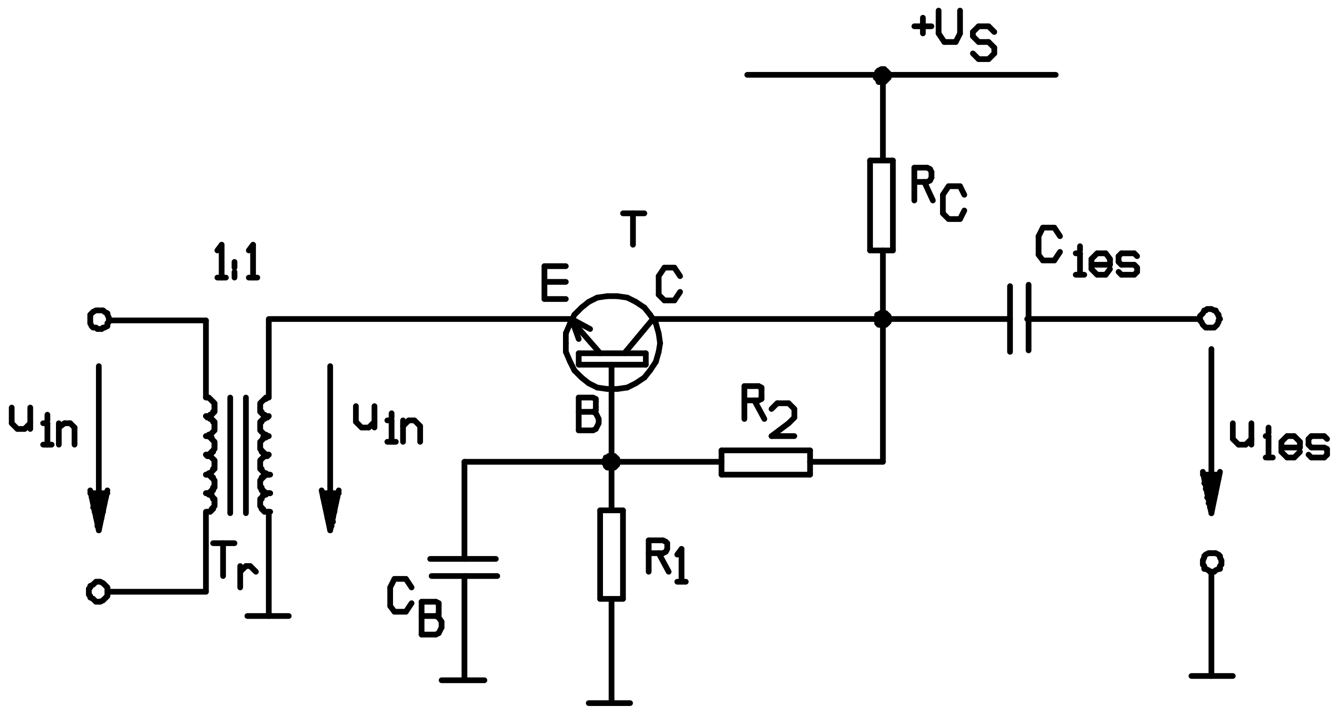
Circuite simple cu tranzitoare bipolare

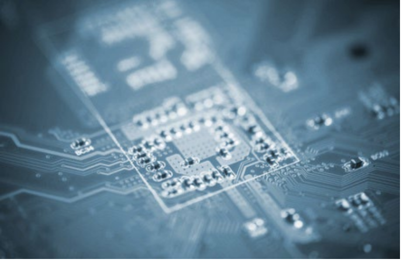
- Polarizarea tranzistorului in conexiune colector comun in cazul alimentarii circuitului de la sursa dubla de tensiune continua - simplificari majore, stabilitate.



Circuite simple cu tranzitoare bipolare

- Polarizarea tranzistorului in conexiune baza-comuna prin reactie negativa de tensiune continua.





Circuite simple cu tranzitoare bipolare

- Sa admitem acum ca punctele statice de functionare se gasesc in “A” pe caracteristica de intrare si in “A1” pe familia de caracteristici de iesire a tranzistorului.

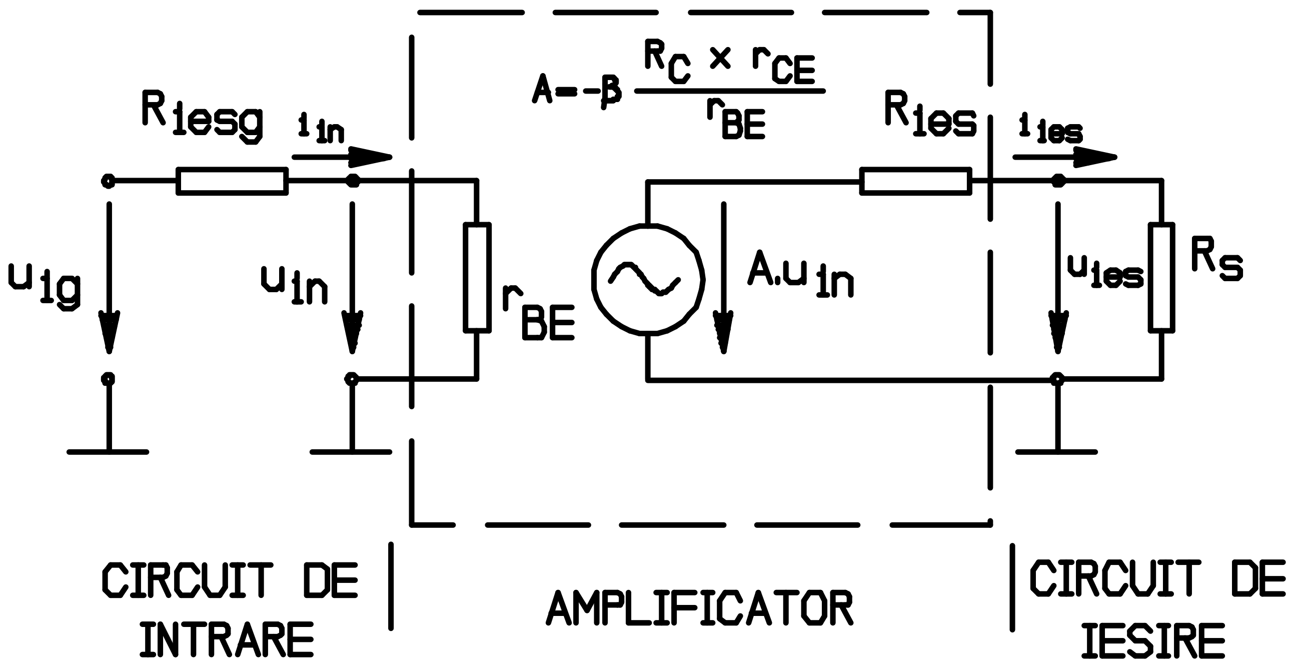
- **Putem trece la studiul functiilor electronice primordiale - principale, ale circuitelor fundamentale cu tranzistoare**

- Vom folosi modelul de semnal mic asociat cu celelalte ecuatii de tensiune si curent din circuit. Vom face calculele detaliate numai pentru primul circuit. La celelalte circuite vom asocia calculele cu argumentari solide !

- Atentie, lucram cu semnale mici si notam totul cu litere mici !

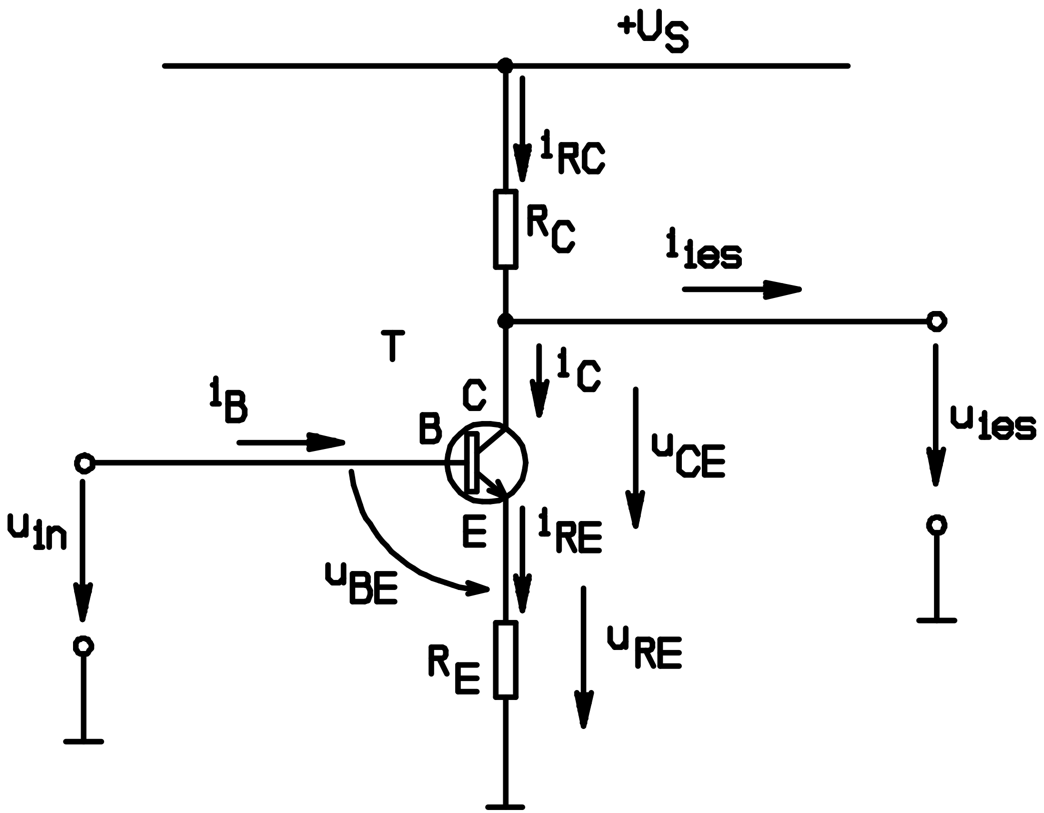
Circuite simple cu tranzitoare bipolare

- Schema echivalenta a amplificatorului cu tranzistor in conexiune emitor comun



Circuite simple cu tranzitoare bipolare

- Si inca o data acelasi amplificator de tensiune, dar cu reactie negativa de curent !



$$\frac{1}{A_b} = -\frac{1}{A_U} - \frac{R_E}{R_C}$$

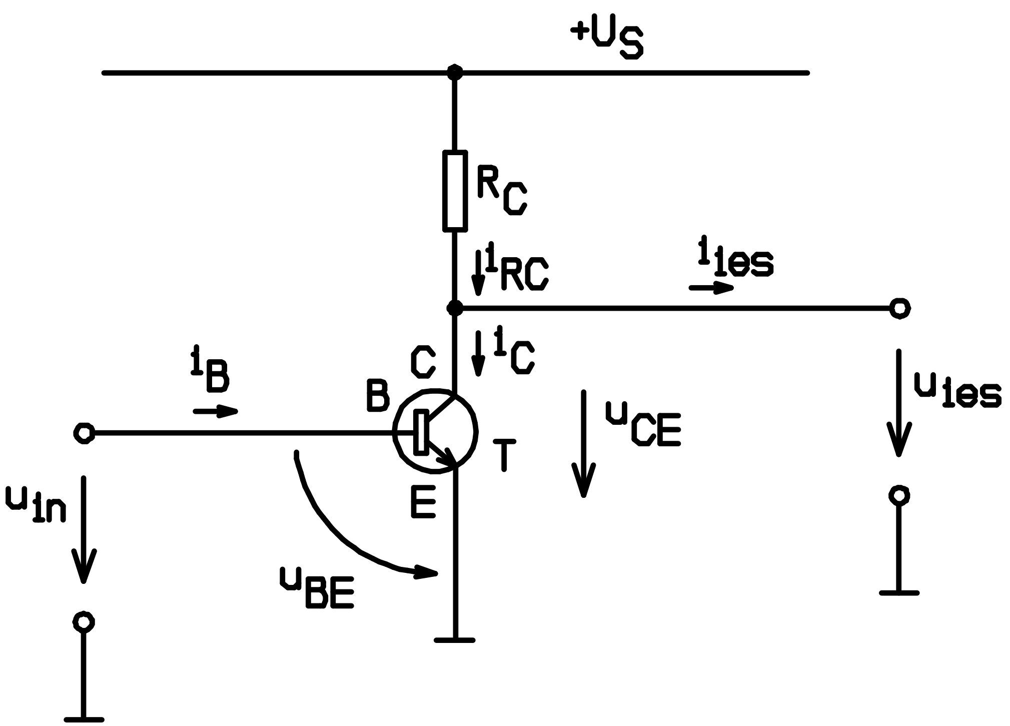
$$A_U = -\beta \frac{R_C \times r_{CE}}{r_{BE}}$$

$$r_{in} = r_{BE} + \beta R_E$$

$$r_{ies} \approx -R_C$$

Circuite simple cu tranzitoare bipolare

- Cel mai simplu circuit: Amplificatorul de tensiune cu un singur tranzistor in conexiune EC. Conexiunea emitor-comun simpla.



$$A_U = -\beta \frac{R_C \times r_{CE}}{r_{BE}} \approx -\beta \frac{R_C}{r_{BE}}$$

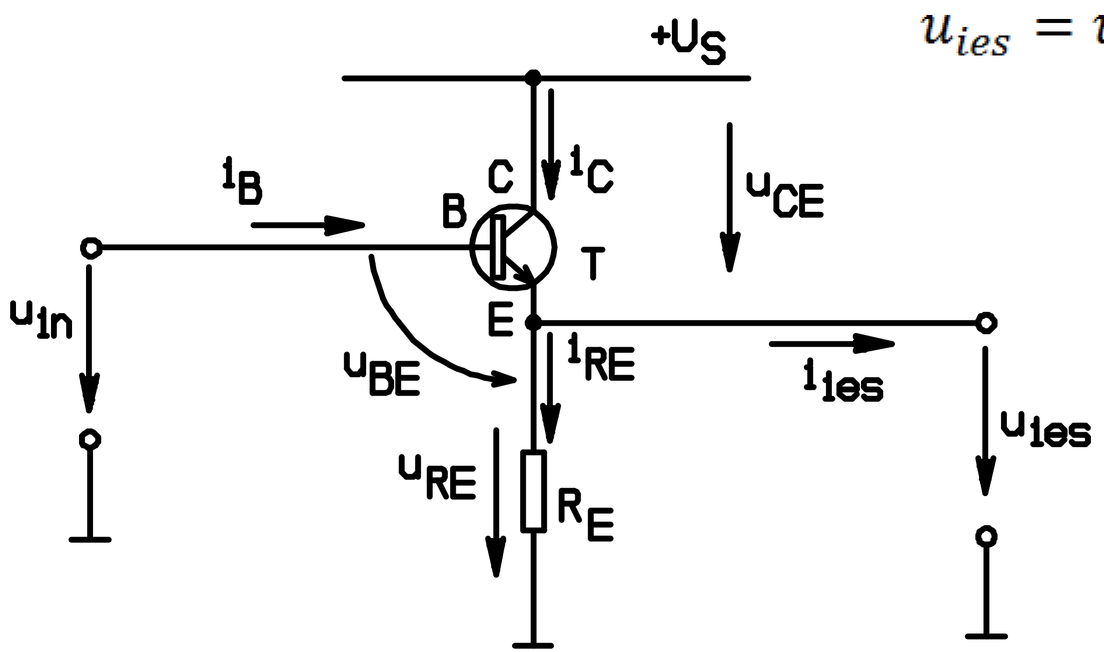
$$di_c = \beta i_b$$

$$r_{in} = r_{BE}$$

$$r_{ies} = R_C \times r_{CE} \approx R_C$$

Circuite simple cu tranzitoare bipolare

- Amplificatorul in conexiune colector comun:
  - Circuitul repetor pe emitor.
  - Circuitul de adaptare de impedanta.
  - Amplificatorul de curent.



$$u_{ies} = u_{in} - U_{BE} \approx u_{in} - 0.6 \approx u_{in}$$

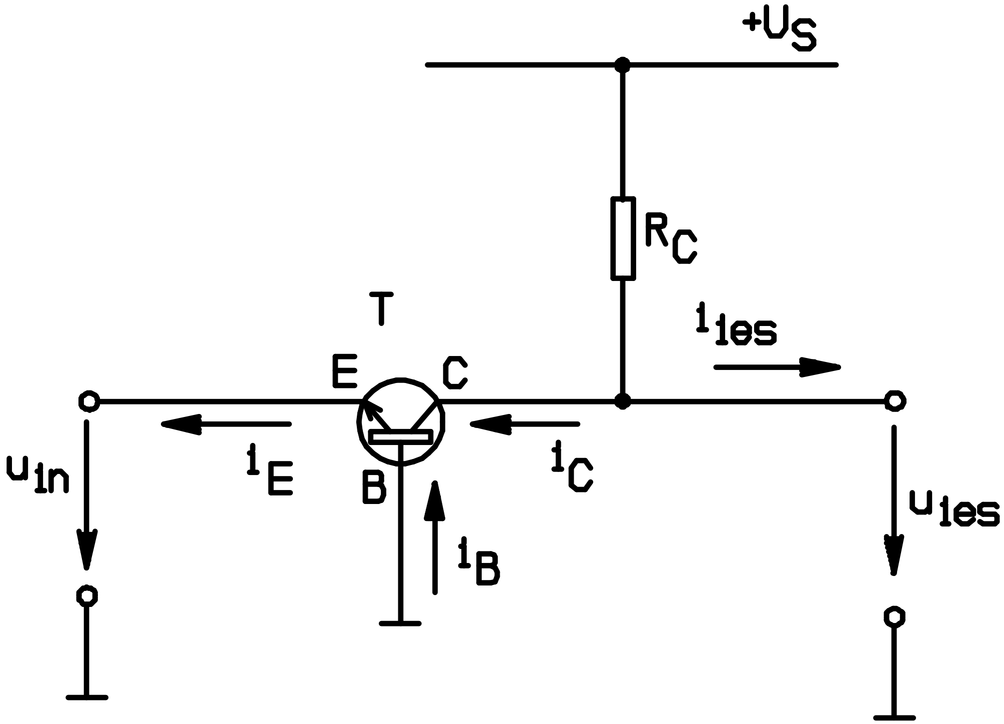
$$A = \frac{u_{ies}}{u_{in}} = \frac{du_{ies}}{du_{in}} \approx 1$$

$$r_{in} = r_{BE} + \beta R_E$$

$$r_{ies} = R_E \times \frac{r_{BE}}{\beta}$$

Circuite simple cu tranzitoare bipolare

- Amplificatorul de tensiune cu tranzistor bipolar in conexiune baza-comuna.
  - Factorul de amplificare in curent este unitar



$$u_{in} = -u_{BE}$$

$$A = -\beta \frac{R_C \times r_{CE}}{r_{BE}} \approx -\beta \frac{R_C}{r_{BE}}$$

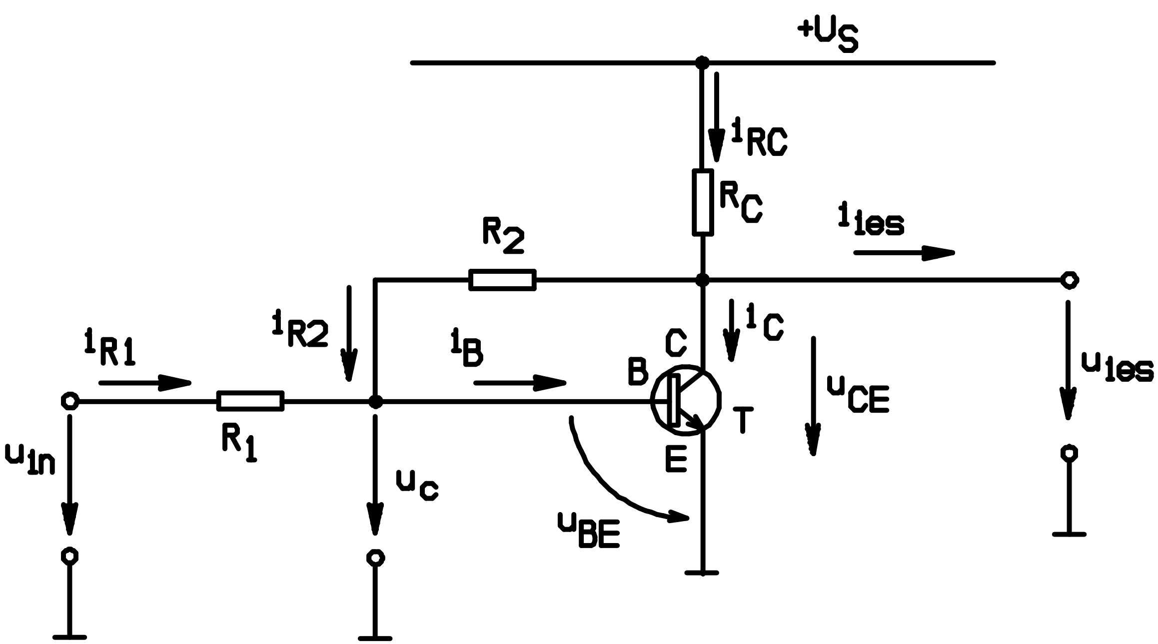
$$r_{in} = \frac{r_{BE}}{\beta}$$

$$r_{ies} = R_C \times r_{CE} \approx R_C$$

$$\alpha = \frac{di_C}{di_E} = \frac{\beta di_B}{(1+\beta)di_B} = \frac{\beta}{1+\beta} \approx 1$$

Circuite simple cu tranzitoare bipolare

- Acelasi amplificator prevazut insa cu reactie negativa de tensiune.



$$A_b = -\frac{R_2}{R_1}$$

$$\frac{1}{A_b} = -\frac{1}{A_U} - \frac{R_1}{R_2}$$

$$A_U = -\beta \frac{R_C \times r_{CE} \times R_2}{R_1 + r_{BE}}$$

$$g = \frac{A_U}{A_b}$$

$$r_{in} = R_1 + \left(r_{BE} \times \frac{R_1}{A_U} \right) \approx R_1$$

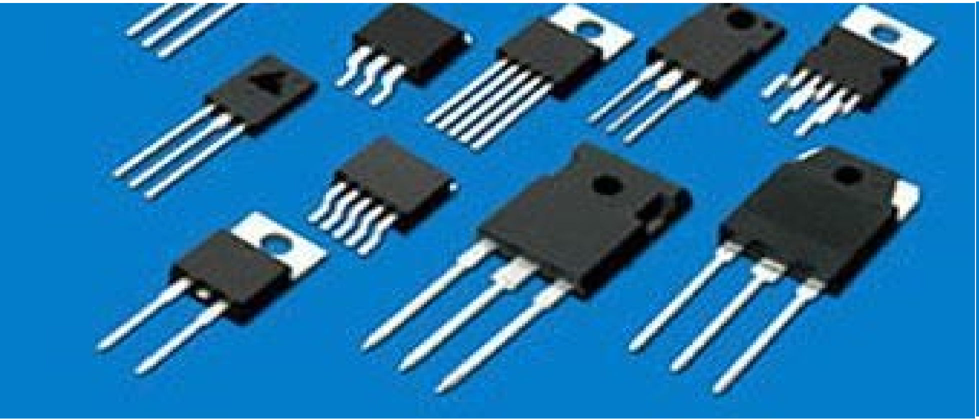
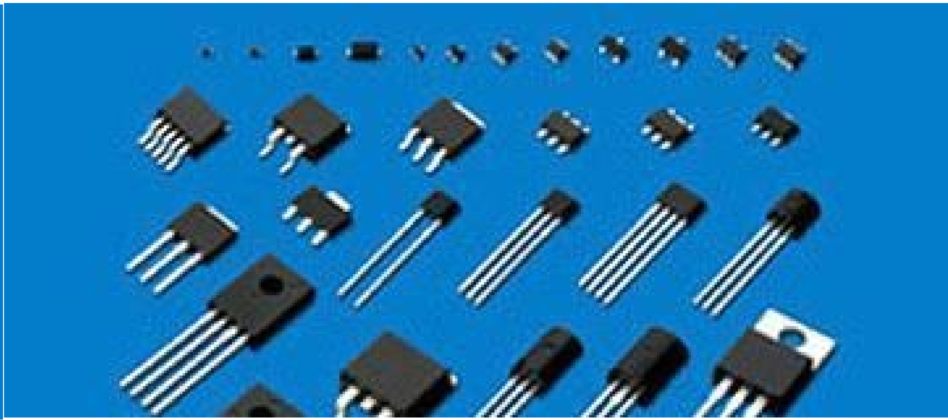
$$r_{ies} = \frac{1}{g} \left(R_C \times r_{CE} \times R_2 \right)$$

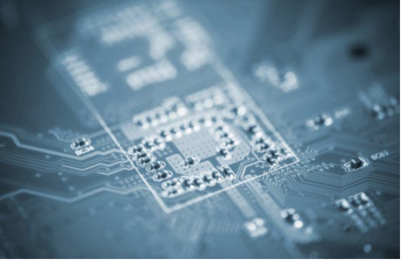
Circuite simple cu tranzitoare bipolare

- Etc., etc. !
- La momentul oportun vom vedea cum, combinind circuitele prezentate vom analiza amplificatoarele cu mai multe etaje.

Tranzitorul bipolar

Tranzitoare bipolare



Tranzitoare bipolare

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- De ce bipolare?
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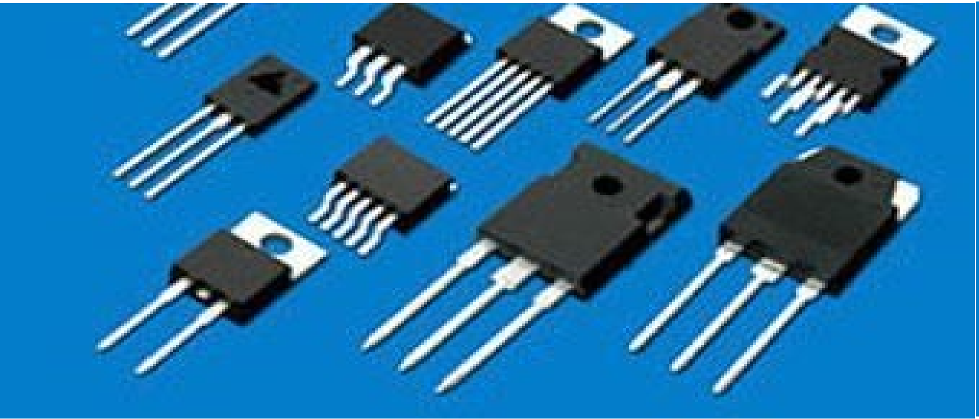
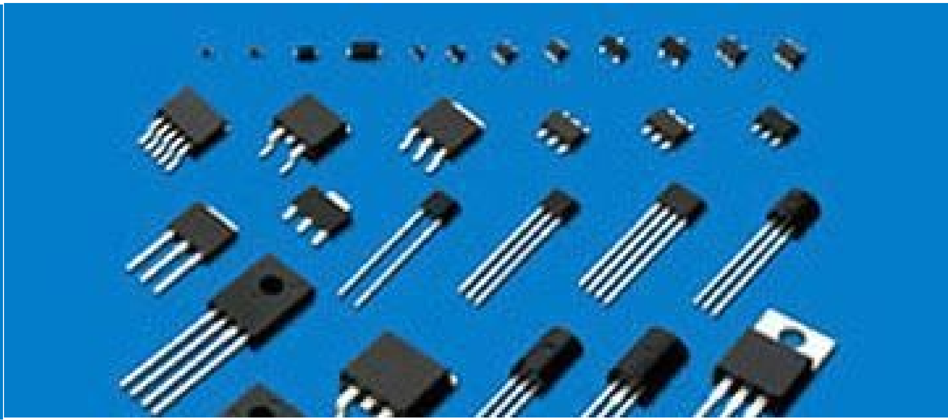
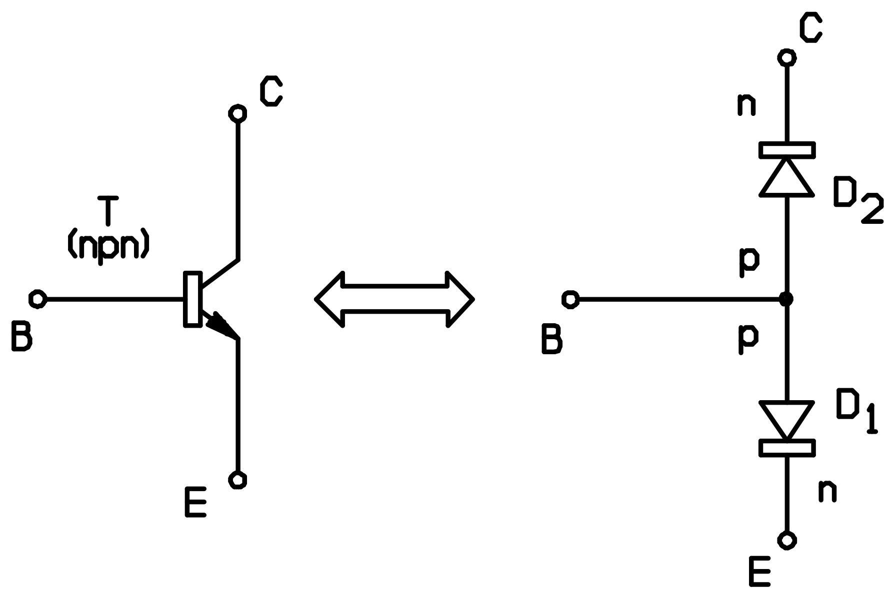




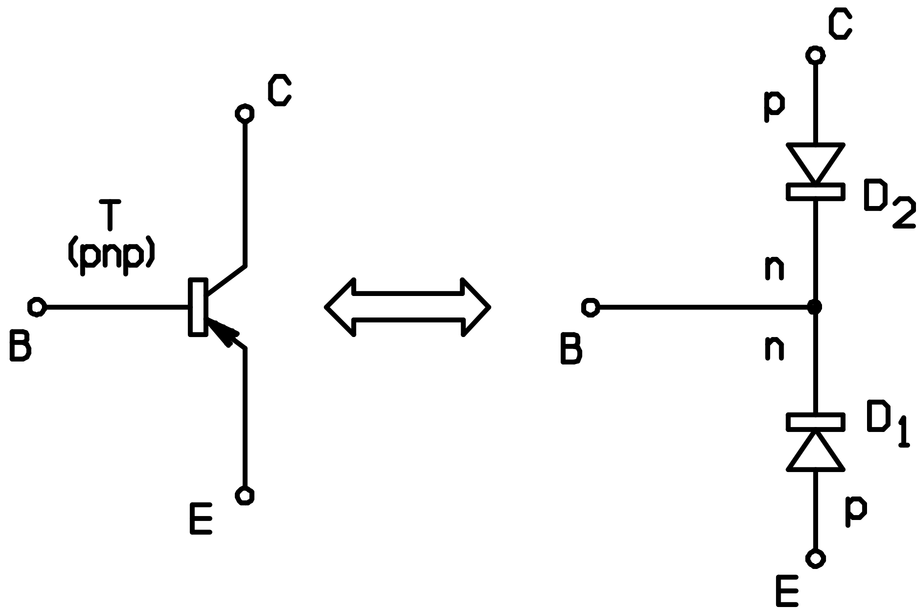
Tranzitoare bipolare

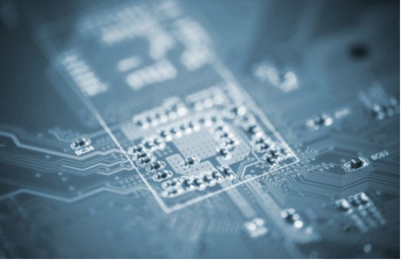
- Simbolul si schema echivalenta cu diode pentru tranzistorul de tip NPN.
- Atentie: schema echivalenta serveste numai pentru retinerea modului de polarizare corecta !



Tranzitoare bipolare

- Simbolul si schema echivalenta pentru tranzistoarele PNP.
- Observatia ramine valabila: schema echivalenta numai pentru intelegerea polarizarii corecte.



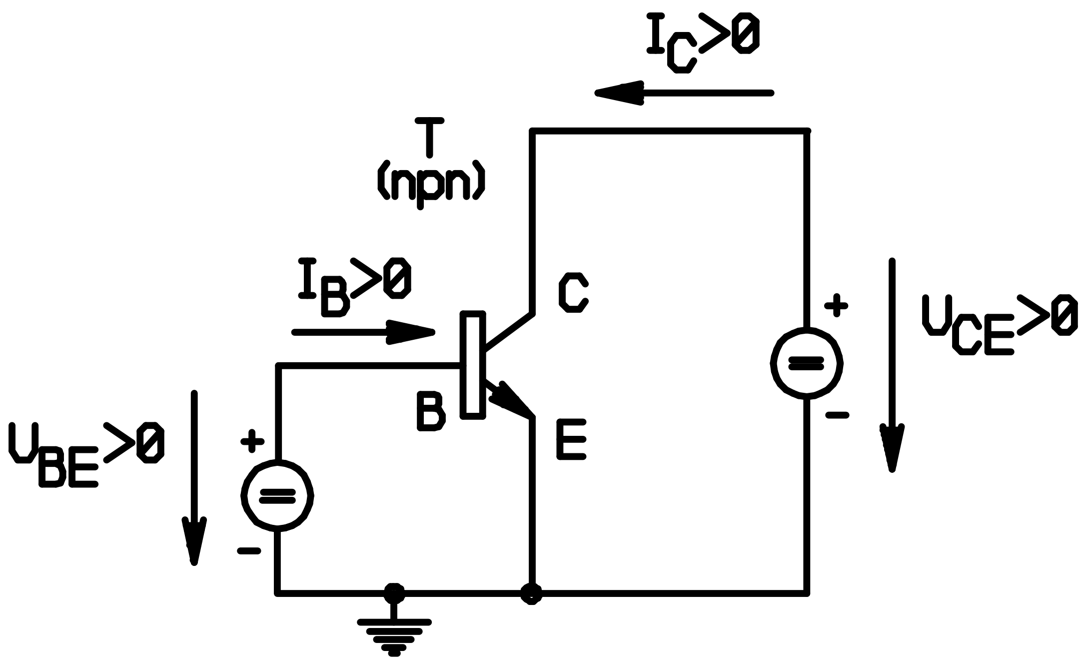


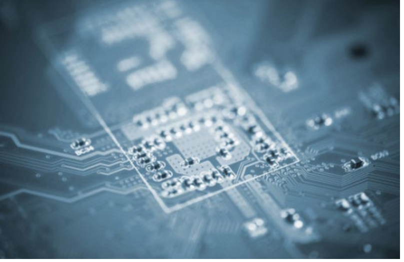
Tranzitoare bipolare

- Ce inseamna polarizare ?
  - Alegerea corecta a semnului si nivelului tensiunilor continue din circuitul de intrare si de iesire !
- Cum se face?
  - Din punctul de vedere al semnului trebuie retinut ca circuitul de intrare, BE, lucreaza la polarizare directa a jonctiunii iar circuitul de iesire, de obicei CE, lucreaza la polarizare inversa a jonctiunii colector-baza.
- Din punctul de vedere al nivelelor: conform catalogului asociat cu dorintele proiectantului
- **CA URMARE:**

Tranzitoare bipolare

- Polarizarea corecta a unui tranzistor PNP.



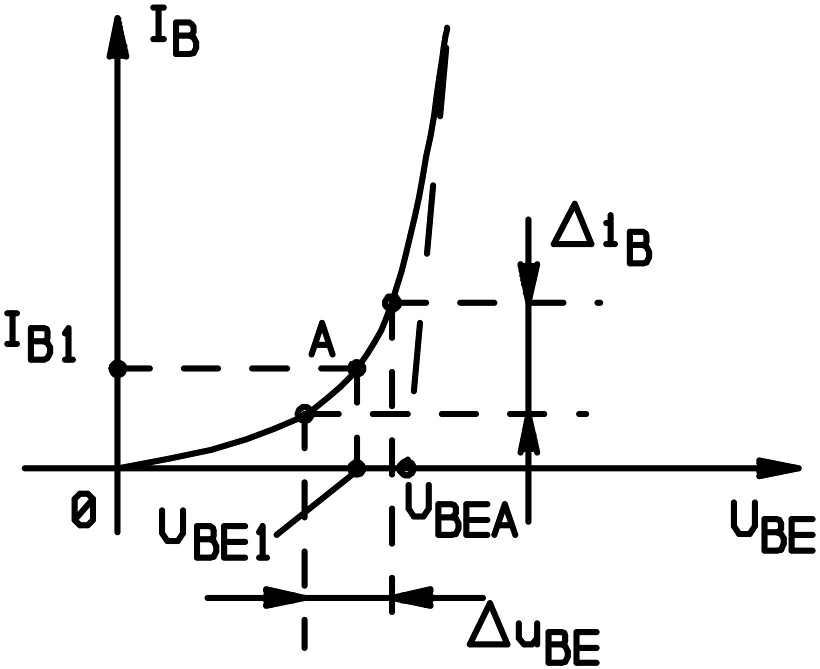


Tranzitoare bipolare

- Dar ce putem face un tranzistor ?
  - **Deocamdata nimic !**
- **Atunci cel putin sa aflam ce proprietate fundamentala are !**
  - **Una singura:**
    - Curentul de colector este un multiplu bine determinat al curentului din circuitul de baza**:** $I_C = \beta I_B$
    - Si sa mai vedem ce caracteristici statice si dinamice are si ce parametri specifici putem defini.

Tranzitoare bipolare

- Caracteristica de intrare a tranzistorului bipolar. Fata de o simpla jonctiune, tensiunea baza-emitor, la curent de baza constant depinde si de tensiunea colector-emitor prin factorul v_r, neglijabil in aplicatiile practice !

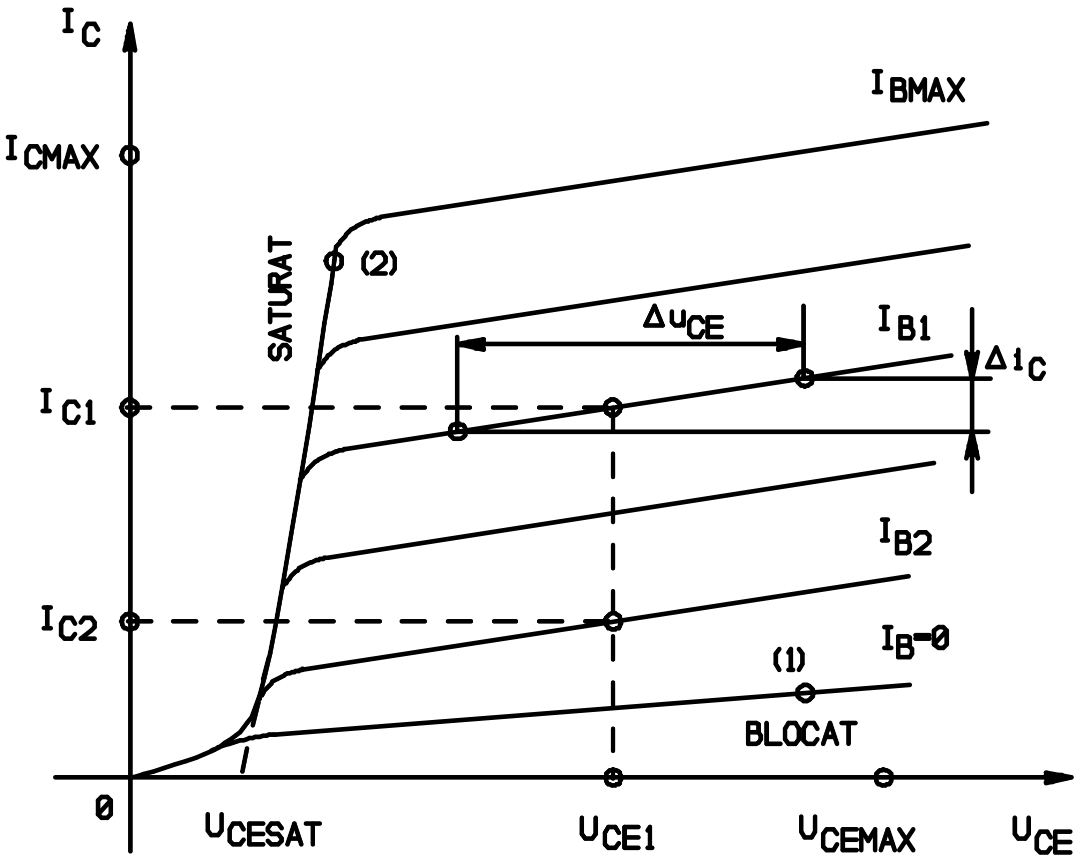


$$R_{BE} = \frac{U_{BE1}}{I_{B1}}$$

$$r_{BE} = \frac{\Delta u_{BE}}{\Delta i_B} = \left[\frac{\partial u_{BE}}{\partial i_B}\right]_{U_{CE} = cst}$$

Tranzitoare bipolare

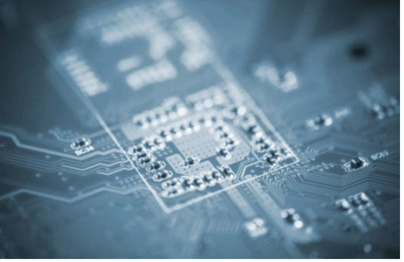
- Familia de caracteristici de iesire a tranzistorului bipolar.



$$R_{CE} = \frac{U_{CE1}}{I_{C1}}$$

$$r_{CE} = \frac{\Delta u_{CE}}{\Delta i_C} = \left[\frac{\partial u_{CE}}{\partial i_C}\right]_{I_B = cst}$$

$$\beta = \frac{\Delta i_C}{\Delta i_B} = \left[\frac{\partial i_C}{\partial i_B}\right]_{U_{CE} = cst}$$

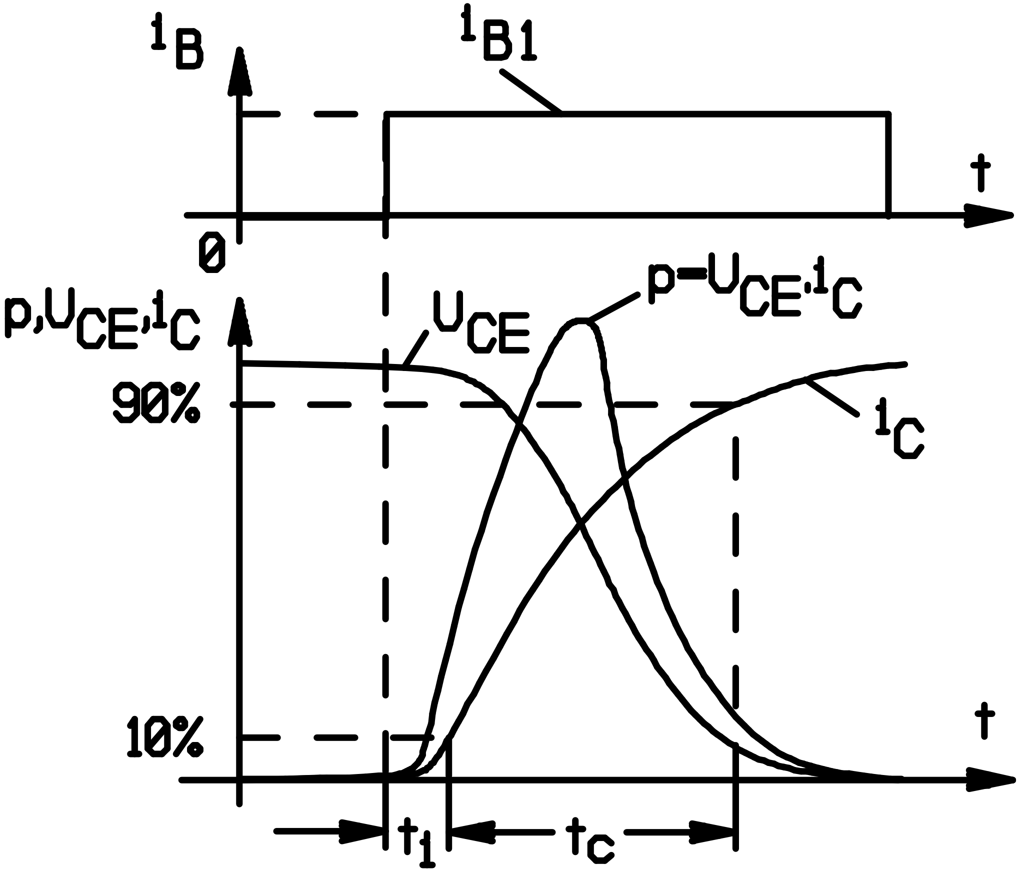


Tranzitoare bipolare

- Pentru a putea amplifica sau comuta semnale electrice cu ajutorul tranzistorului bipolar trebuie sa stim a deplasa controlat punctele de functionare pe caracteristicile de intrare si iesire, exploatind proprietatea dispozitivului de a amplifica curentul din circuitul de baza.
- Din pacate caracteristicile sunt **neliniare.** Deci efectul controlului depinde de zona in care il facem. Trebuie, prin urmare sa liniarizam caracteristicile si sa lucram cu "semnale mici", in zona liniarizata. Rezulta **modelul de semnal mic** al tranzistorului bipolar:
- $du_{BE} = r_{BE}\, di_B + v_r\, du_{CE}$
- $di_C = \beta\, di_B + (1 / r_{CE})\, du_{CE}$
- Acest lucru nu este necesar cand lucram in comutatie:

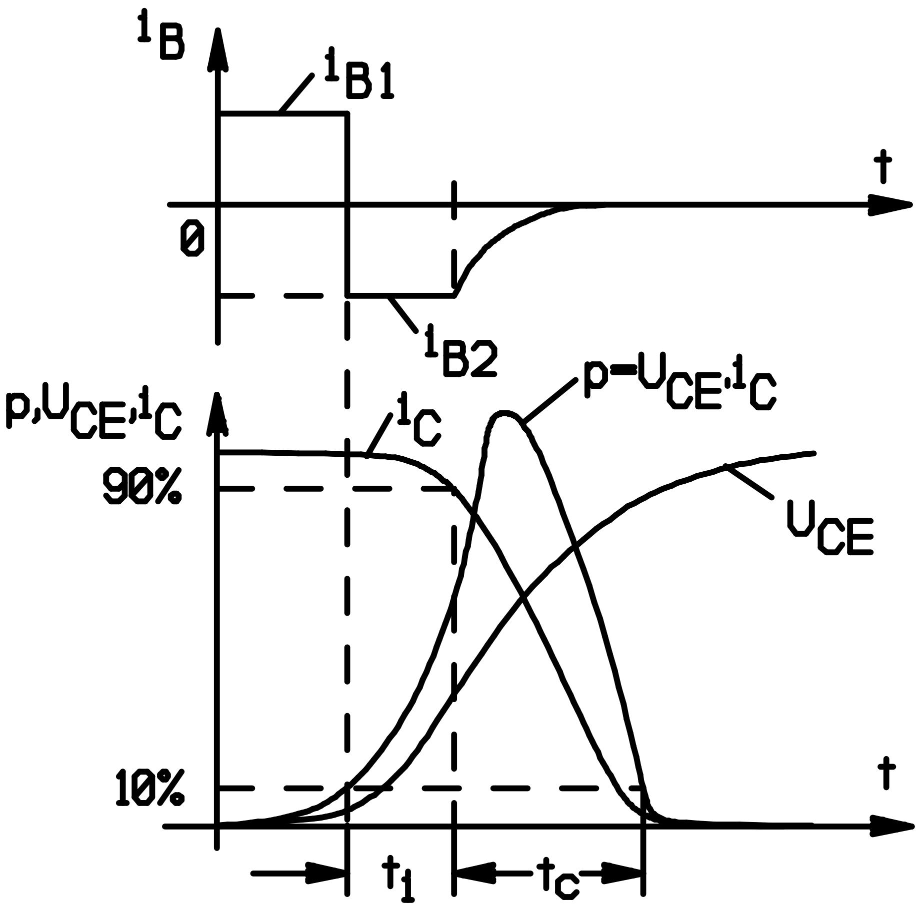
Tranzitoare bipolare

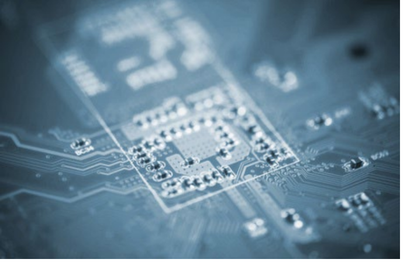
- Comutatia directa la tranzistoarele bipolare.



Tranzitoare bipolare

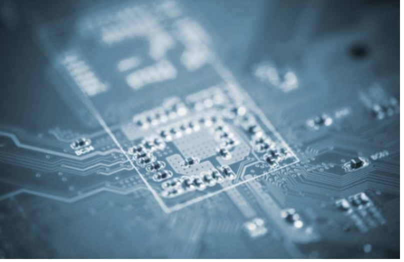
- Comutatia inversa la tranzistoarele bipolare.





Tranzitoare bipolare. Concluzii

- De un mare ajutor ne este aici stabilirea **conexiunii in care opereaza tranzistorul:**
  - EC - emitor comun
  - CC - colector comun
  - BC - baza comuna
- Conexiunea este determinata de acel electrod al dispozitivului care este conectat la potential electric constant, in particular la potentialul masei circuitului.



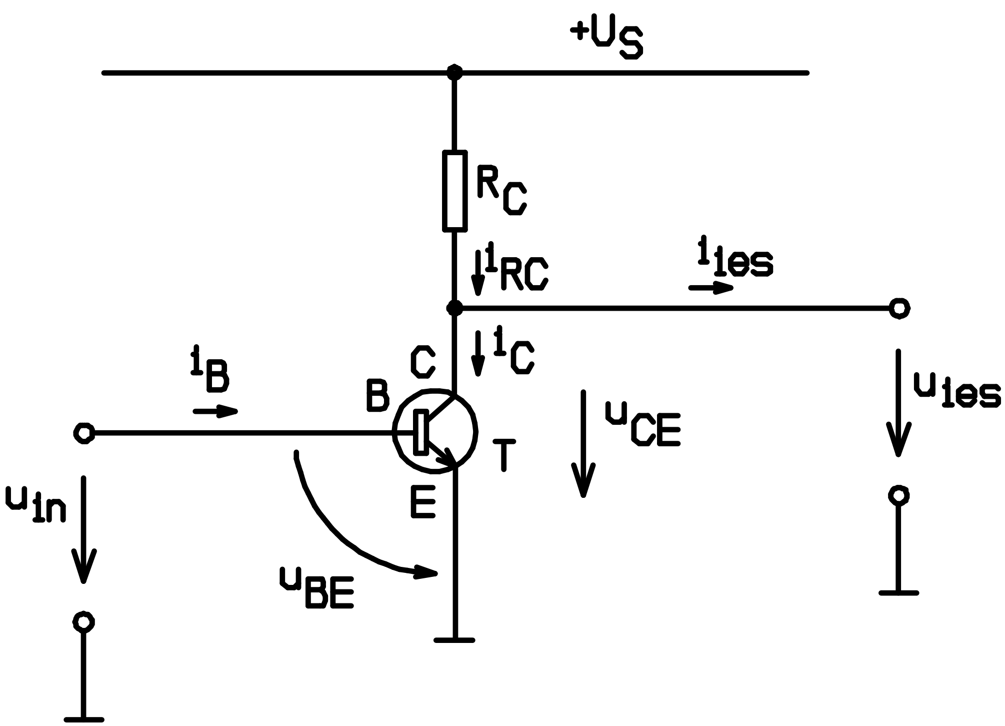
Circuite simple cu tranzistoare bipolare

- Problema electronica secundara = polarizare = stabilire a punctului static de functionare.

- Analiza o vom face pe cazul celor mai simple circuite, fara a apela mult la reactii, acestea urmind a fi introduse in a doua parte a acestui curs, la studiul circuitelor ce indeplinesc functiile electronice fundamentale principale.

Circuite simple cu tranzistoare bipolare

- Cel mai simplu circuit: Amplificatorul de tensiune cu un singur tranzistor in conexiune EC. Conexiunea emitor-comun simpla.

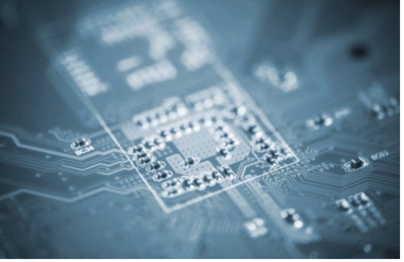


$$A_U = -\beta \frac{R_C \times r_{CE}}{r_{BE}} \approx -\beta \frac{R_C}{r_{BE}}$$

$$di_c = \beta i_b$$

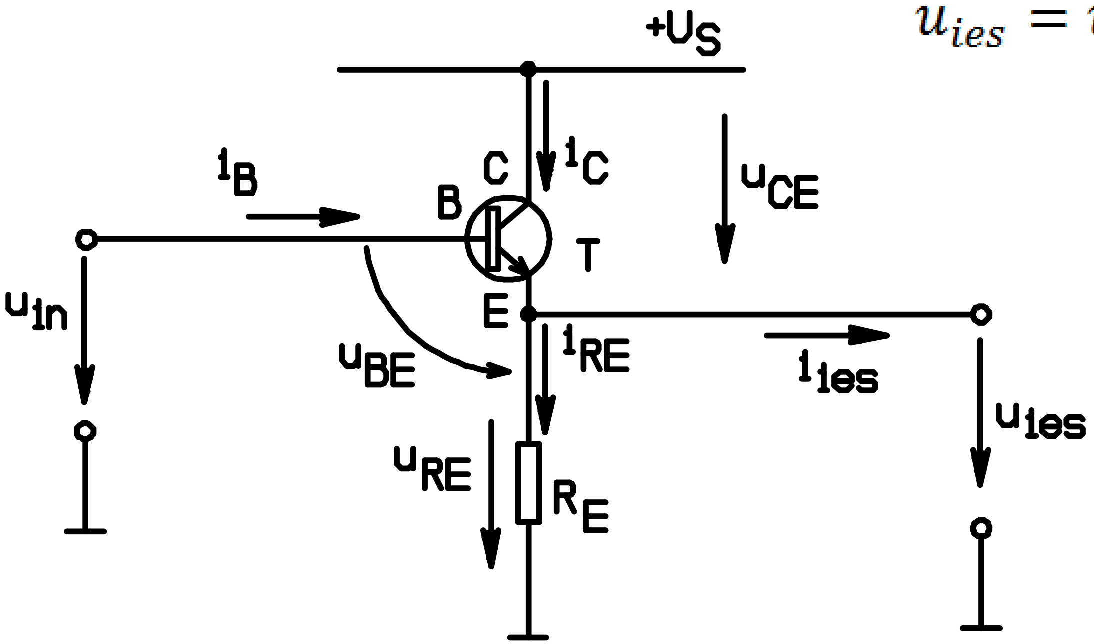
$$r_{in} = r_{BE}$$

$$r_{ies} = R_C \times r_{CE} \approx R_C$$



Circuite simple cu tranzistoare bipolare

- Amplificatorul in conexiune colector comun:
  - Circuitul repetor pe emitor.
  - Circuitul de adaptare de impedanta.
  - Amplificatorul de curent.



$$u_{ies} = u_{in} - U_{BE} \approx u_{in} - 0.6 \approx u_{in}$$

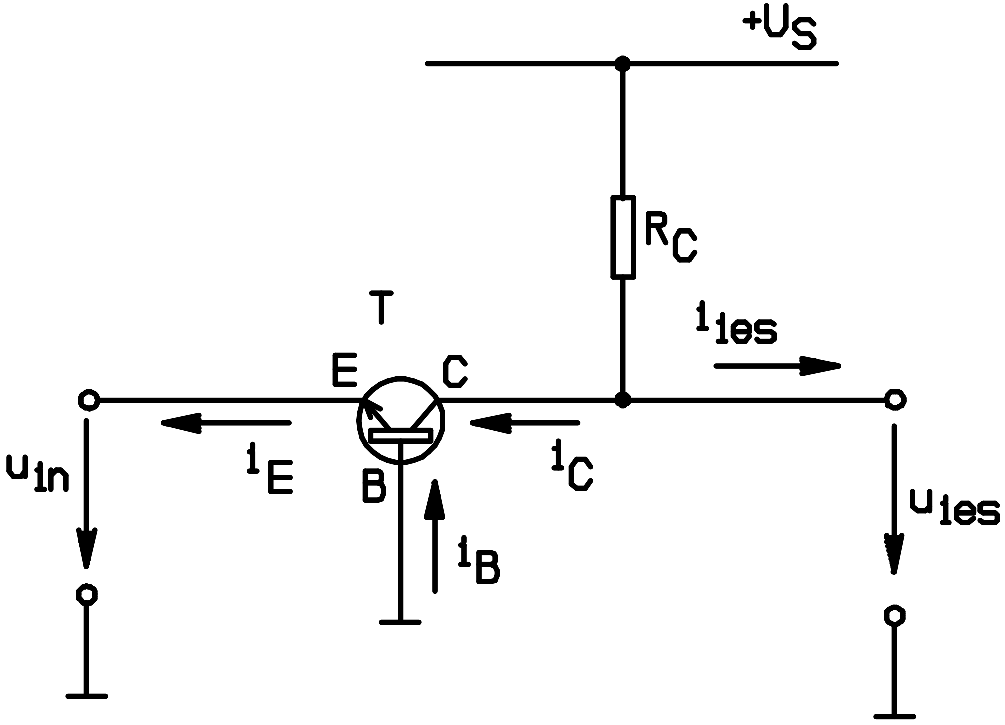
$$A = \frac{u_{ies}}{u_{in}} = \frac{du_{ies}}{du_{in}} \approx 1$$

$$r_{in} = r_{BE} + \beta R_E$$

$$r_{ies} = R_E \times \frac{r_{BE}}{\beta}$$

Circuite simple cu tranzistoare bipolare

- Amplificatorul de tensiune cu tranzistor bipolar in conexiune baza-comuna.
  - Factorul de amplificare in curent este unitar



$$u_{in} = -u_{BE}$$

$$A = -\beta \frac{R_C \times r_{CE}}{r_{BE}} \approx -\beta \frac{R_C}{r_{BE}}$$

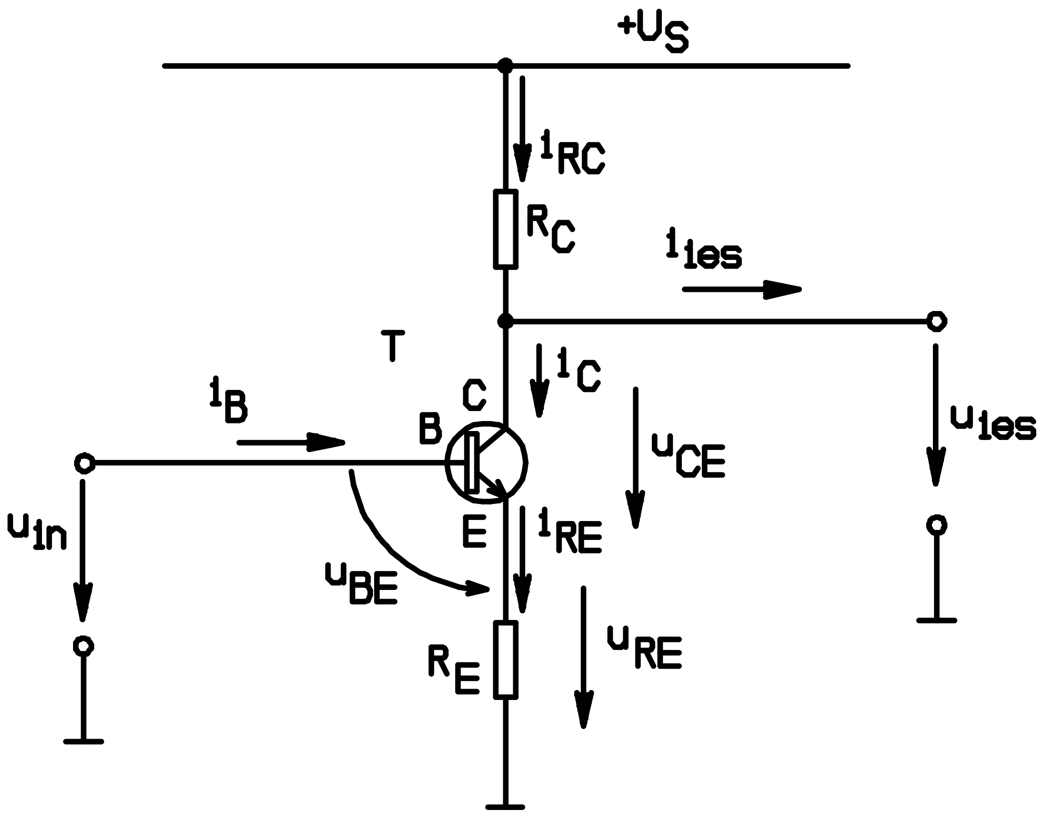
$$r_{in} = \frac{r_{BE}}{\beta}$$

$$r_{ies} = R_C \times r_{CE} \approx R_C$$

$$\alpha = \frac{di_C}{di_E} = \frac{\beta di_B}{(1+\beta)di_B} = \frac{\beta}{1+\beta} \approx 1$$

Circuite simple cu tranzistoare bipolare

- Si inca o data acelasi amplificator de tensiune, dar cu reactie negativa de curent !



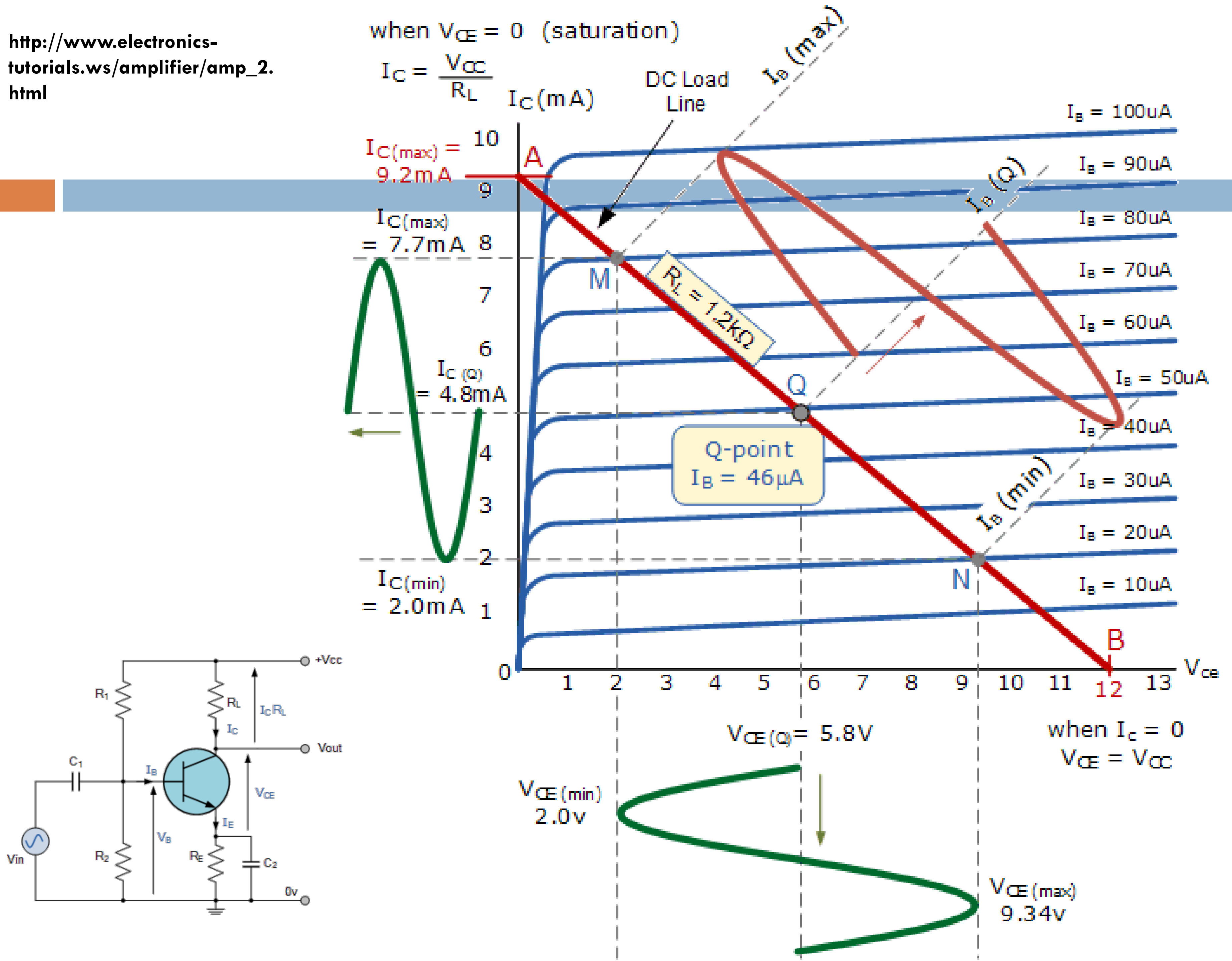
$$\frac{1}{A_b} = -\frac{1}{A_U} - \frac{R_E}{R_C}$$

$$A_U = -\beta \frac{R_C \times r_{CE}}{r_{BE}}$$

$$r_{in} = r_{BE} + \beta R_E$$

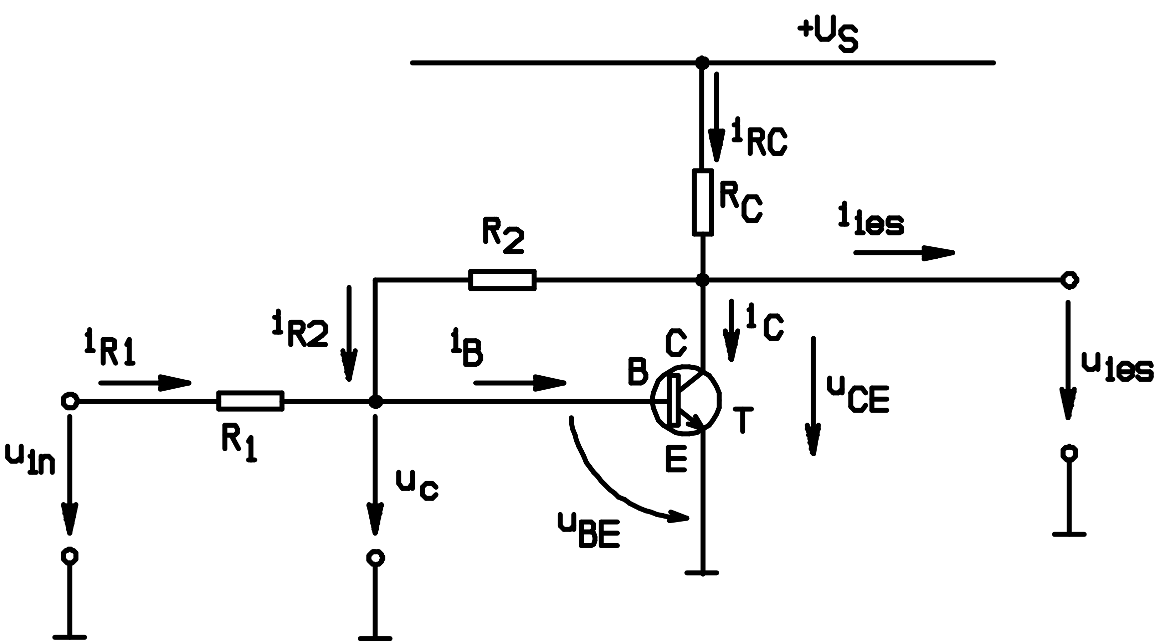
$$r_{ies} \approx -R_C$$

http://www.electronics-tutorials.ws/amplifier/amp_2.html



Circuite simple cu tranzistoare bipolare

- Acelasi amplificator prevazut insa cu reactie negativa de tensiune.



$$A_b = -\frac{R_2}{R_1}$$

$$\frac{1}{A_b} = -\frac{1}{A_U} - \frac{R_1}{R_2}$$

$$A_U = -\beta\frac{R_C \times r_{CE} \times R_2}{R_1 + r_{BE}}$$

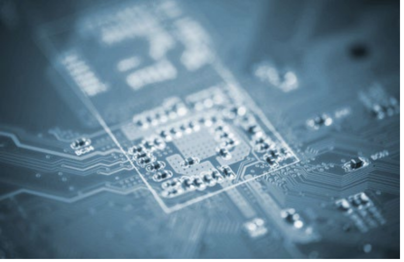
$$g = \frac{A_U}{A_b}$$

$$r_{in} = R_1 + \left(r_{BE} \times \frac{R_1}{A_U}\right) \approx R_1$$

$$r_{ies} = \frac{1}{g}(R_C \times r_{CE} \times R_2)$$

Circuite simple cu tranzistoare bipolare

- Etc., etc. !
- La momentul oportun vom vedea cum, combinind circuitele prezentate vom analiza amplificatoarele cu mai multe etaje.

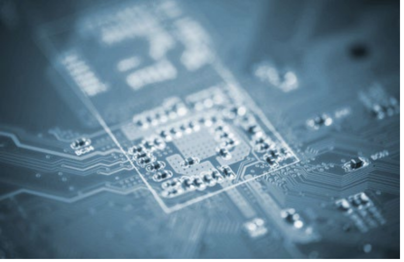


Amplificatoare electronice

- Categorie foarte importanta de circuite electronice caracterizate de proprietatea ca la iesire genereaza un semnal mai mare decit semnalul aplicat la intrare

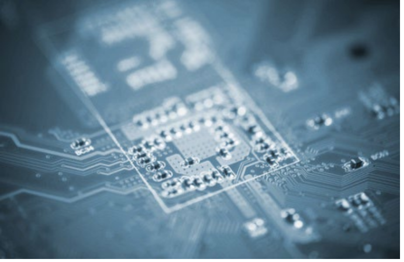
$$u_e(t) = Au_i(t)$$

- Foarte important: Este de dorit ca factorul A, numit factor sau coeficient de amplificare, sa fie o constanta scalara !



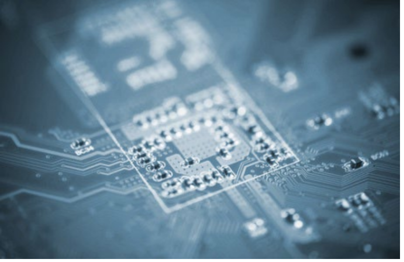
Amplificatoare electronice

- Clasificari:
  - Dupa tipul dispozitivelor electronice folosite
  - In functie de plasarea punctului static de functionare al dispozitivelor folosite
  - In functie de marimea amplificata
  - Dupa domeniul frecventelor de lucru
  - Din punctul de vedere al gamei de frecvente amplificate



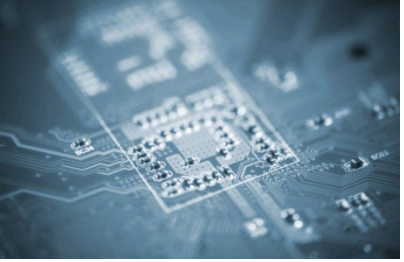
Amplificatoare electronice

- Performantele de interes general ale amplificatoarelor:
  - coeficientul de amplificare
  - sensibilitatea amplificarii
  - raportul semnal/zgomot
  - gama dinamica
  - caracteristica de frecventa
  - coeficientul de distorsiuni



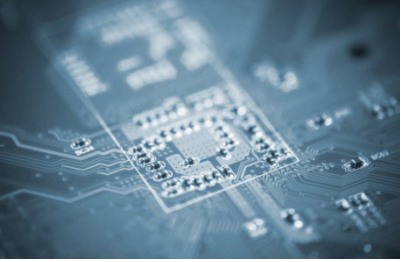
REACTIA IN CIRCUITUL AMPLIFICATOARELOR ELECTRONICE

- Transforma amplificatorul electronic dintr-un sistem de comanda a tensiunii de iesire intr-un sistem de reglare a tensiunii de iesire.



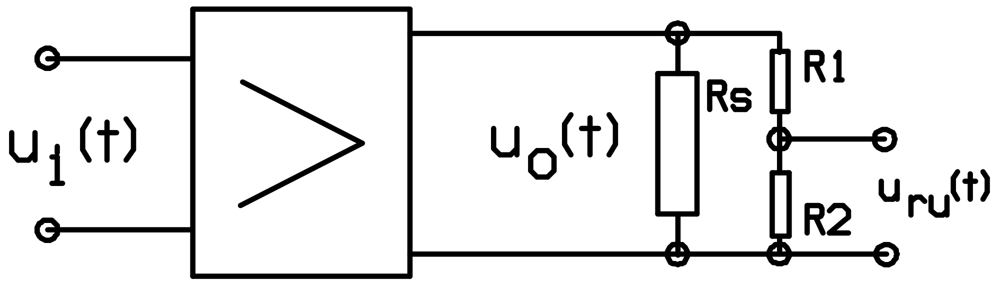
Amplificatoare electronice

- In ce consta ?
  - Aplicarea unei parti din marimea de iesire, numita marime de reactie, la intrarea circuitului, prin insumare sau scadere din marimea de intrare.
- Cum se aplica ?
  - Prin insumare: reactie pozitiva
  - Prin scadere: reactie negativa

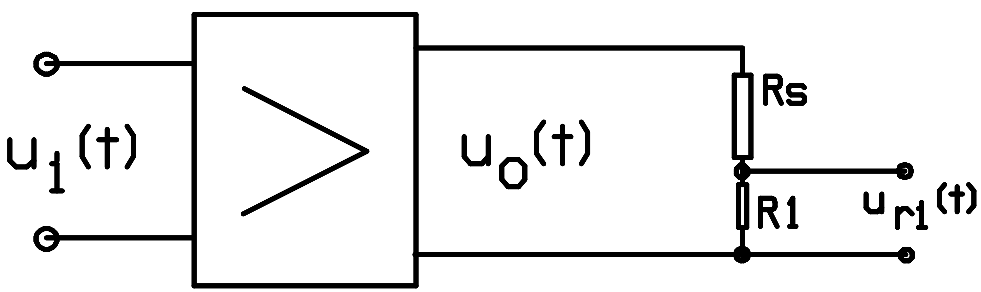


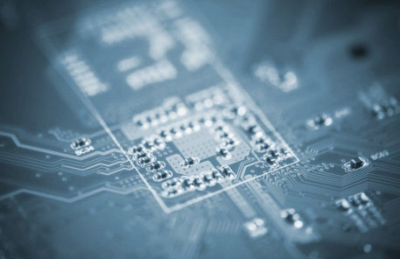
Amplificatoare electronice

- Masurarea marimii de reactie de tensiune . Divizor rezistiv de tensiune



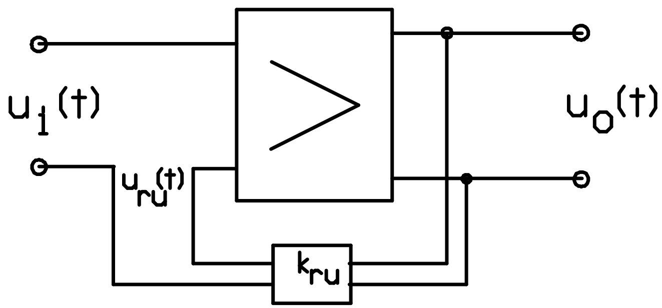
- Masurarea marimii de reactie de curent
  - Sunt cu rezistenta ohmica mica. Marimea de reactie este o tensiune proportionala cu curentul masurat !



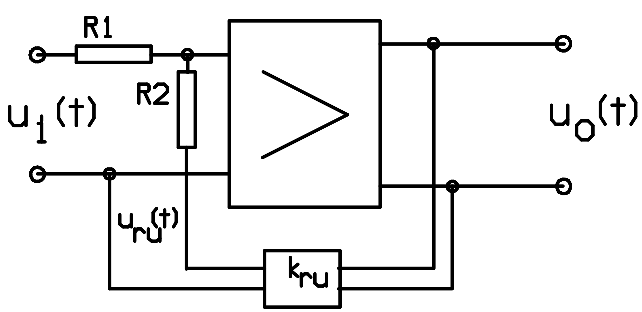


Amplificatoare electronice

- Amplificator electronic cu reactie serie de tensiune

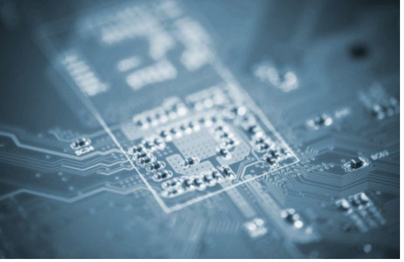


- Amplificator electronic cu reactie paralel de tensiune.

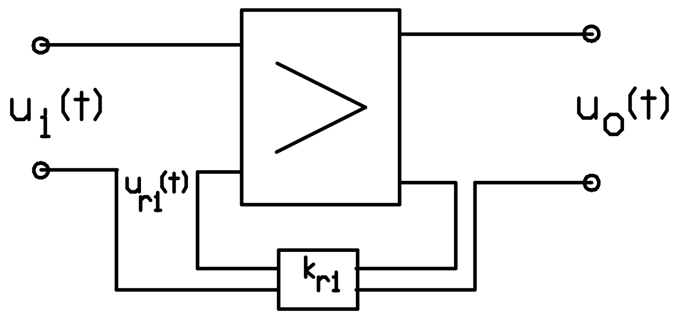


  - Cele doua rezistente sunt necesare deoarece nu putem lega in paralel in mod direct doua surse de tensiune !

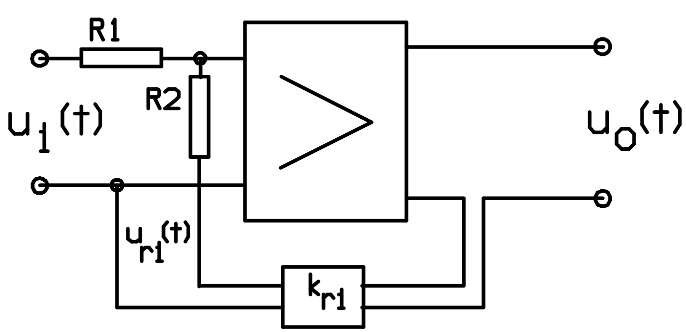
- Sursa de tensiune….sursa de curent

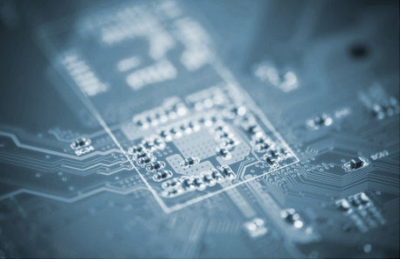


- Amplificator electronic cu reactie serie de curent.



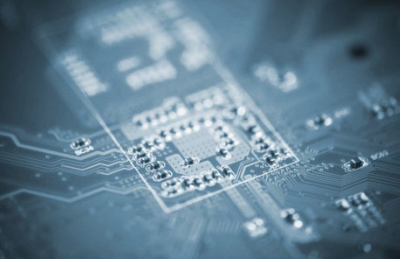
- Amplificator electronic cu reactie paralel de curent.





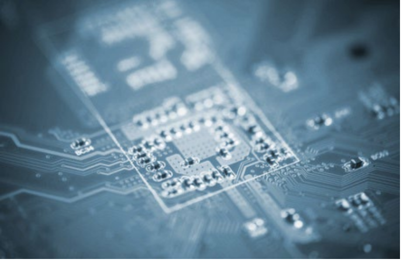
- **FACTORUL DE AMPLIFICARE AL AMPLIFICATOARELOR CU REACTIE :**

$$A_b = \frac{A}{1 \pm k_r A}$$



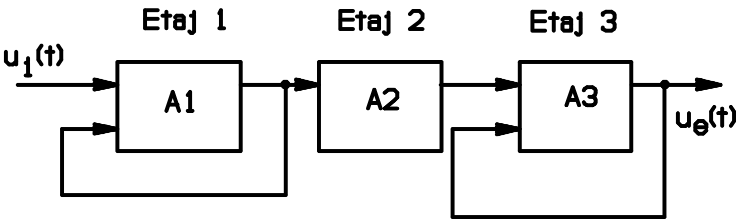
Amplificatoare electronice

- Performante generale:
  - **Reactia pozitiva**
    - mareste factorul de amplificare
    - favorizeaza instabilitatea si mareste coeficientul de distorsiuni
    - sta la baza circuitelor oscilatoare
  - **Reactia negativa**:
    - micsoreaza factorul de amplificare
    - stabilitatea circuitului creste
    - distorsiunile scad
    - pentru A foarte mare, A_b depinde numai de circuitul de reactie !!!!

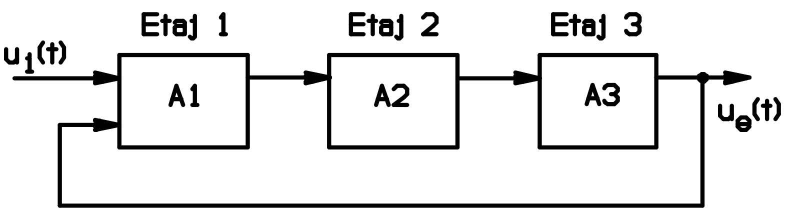


Amplificatoare electronice

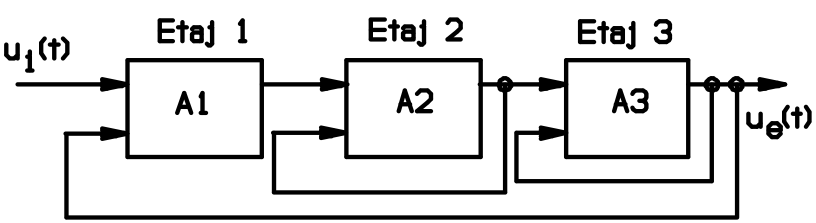
- Amplificator electronic cu mai multe etaje, cu reactii negative locale.



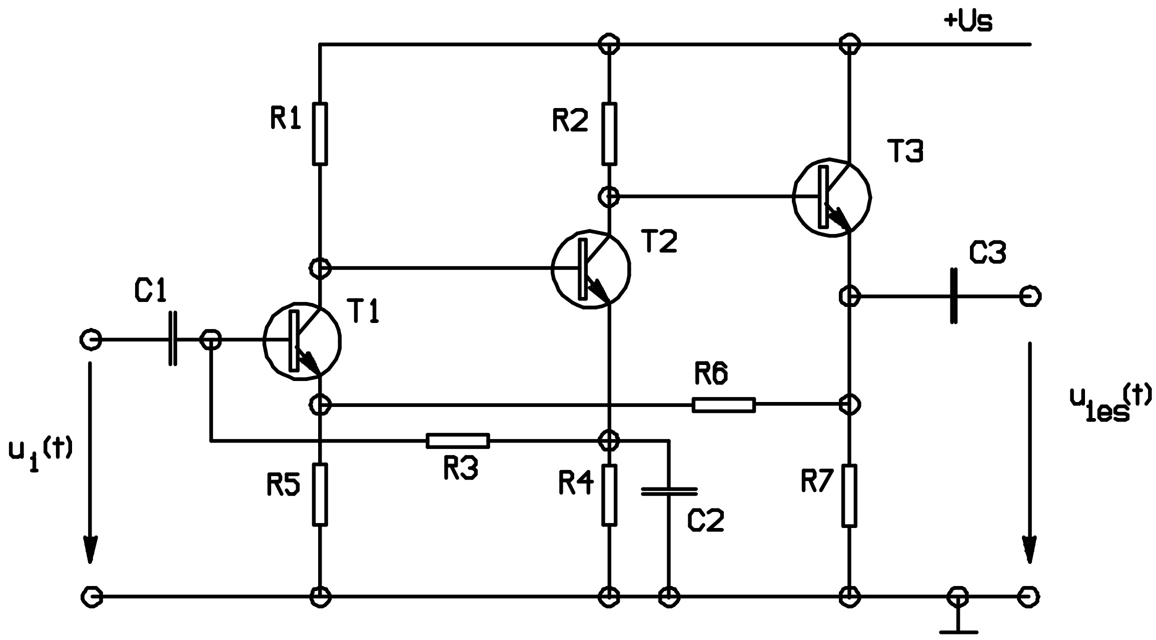
- Amplificator electronic cu mai multe etaje, prevazut cu reactie negativa globala.



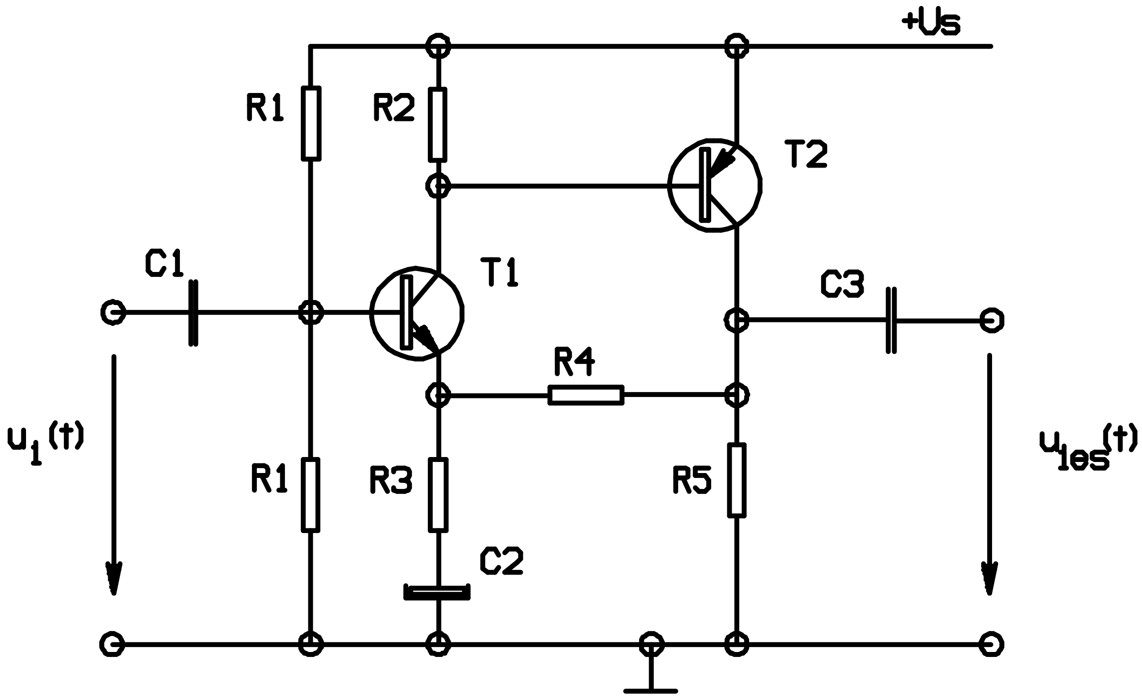
- Amplificator electronic cu mai multe etaje, cu reactie mixta

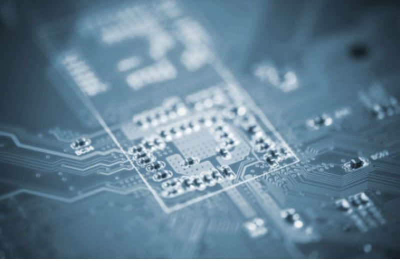


- Exemplu 1. Amplificator cu doua etaje, cu reactie negativa globala serie de tensiune.
  - Polarizarea se face tot cu reactie negativa dar de tip paralel de curent.

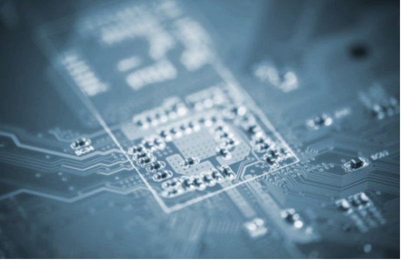


- Exemplul 2: Amplificator cu tranzistoare complementare si reactie negativa globala de tensiune.
  - Cum se poate transforma circuitul intr-un amplificator cu tranzistor compus ?





- # CONCLUZII:
  - majoritatea circuitelor sunt in conexiune EC sau SC.
  - stabilitatea termica a circuitelor ridica probleme dificile.
  - pentru amplificari mari avem nevoie de multe etaje - apar atunci probleme de cuplare, atenuari sau defazari nedorite si probleme de stabilitate !
- ## Solutia: Amplificatoarele operationale!!

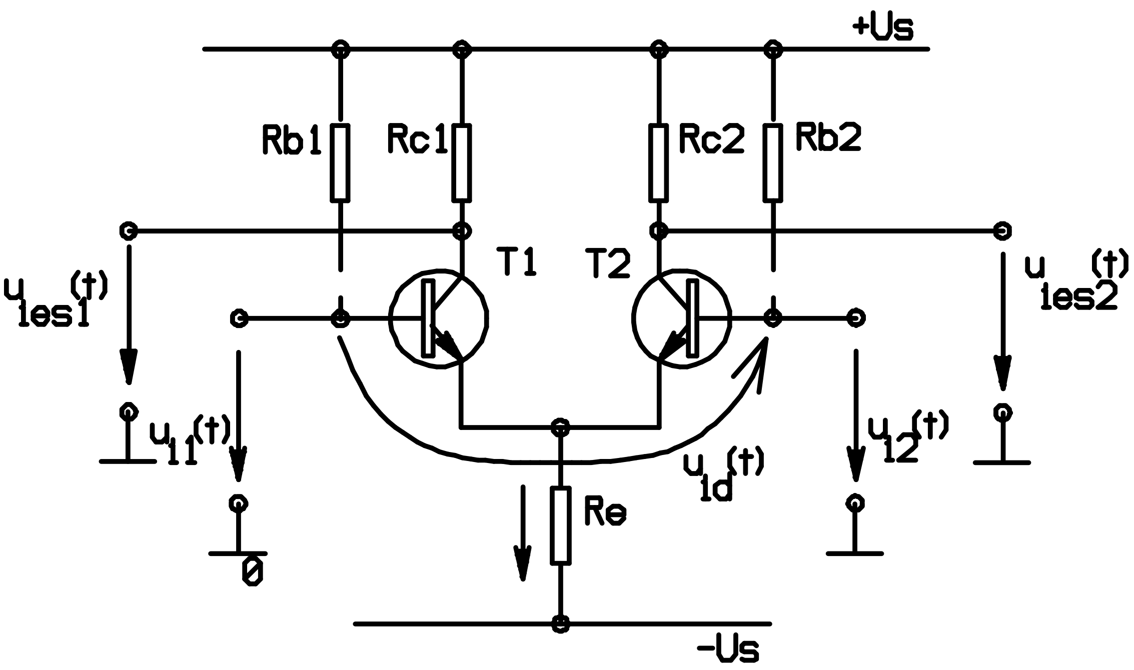


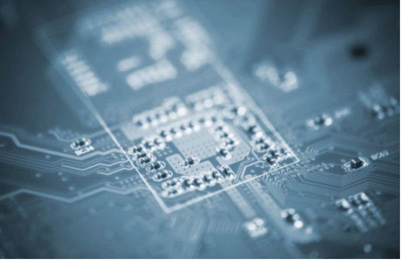
Amplificatoare diferentiale

- Pentru inceput: amplificatoarele diferentiale !
- De ce ?
  - Fiindca sunt niste circuite electronice speciale care au proprietatea de a prelucra semnalele aplicate intre sau la intrari in mod diferentiat.
  - Cu amplificatoarele diferentiale se pot dezvolta amplificatoare electronice superioare celor cu mai multe etaje, chiar si prevazute cu reactii.

Amplificatoare diferentiale

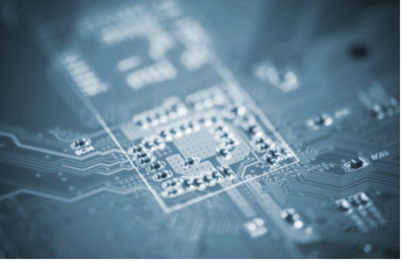
- Amplificator diferential cu tranzistoare bipolare





Amplificatoare diferentiale

- Amplificatoarele diferentiale se folosesc, ca etaje de sine statatoare, relativ rar.
- Cunoasterea lor ne permite insa sa trecem la investigarea **amplificatoarelor operationale !**

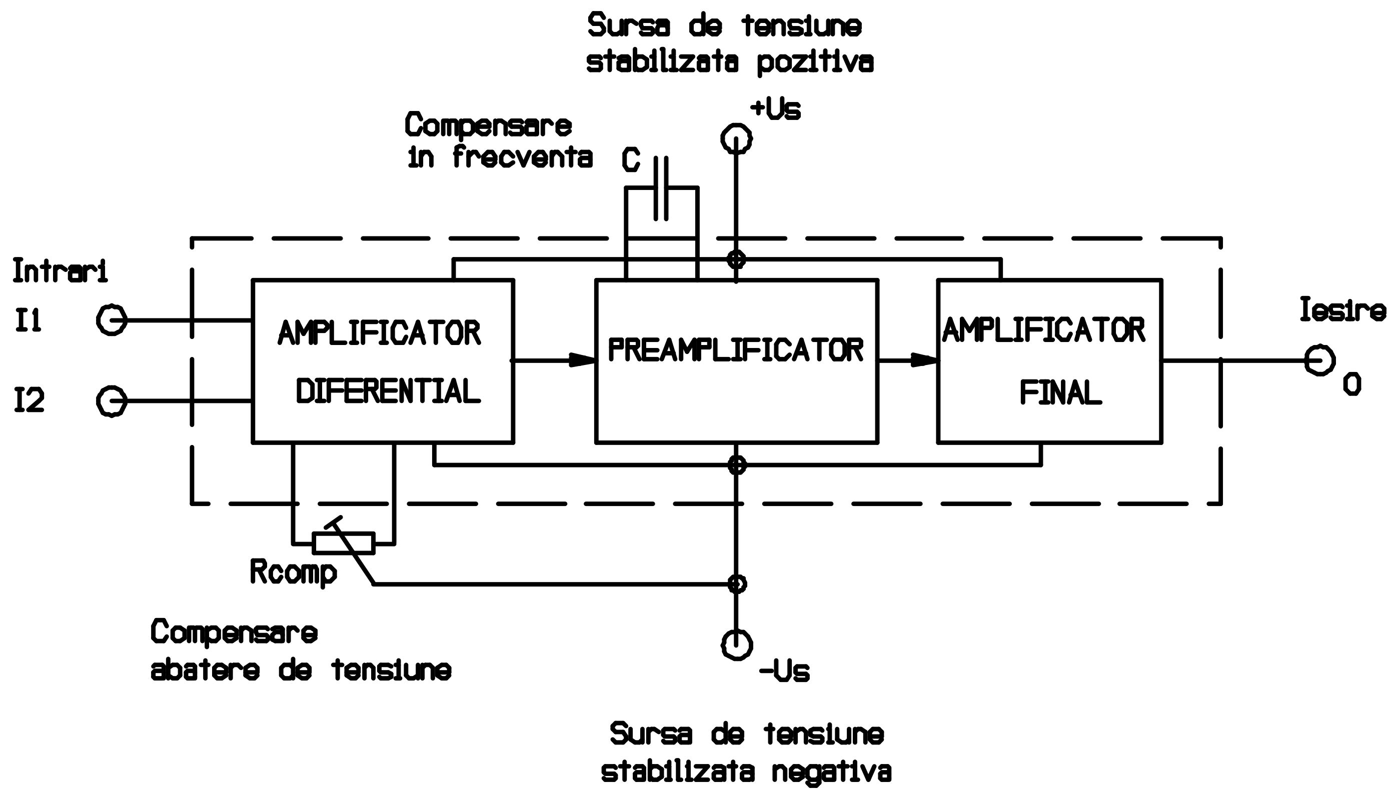


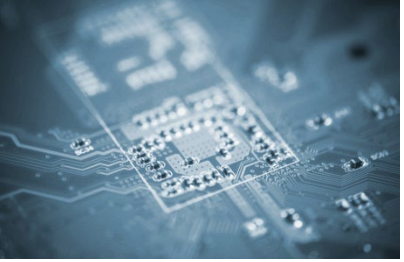
Amplificatoare operationale

- Ce este un amplificator operational ?
  - Este un amplificator electronic cu mai multe etaje, dintre care primul este totdeauna un amplificator diferential.
  - Cuplarea dintre etaje este directa, ca urmare caracteristicile de frecventa sunt bune, in masura in care nu utilizam circuitul la frecvente atit de mari incit capacitatile parazite si cele asociate jonctiunilor sa nu mai poata fi neglijate.
  - Amplificatorul operational este un amplificator in bucla deschisa, deci nu prezinta reactii interne.

Amplificatoare operationale

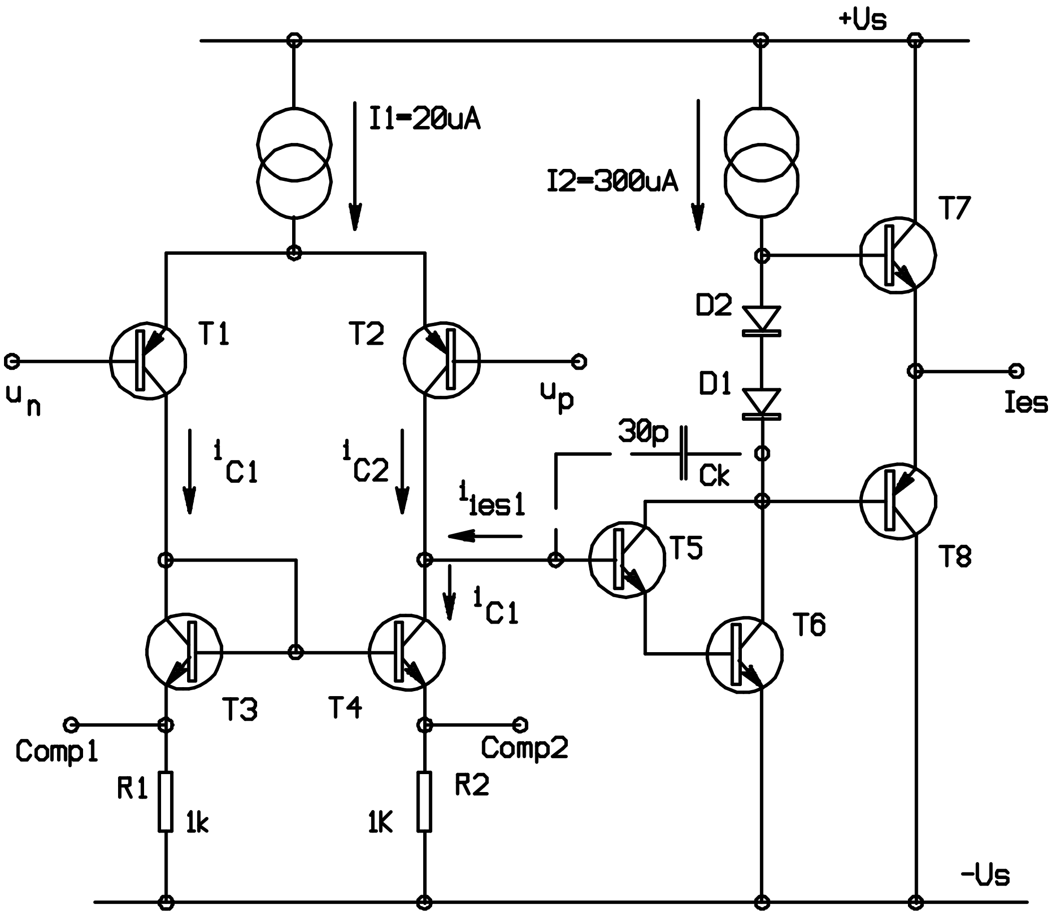
- Amplificatorul operational. Schema bloc generala.





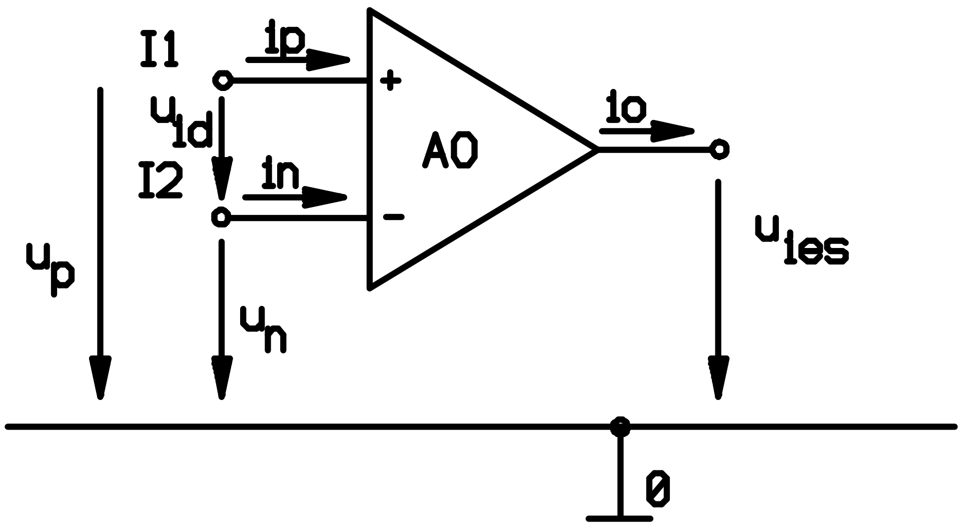
Amplificatoare operationale

- AO integrat 741, implementat cu succes si in prezent!



Amplificatoare operationale

- Amplificatorul operational.
  - Simbol. Functiune electronica.

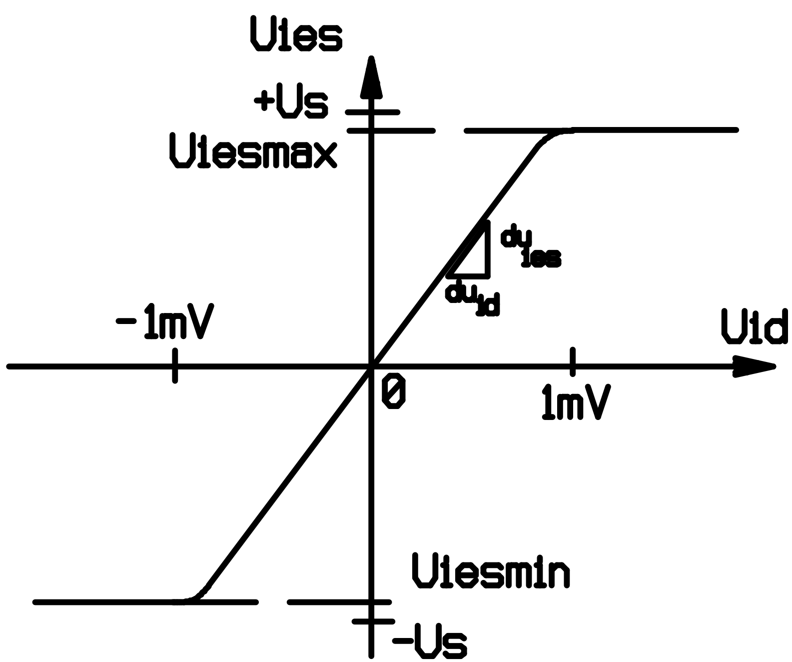


$$u_{ies} = A_D . u_{id}$$

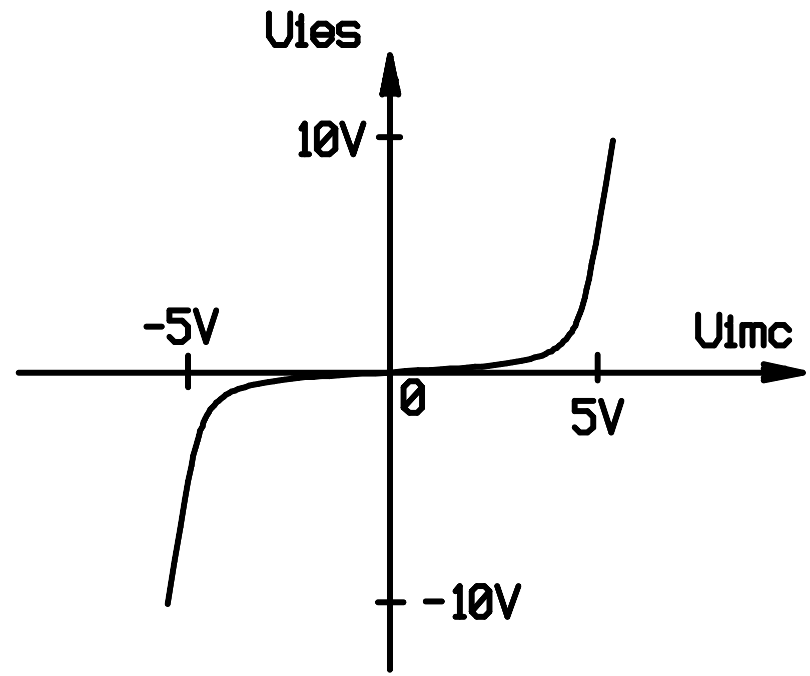
$$u_{ies} = A_D .(u_p - u_n)$$

$$A_D = \frac{u_{ies}}{u_{id}} = \frac{u_{ies}}{u_p - u_n} = \begin{cases} -\dfrac{u_{ies}}{u_n} & u_p = 0 \\ +\dfrac{u_{ies}}{u_p} & u_n = 0 \end{cases}$$

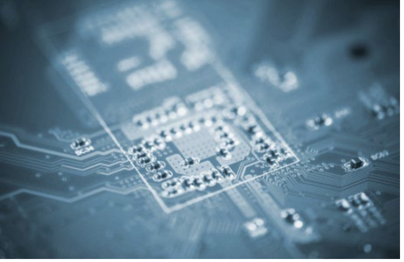
- Amplificatorul operational. Caracteristici statice.



Semnale diferentiale de intrare



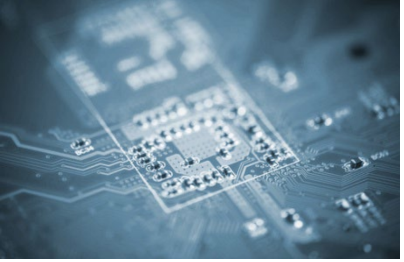
Semnale de mod comun de intrare.



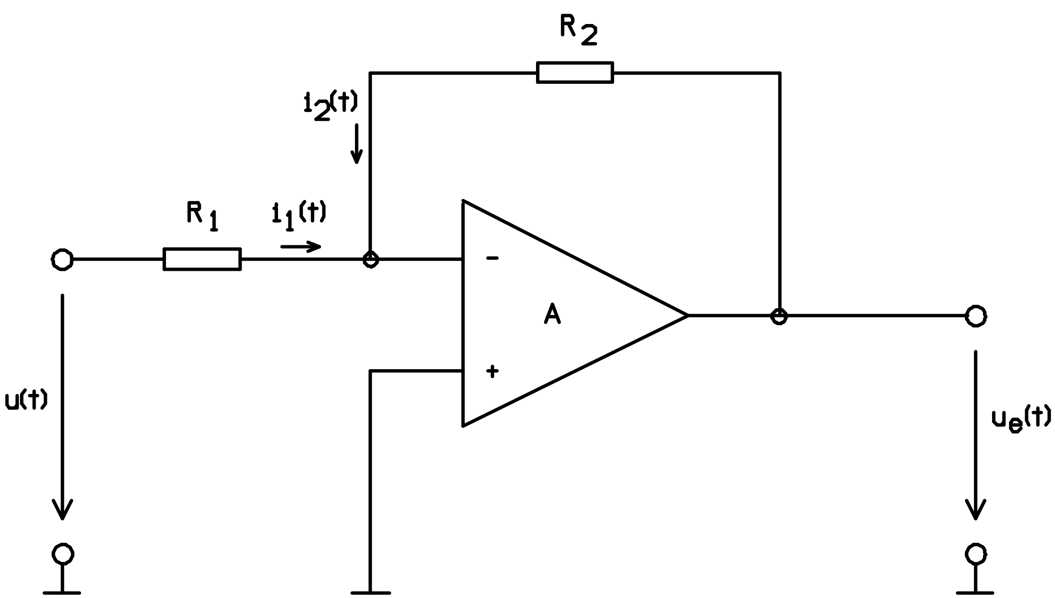
Amplificatoare operationale

- Ipotezele simplificatoare de calcul.

Nr Crt	Caracteristica	AO741	AO ideal
1	Coeficient de amplificare diferentiala	100.000	∞
2	Factorul de amplificare de mod comun	10	0
3	Factorul de atenuare al amplificarii de mod comun	10.000	∞
4	Rezistenta de intrare diferentiala	1MΩ	∞
5	Rezistenta de intrare de mod comun	1GΩ	∞
6	Curentul de intrare	50nA	0
7	Curentul de eroare la intrare	5nA	0
8	Curentul de iesire	±20mA	∞
9	Rezistenta de iesire	1kΩ	0



- Circuitul fundamental inversor



$$u_e(t) = 0\ ;\ \ t = 0$$

$$u_n = \frac{R_2}{R_1 + R_1}\,[u(t) - 0] > 0$$

$$u_i = u_p - u_n \quad = 0 - u_n \ < 0$$

$$i_1(t) + i_2(t) = 0$$

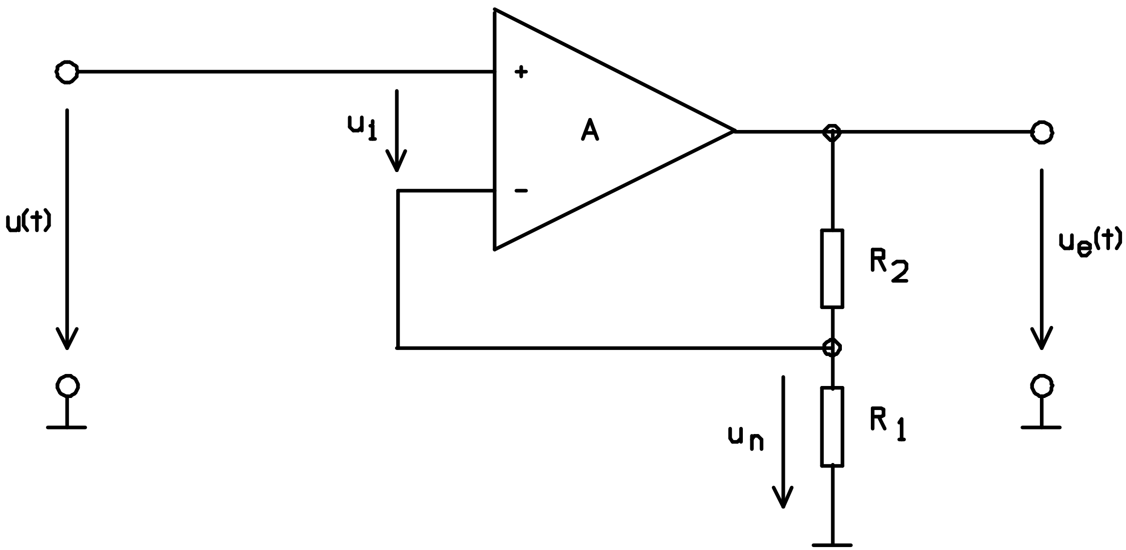
$$\frac{u(t)}{R_1} + \frac{u_e(t)}{R_2} = 0$$

$$\boxed{u_e(t) = -\frac{R_2}{R_1}u(t)}$$

$$A_b = -\frac{R_2}{R_1}$$

Amplificatoare operationale

- Circuitul fundamental neinversor



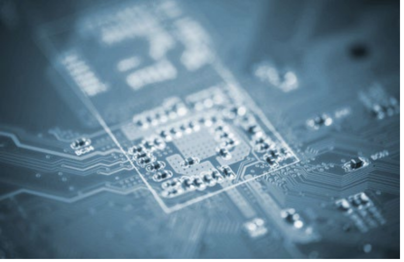
$$u_p = u(t)$$

$$u_n = \frac{R_1}{R_1 + R_2} u_e(t)$$

$$u_n = u_p$$

$$u_e(t) = \frac{R_1 + R_2}{R_1} \cdot u(t)$$

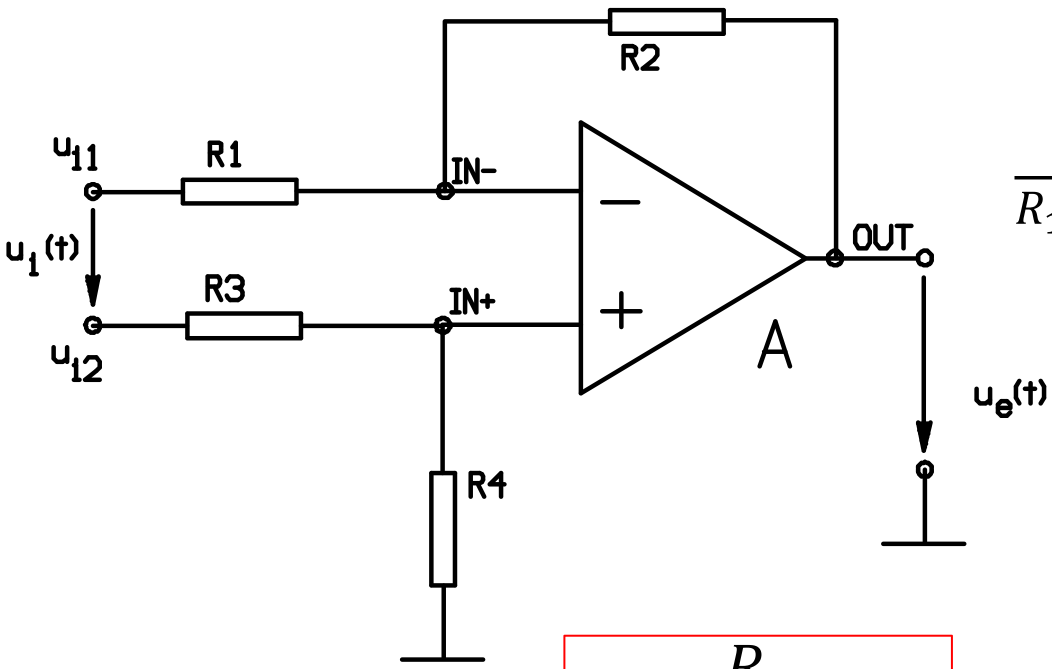
$$\boxed{u_e(t) = (1 + \frac{R_2}{R_1}) \cdot u(t)}$$



Amplificatoare operationale

- Circuitul fundamental deferential

$$u_n = u_p$$



$$u_e = \frac{R_2}{R_1} \cdot u_{id}$$

$$u_n = U_{R2} + u_e$$

$$u_n = \frac{R_2}{R_1 + R_2} \cdot (u_{i1} - u_e) + u_e$$

$$u_p = \frac{R_4}{R_4 + R_3} \cdot u_{i2}$$

$$\frac{R_2}{R_1 + R_2} \cdot (u_{i1} - u_e) + u_e = \frac{R_4}{R_4 + R_3} \cdot u_{i2}$$

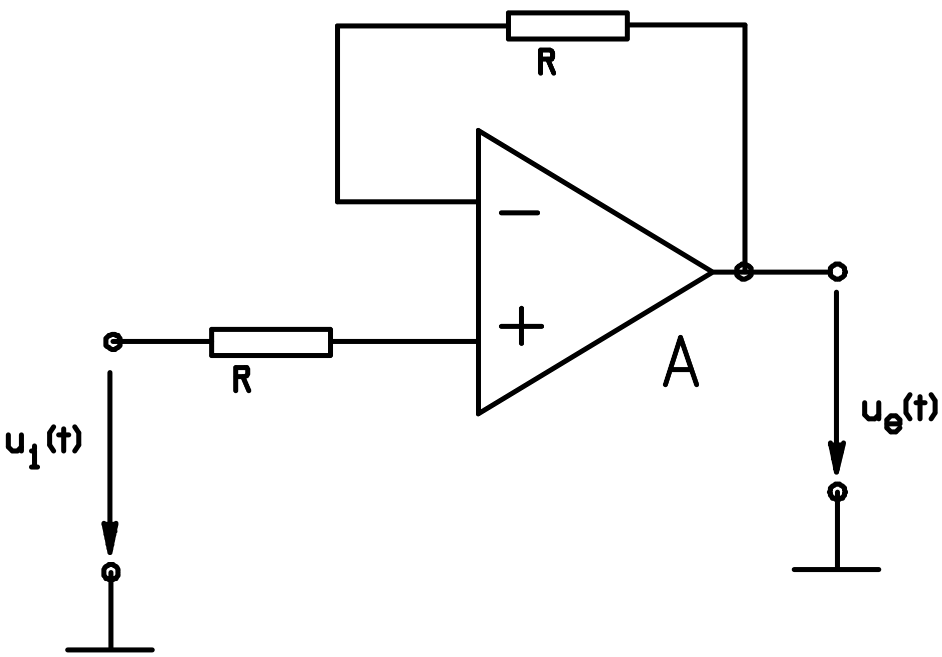
$$R_1 = R_3 \qquad R_2 = R_4$$

$$\frac{R_2}{R_1 + R_2} \cdot (u_{i1} - u_{i2}) = u_e \cdot (\frac{R_2}{R_1 + R_2} - 1)$$

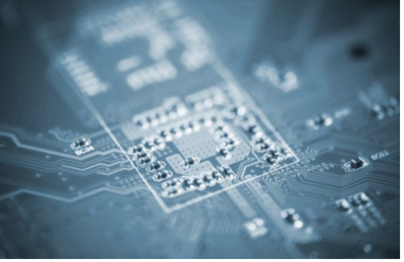
$$u_e = \frac{R_2}{R_1}(u_{i2} - u_{i1})$$

Amplificatoare operationale

- Circuitul fundamental repetor

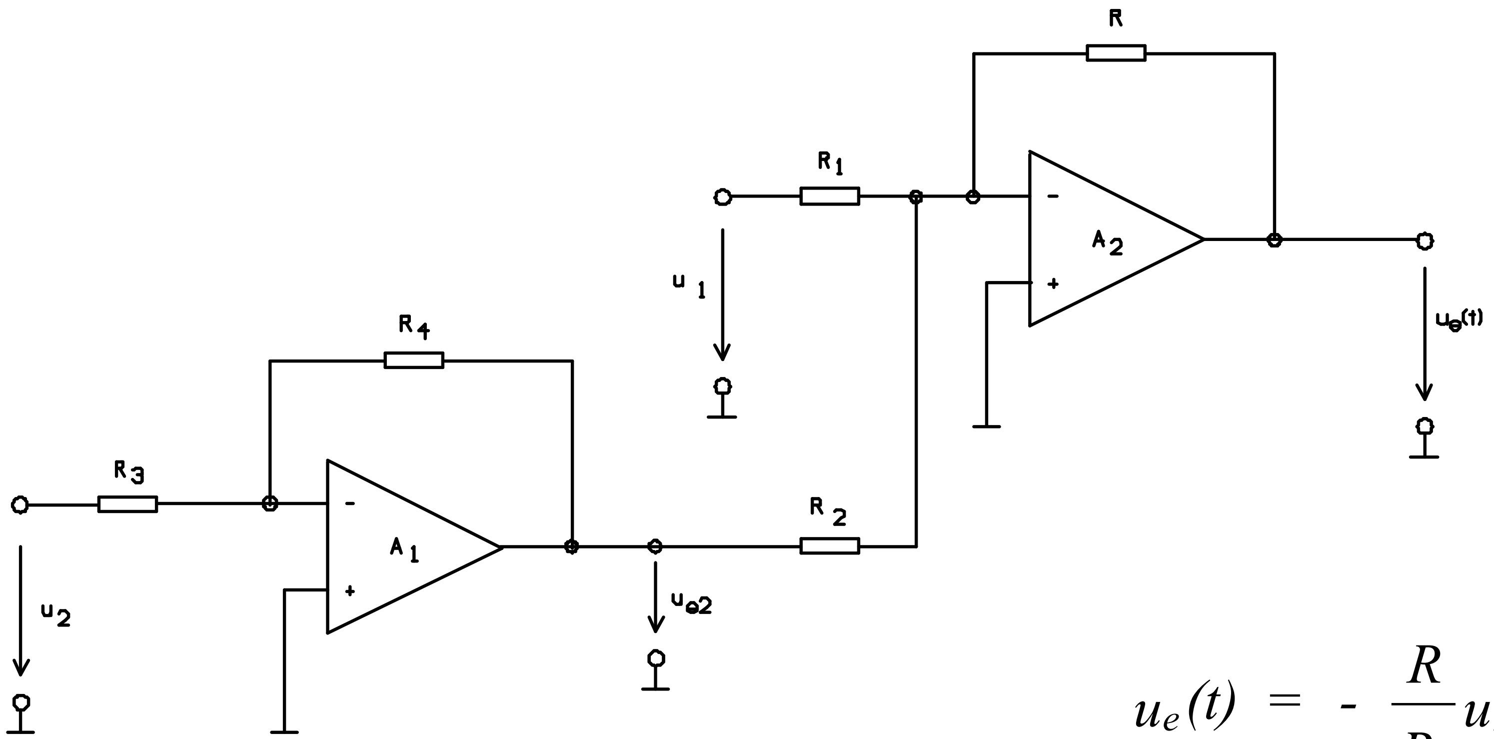


$$u_e(t) = u_i(t)$$



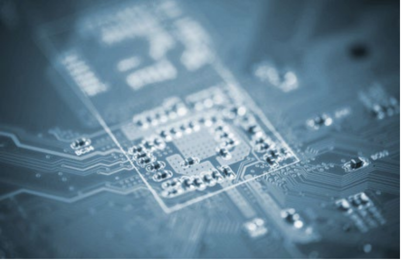
CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Circuitul de scadere cu doua amplificatoare operationale



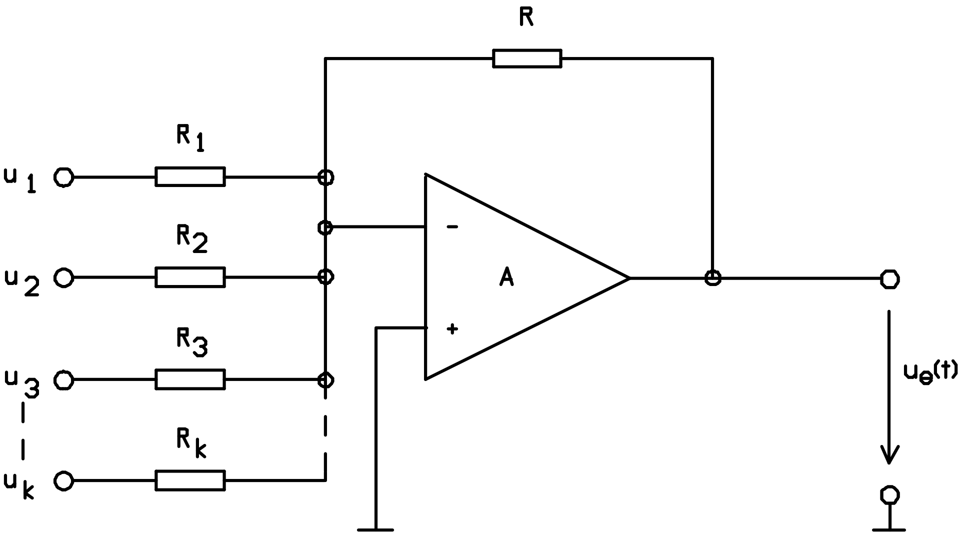
$$u_e(t) = -\frac{R}{R_1}u_1 + \frac{R}{R_2}\frac{R_4}{R_3}u_2$$

$$u_e(t) = -(u_1 - u_2)$$



CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

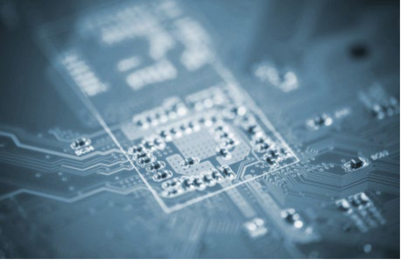
- Circuitul sumator-inversor cu mai multe intrari



$$u_e(t) = -(k_1 u_1 + k_2 u_2 + \ldots + k_k u_k)$$

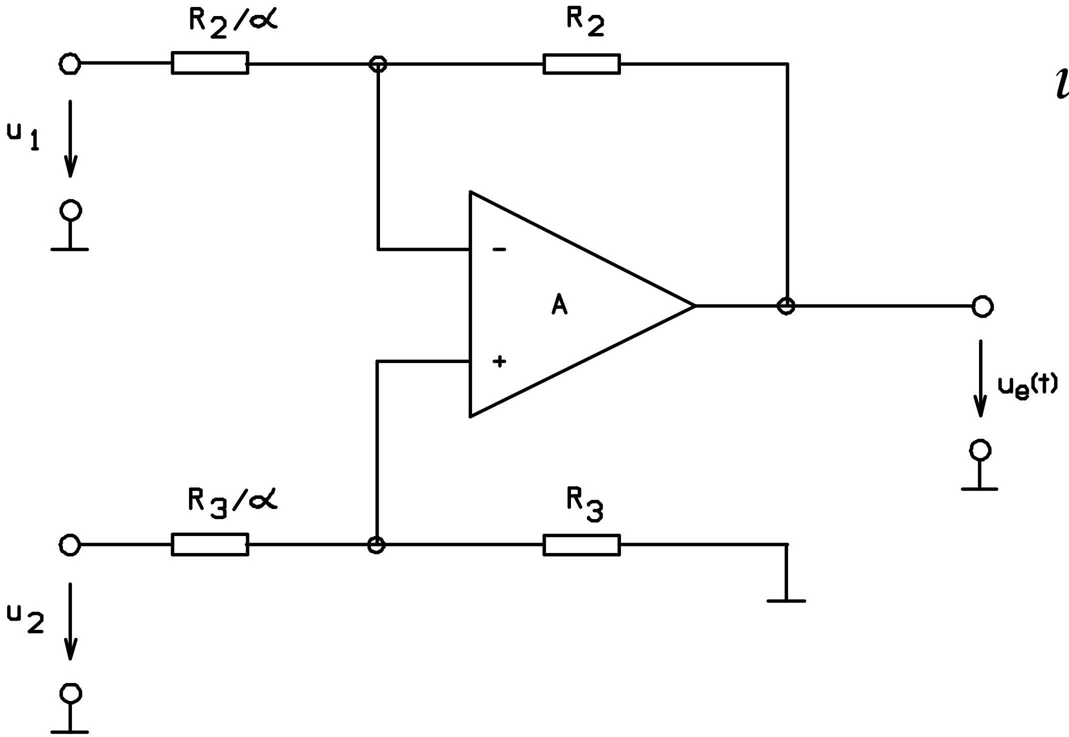
unde :

$$k_1 = \frac{R}{R_1}\ ;\ k_2 = \frac{R}{R_2}\ ;\ldots;\ k_k = \frac{R}{R_k}$$

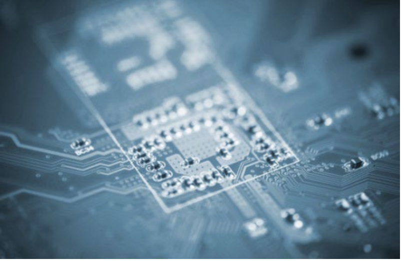


CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Circuit de scadere a doua semnale electrice construit in jurul unui singur amplificator operational. Aplicatii speciale in ingineria electrica.

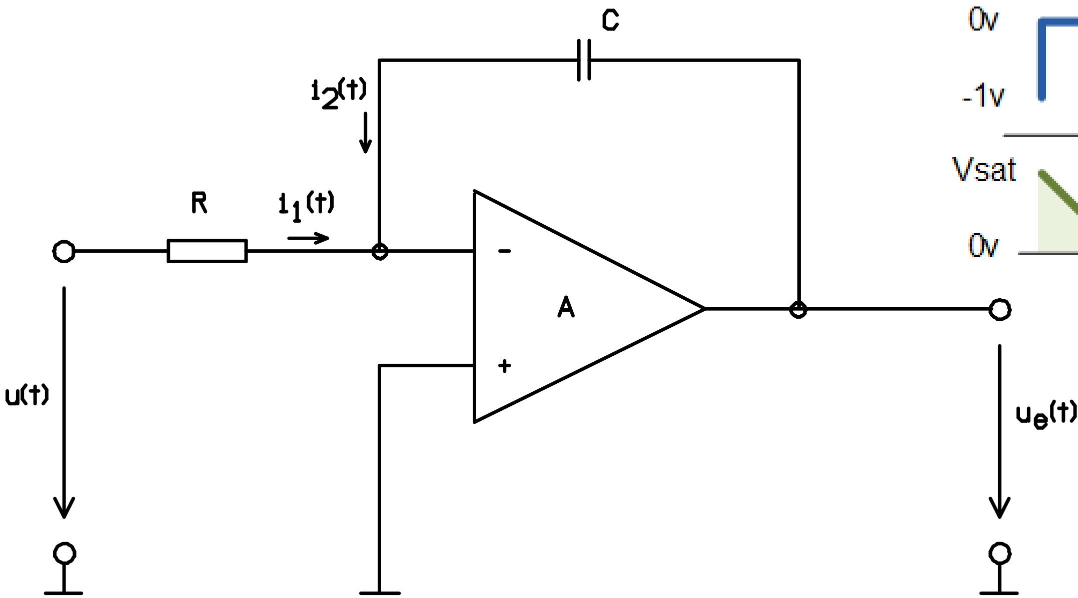


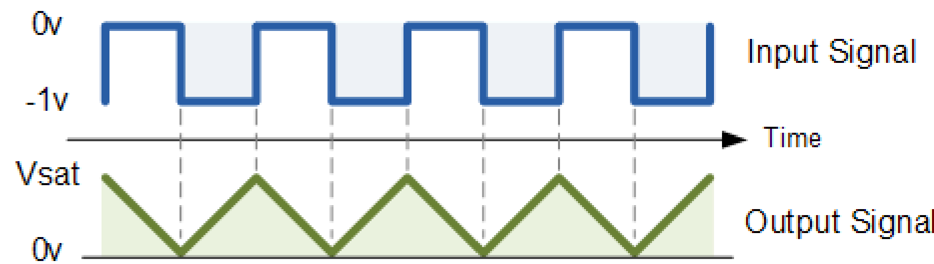
$$u_e(t) = -\alpha(u_1 - u_2)$$



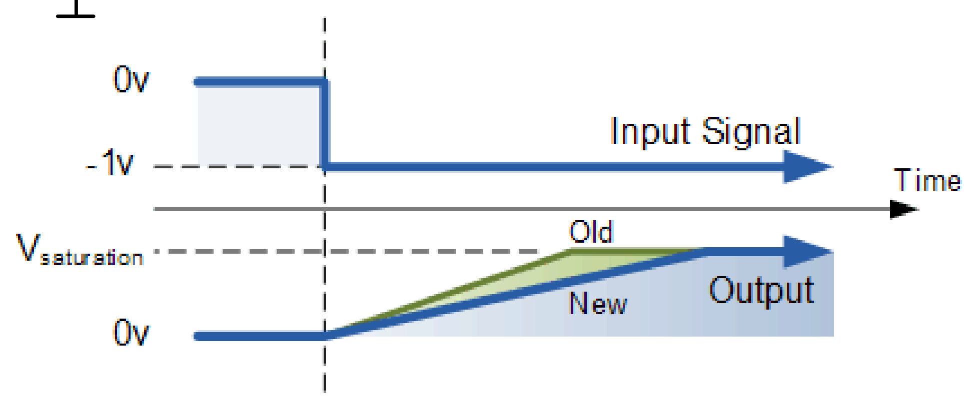
CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Cel mai simplu circuit de integrare cu AO



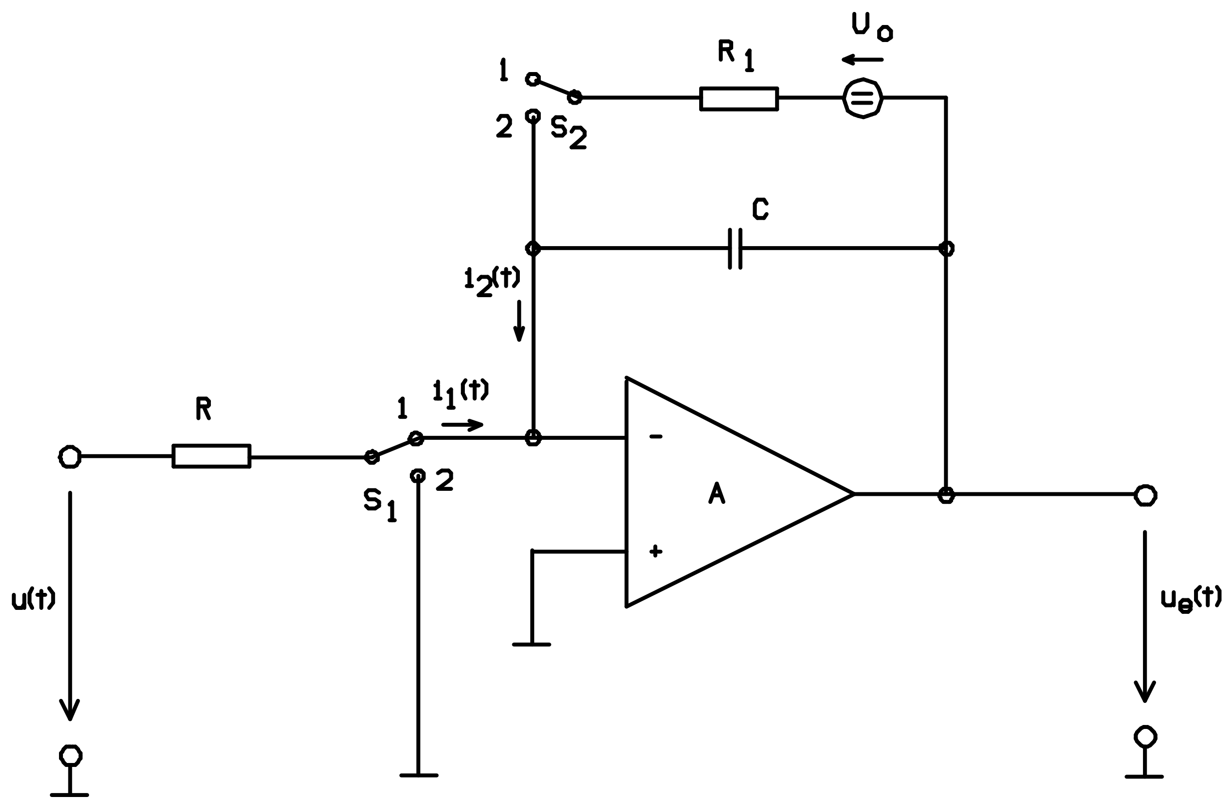


$$u_e(t) = -\frac{1}{RC}\int u(t)\,dt + U_{e0}$$



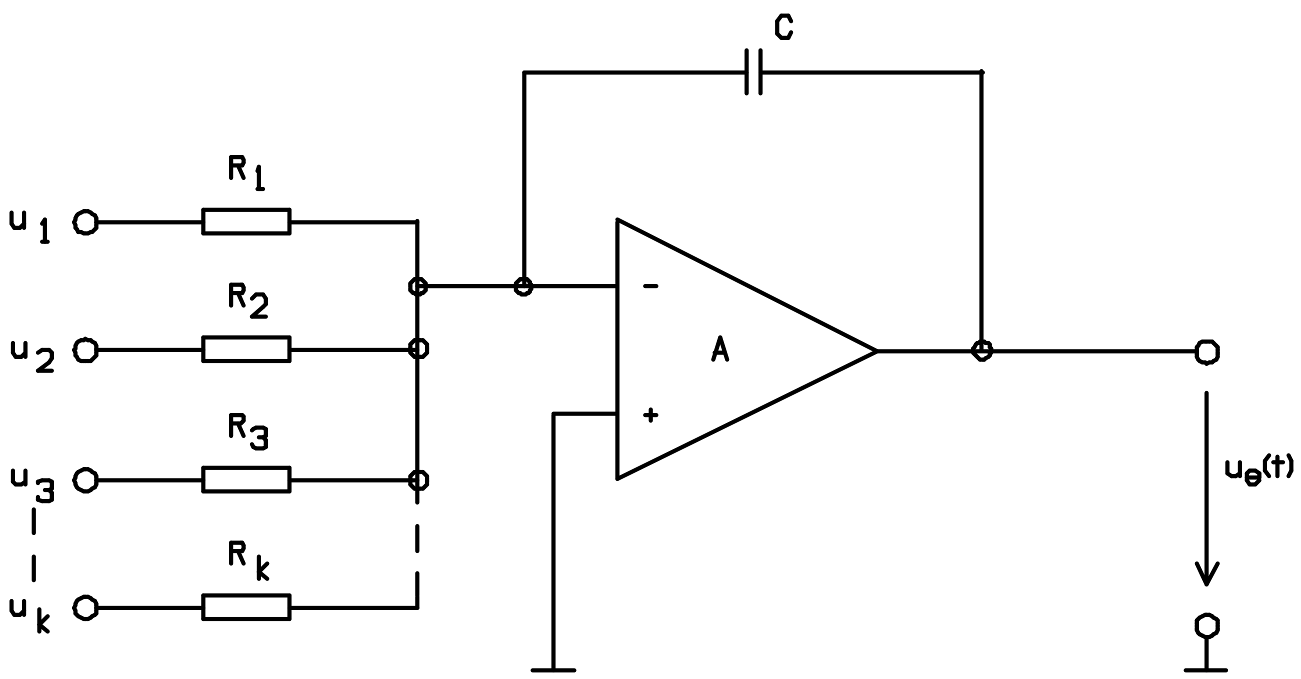
CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Circuitul de integrare profesional cu preluarea conditiilor initiale de la sursa de tensiune continua flotanta.



CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

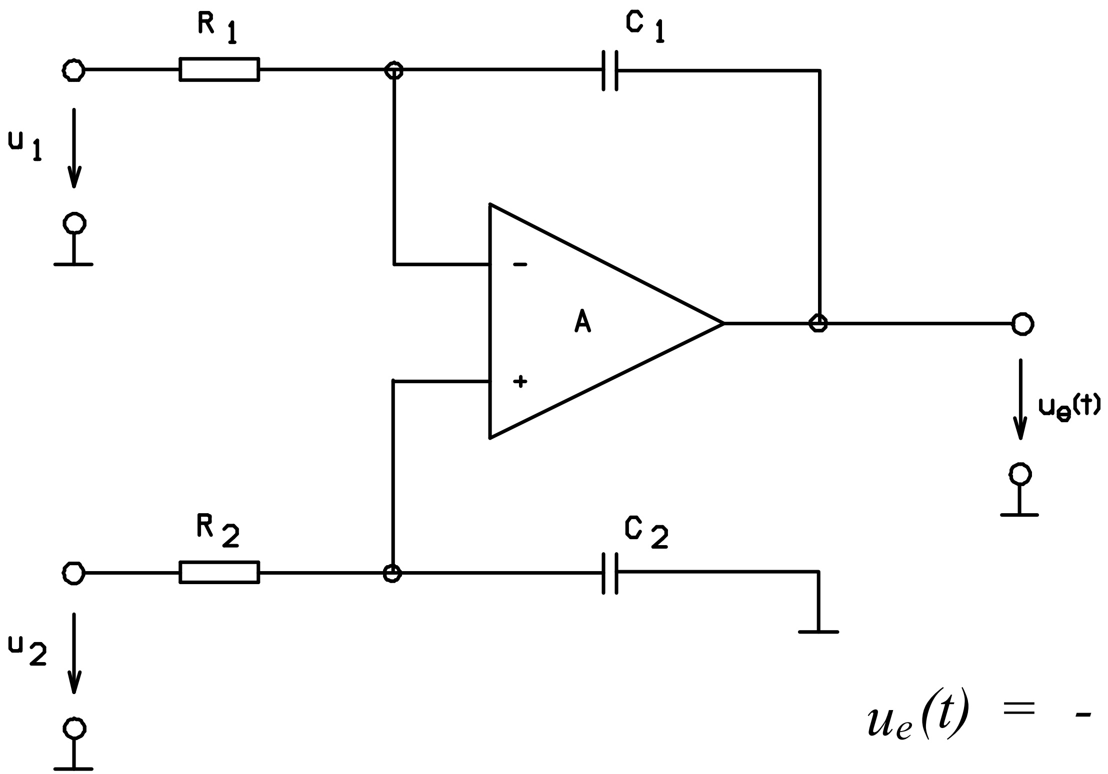
- Circuitul de integrare a sumei a mai multe semnale electrice continue.



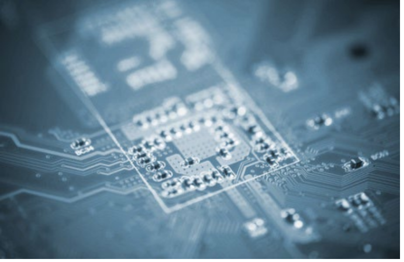
$$u_e(t) = -\frac{1}{C}\int\left(\frac{u_1}{R_1} + \frac{u_2}{R_2} + \ldots + \frac{u_k}{R_k}\right)dt + U_{e0}$$

CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Circuit de integrare a diferentei dintre doua semnale electrice. Aplicatie cu un singur amplificator operational

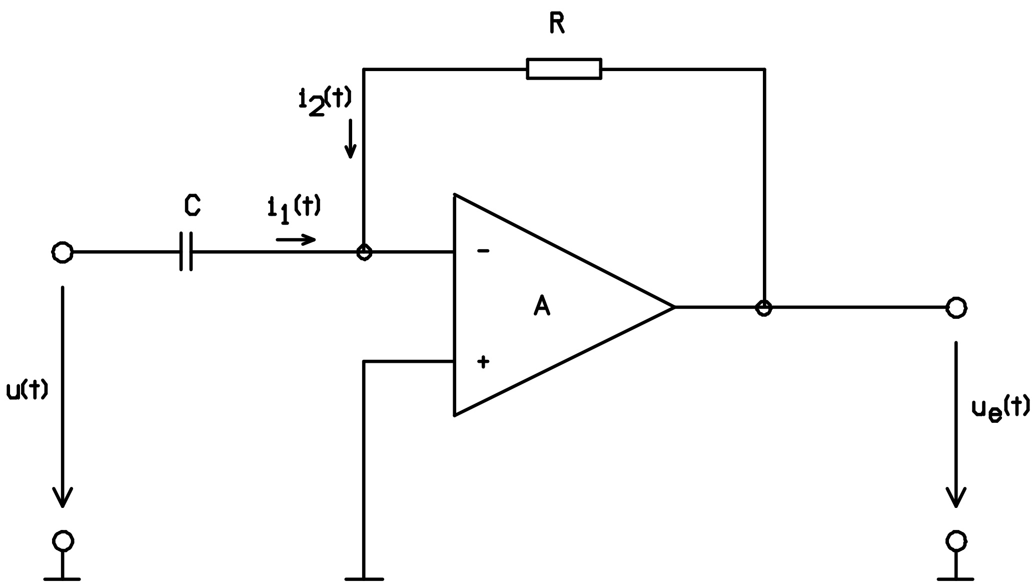


$$u_e(t) = -\frac{1}{RC}\int(u_1 - u_2)\,dt + U_{E0}$$

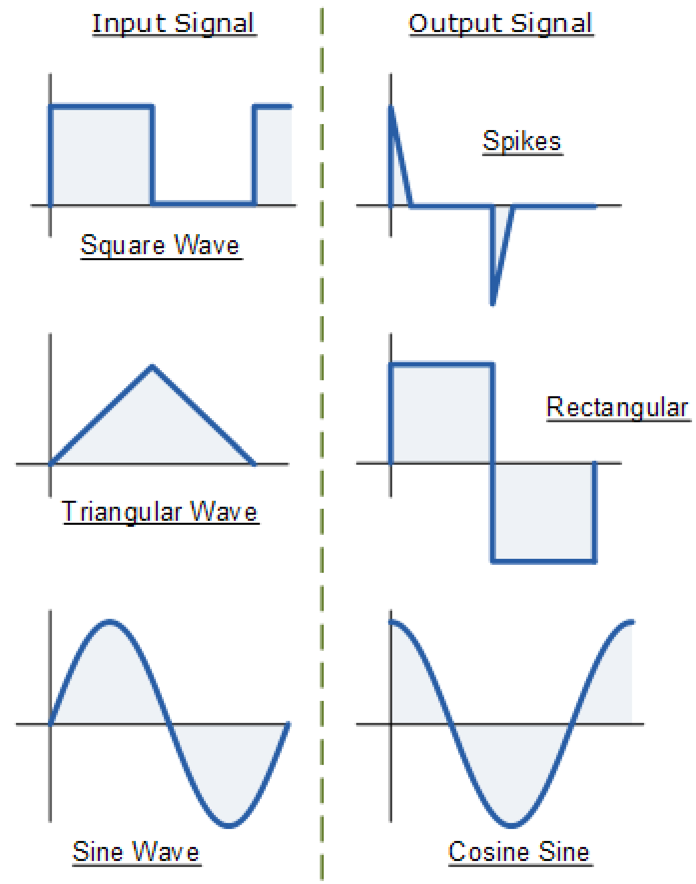


CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Cel mai simplu circuit de diferentiere. Imprecis, instabil si predispus la saturare !

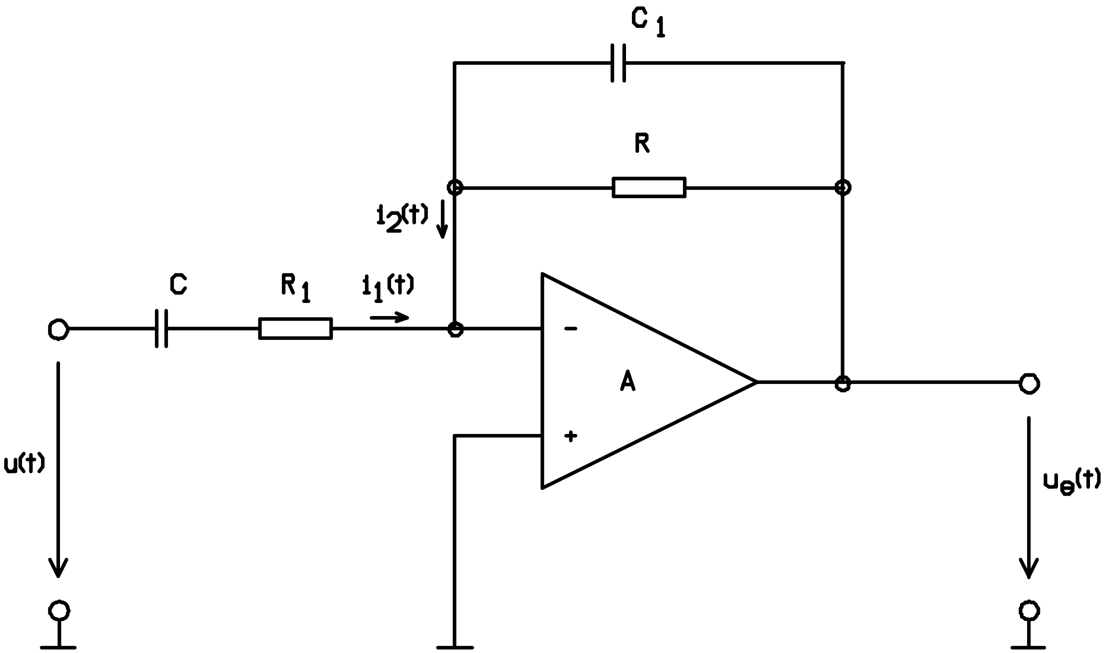


$$u_e(t) = -RC\frac{du(t)}{dt}$$

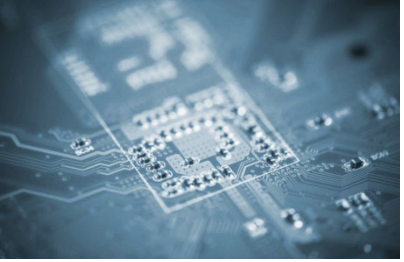


CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Circuitul de diferentiere complet.

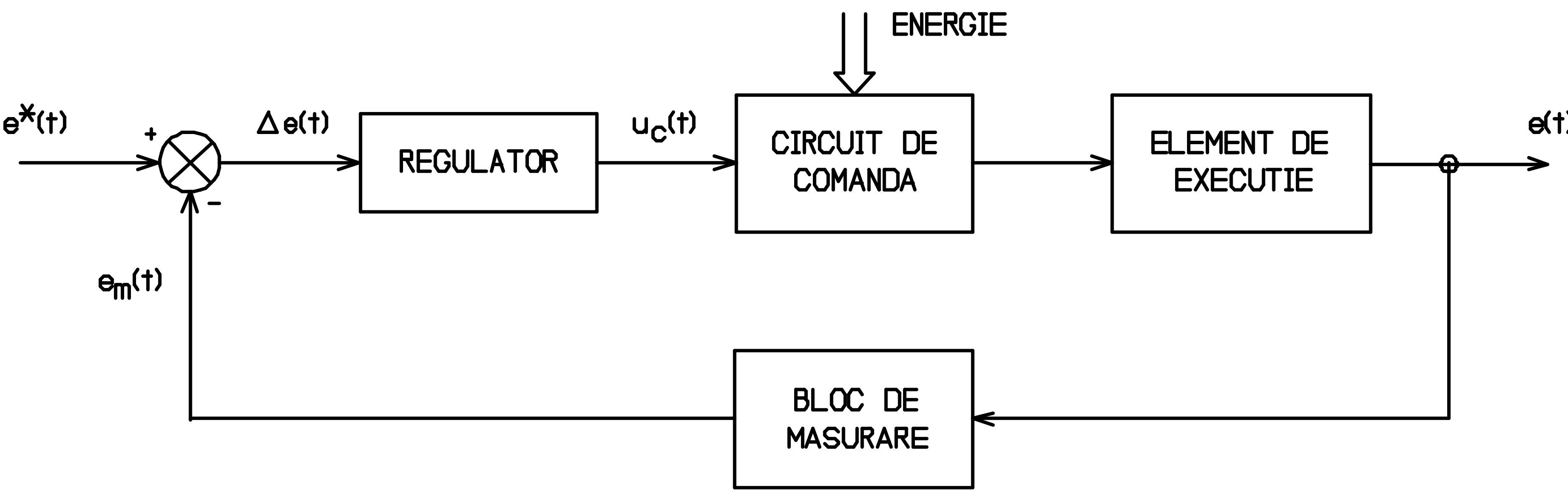


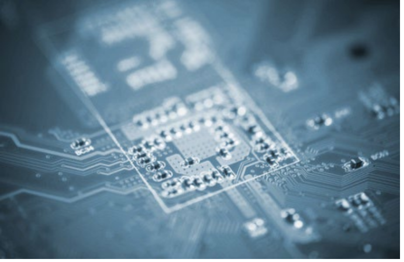
$$\underline{A} = -\frac{\dfrac{1}{\dfrac{1}{R} + j\omega C_1}}{R_1 + \dfrac{1}{j\omega C}}$$



CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

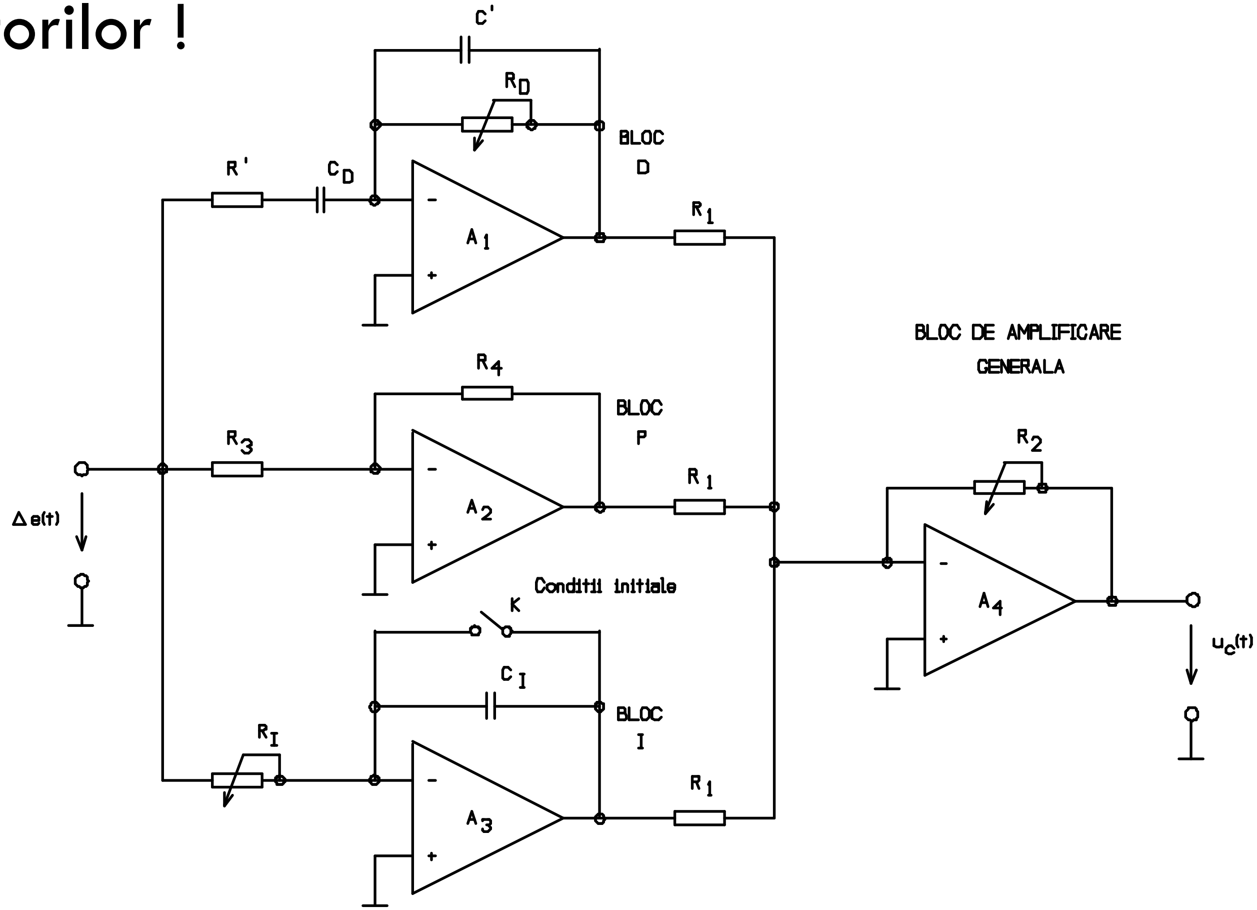
- Sistem de reglare automata. Structura generala.

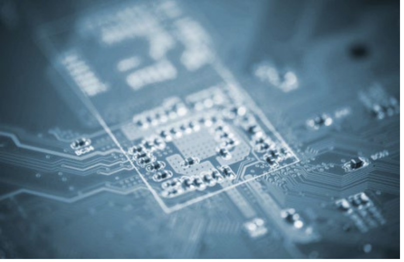




CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

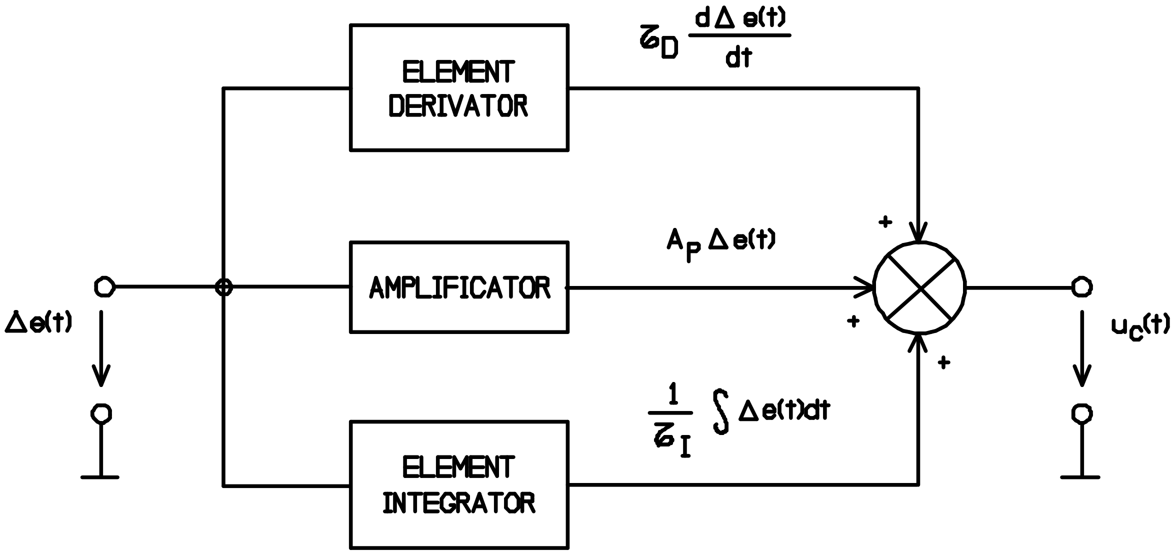
- Structura celui mai simplu regulator electronic PID, construit in jurul a 4 amplificatoare operationale. Reglare independenta a factorilor !





CIRCUITE DE PRELUCRARE A SEMNALELOR CONTINUE

- Schema bloc si functiunea electronica a unui regulator PID



$$u_c(t) = \frac{R_2}{R_1} \left[\frac{R_4}{R_3} \Delta e(t) + \frac{1}{R_I C_I} \int \Delta e(t)\, dt + R_D C_D \frac{d\Delta e(t)}{dt} \right]$$

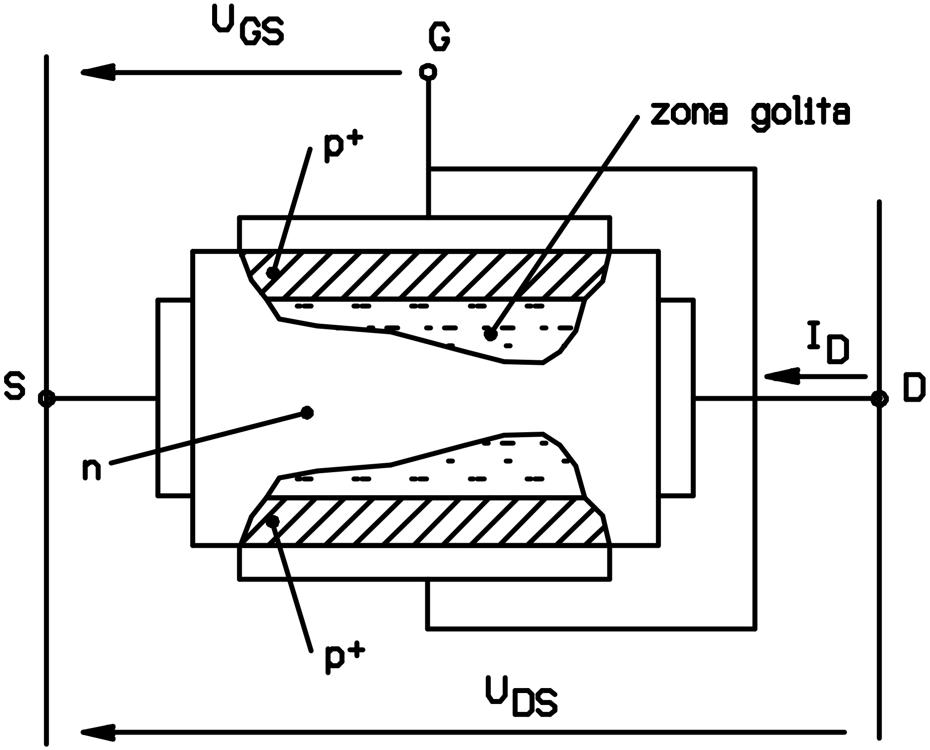
Tranzitoare cu efect de camp si circuite fundamentale

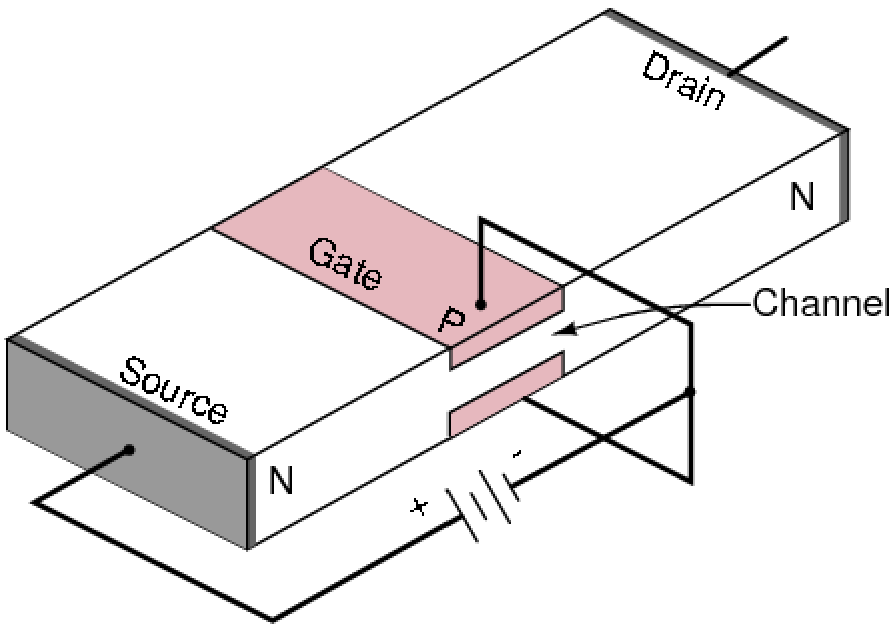
- Tranzistoarele cu efect de camp -TEC - FET:
  - a)
    - -cu jonctiune - J-FET, TEC-J
    - -cu grila izolata - IG-FET, (MOSFET)
  - b)
    - -cu canal “n”
    - -cu canal “p”

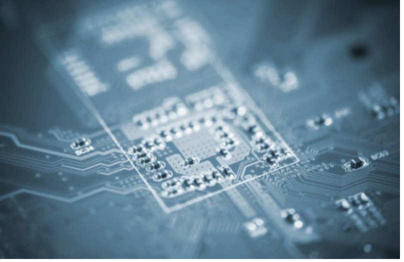
- **Sunt tranzistoare “unipolare” !**

Tranzitoare cu efect de camp

- Principiul constructiv si functional al tranzistoarelor cu efect de cimp cu jonctiune, TEC - J. Exemplificare in cazul tranzistorului cu canal “n”.

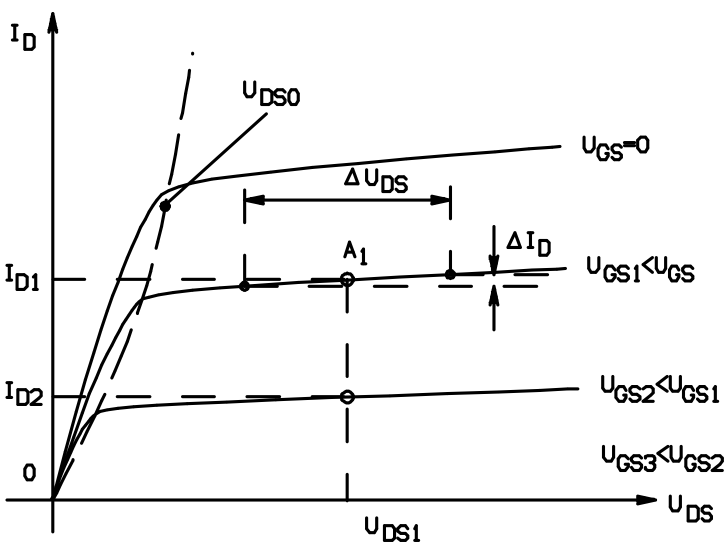


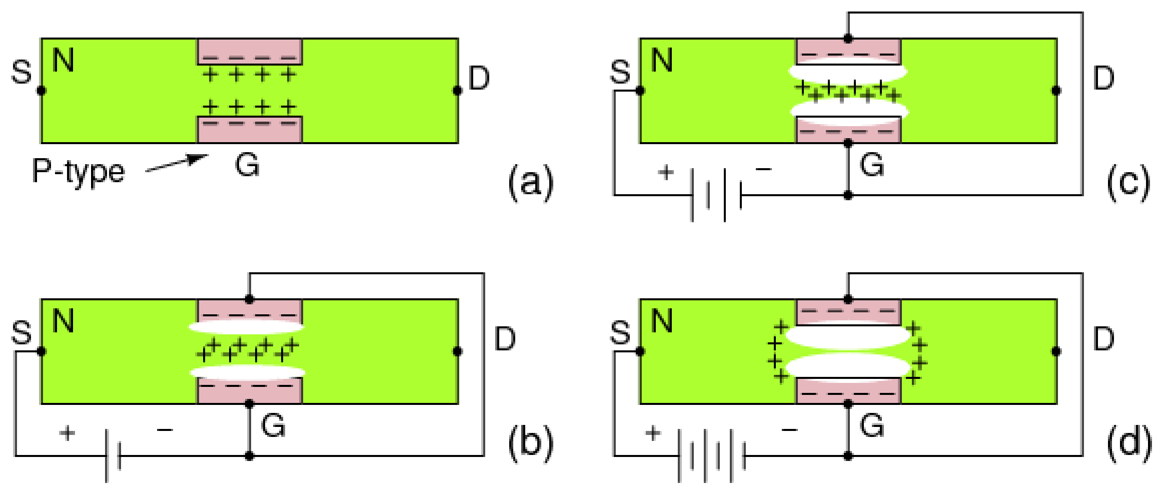


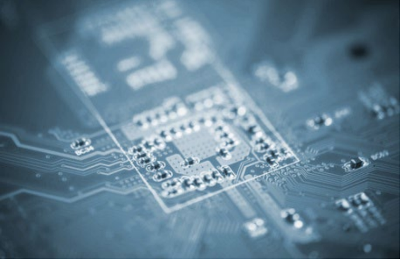


Tranzitoare cu efect de camp

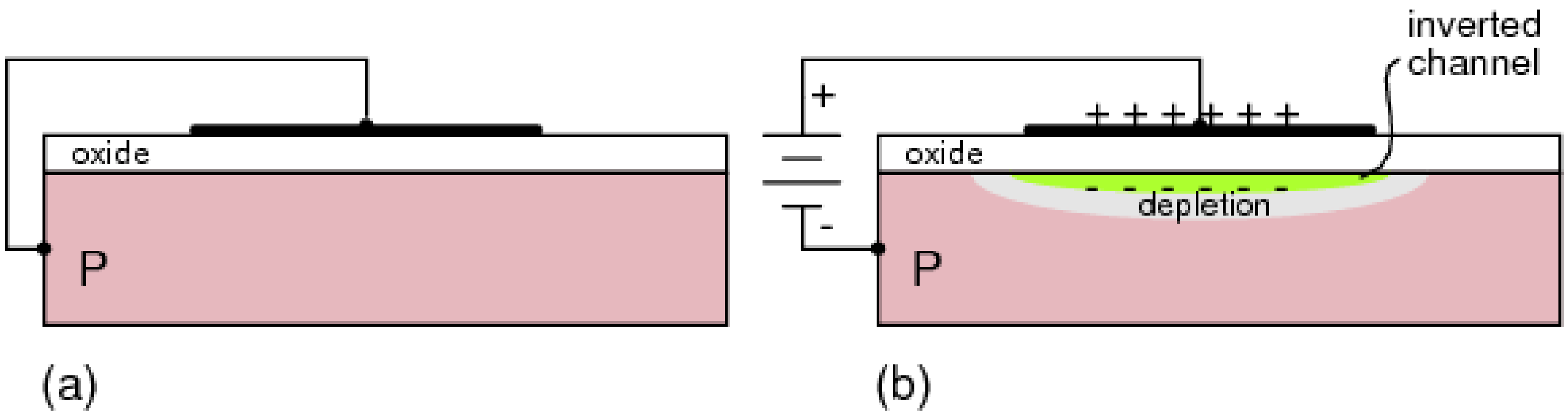
- Caracteristicile de iesire ale tranzistorului TEC-J cu canal “n”.
  - Citeva concluzii: conduce la tensiune de grila nula, se polarizeaza cu tensiune de drena pozitiva, se controleaza cu tensiune de grila negativa.

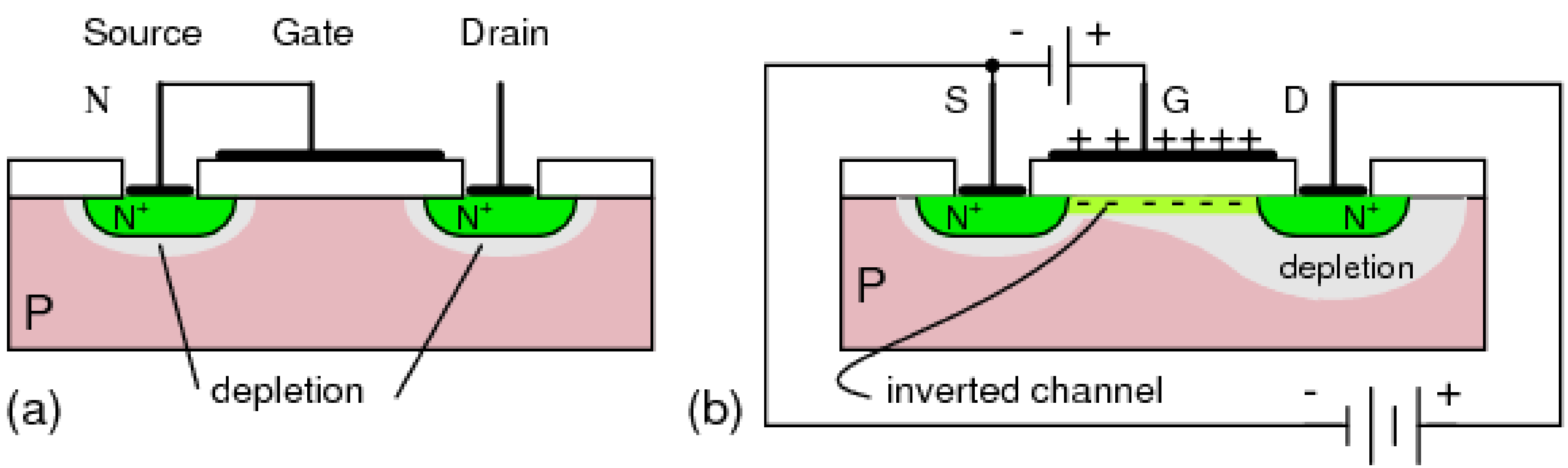




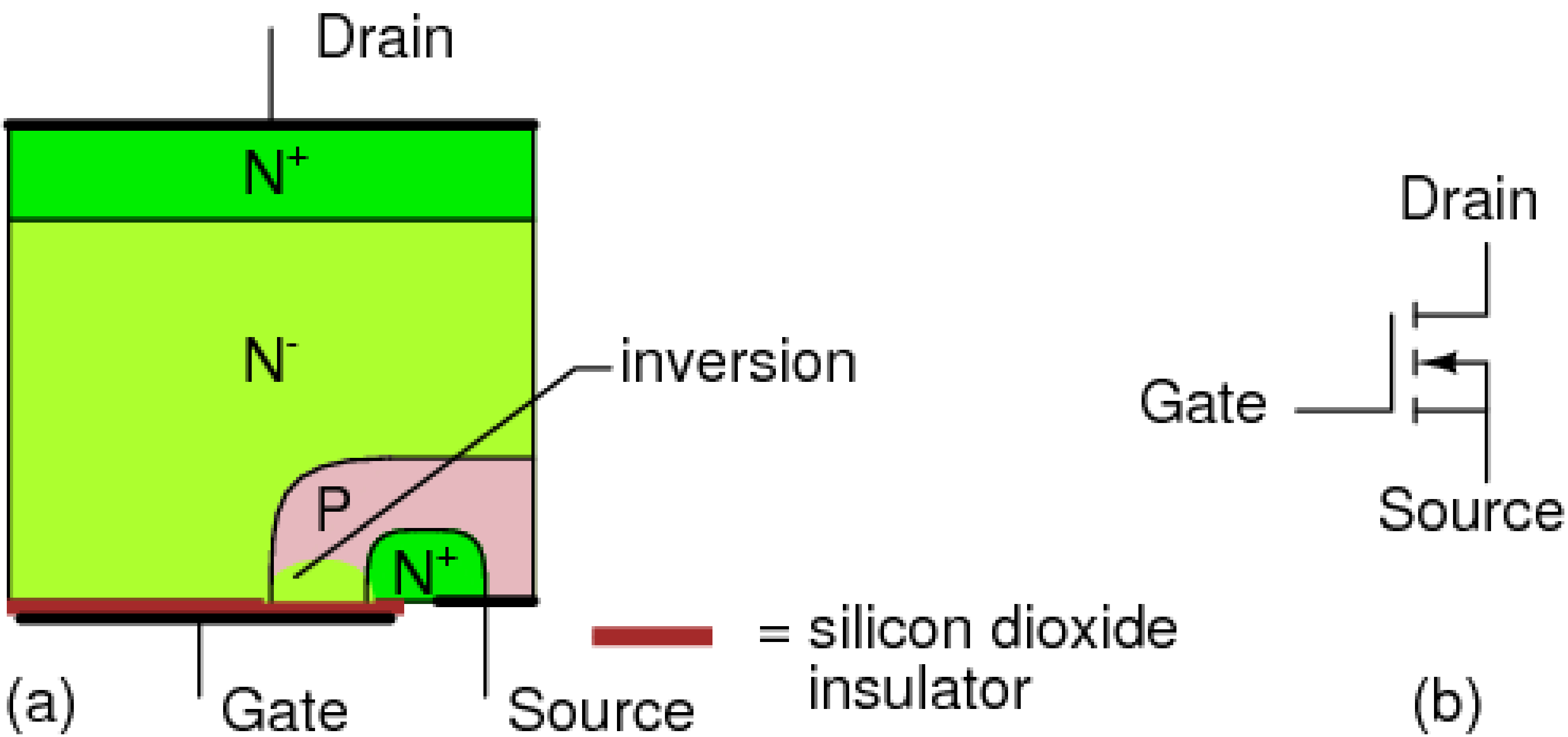


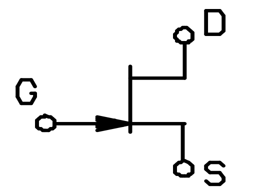
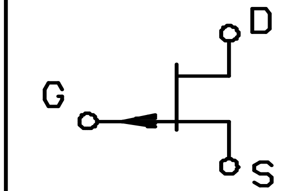
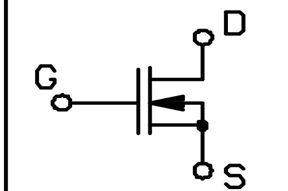
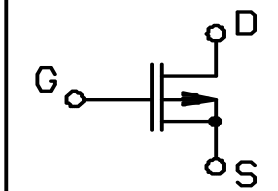
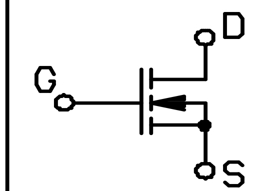
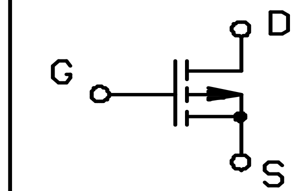
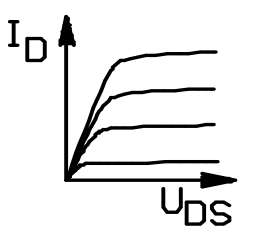
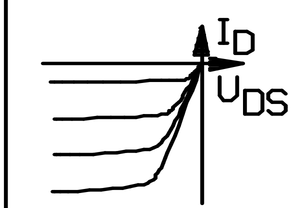
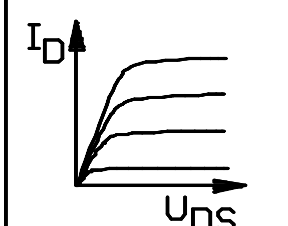
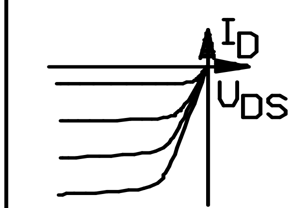
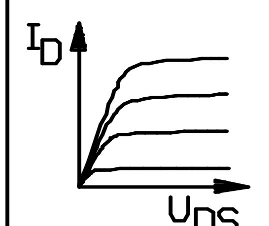
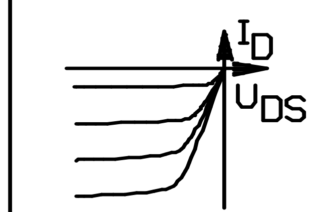
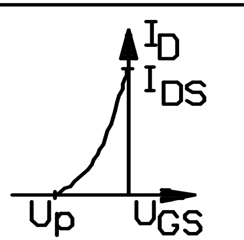
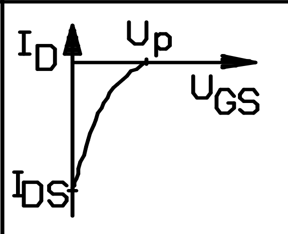
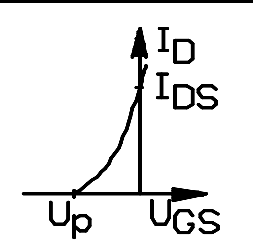
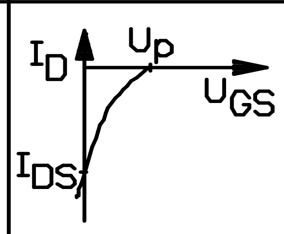
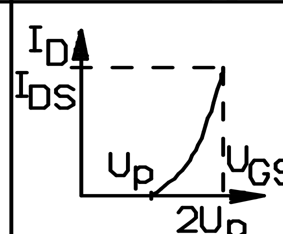
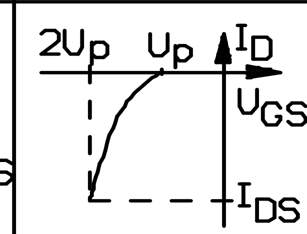
Tranzitoare cu efect de camp

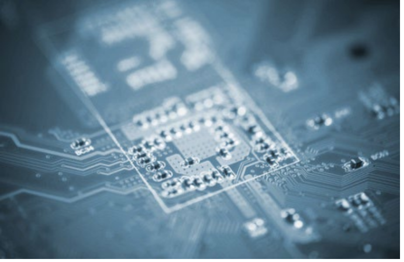




Tranzitoare cu efect de camp

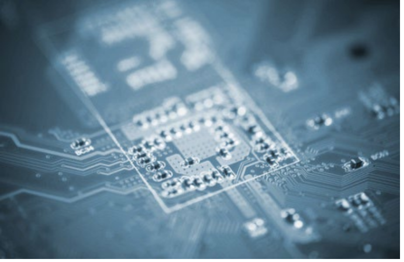


Tranzistoare cu efect de camp - TEC					
TEC - J		MOSFET			
		Mosfet cu canal indus		Mosfet fara canal indus	
Canal n	Canal p	Canal n	Canal p	Canal n	Canal p
					
					
					
Circuite de impulsuri	Circuite de impulsuri	Circuite de impulsuri	Circuite de impulsuri	Circuite de impulsuri	Circuite de impulsuri
Amplificatoare	Amplificatoare	Amplificatoare de if	Amplificatoare de if	Amplificatoare de putere	Amplificatoare de putere
CI analogice	CI analogice	CI digitale	CI digitale	CI digitale	CI digitale
				Electronica de putere	Electronica de putere



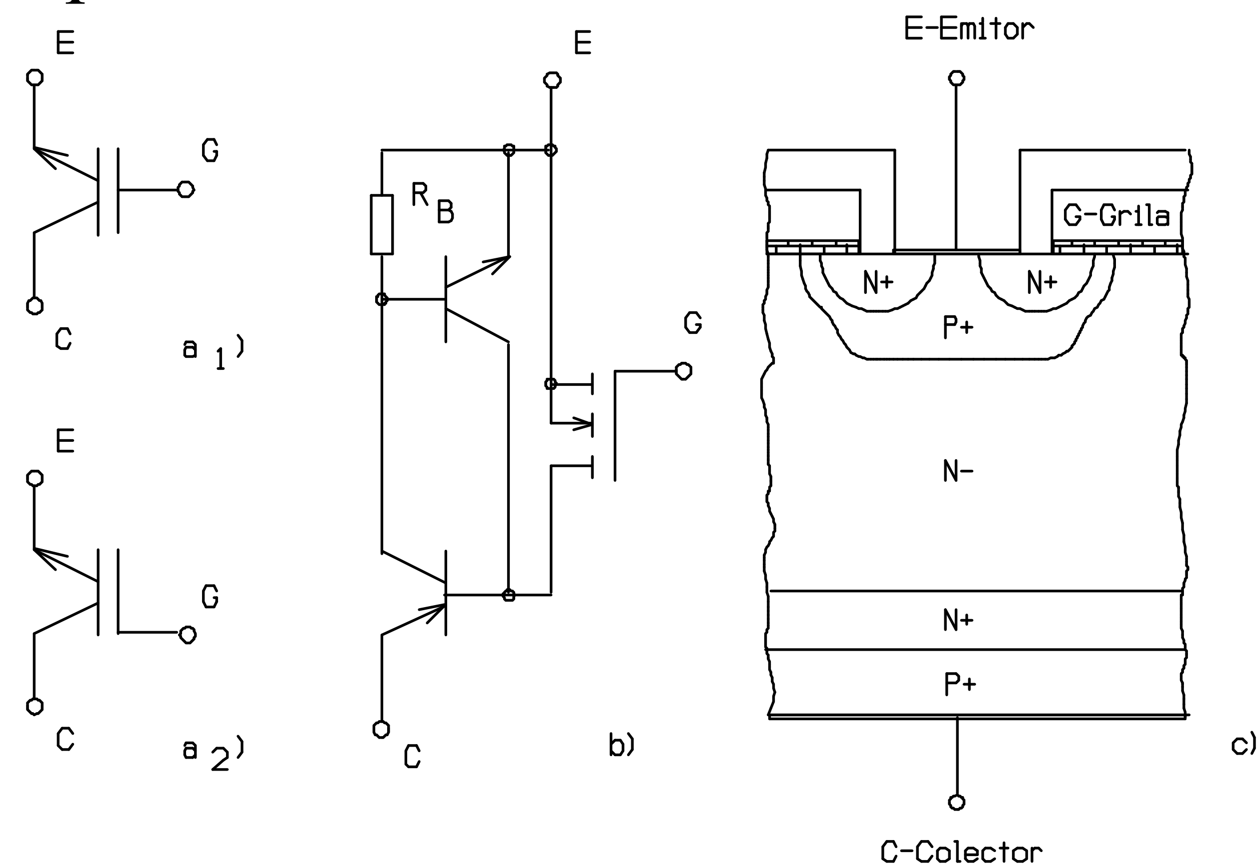
Tranzistorul bipolar cu comanda prin camp

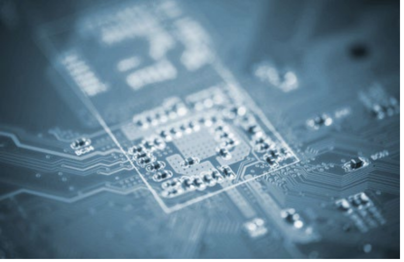
- IGBT - insulated-gate bipolar transistor
- IGT - insulated gate transistor
- Alternativa la tranzistoarele bipolare, MOSFET si tiristoare, in aplicatiile de putere.
- Dezvoltat in anii ‘80 ai secolului trecut de catre Harris Semiconductor. In prezent domina piata semiconductoarelor de putere, tensiuni de lucru de mii de volti si curenti de lucru de sute de amperi.



Tranzistorul bipolar cu comanda prin camp

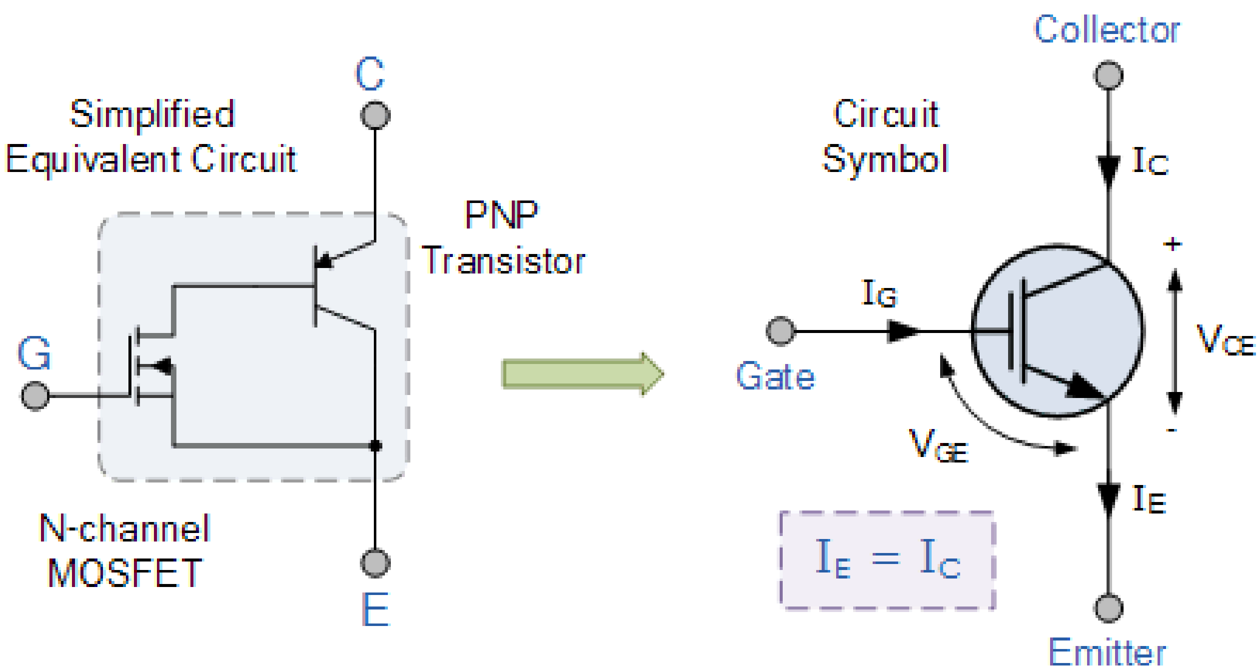
- IGBT. Simboluri uzuale. Schema echivalenta. Principiu constructiv.





Tranzistorul bipolar cu comanda prin camp

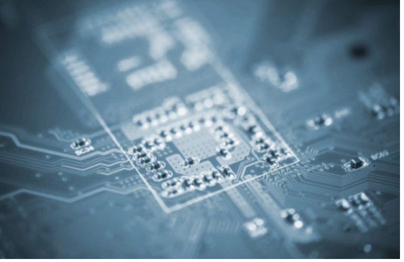
- IGBT. Simboluri uzuale. Schema echivalenta. Principiu constructiv.



Tranzistorul bipolar cu comanda prin camp

- De ce IGBT ?

CARACTERISTICI	Tranzistor bipolar	MOSFET	IGBT
Limita superioara de tensiune de lucru	medie	joasa	inalta
Circuitul de comanda - cheltuieli - putere	 medii mare	 reduse mica	 reduse mica
Caracteristici de comutatie - timp de saturare - timp de blocare - pierderi de putere	mediu lung mari	scurt scurt mici	mediu mediu medii
Caracteristici de conductie - densitate de curent admisibila - pierderi de putere	mare mici	mica mari	mare mici
Functionare în scurtcircuit	imposibil	imposibil	posibil
Frecventa de lucru (limita pentru $0.5xI_{C,D}$) - uzuala - maxima	10 kHz 50 kHz	100 kHz 250 kHz	20 kHz 80 kHz

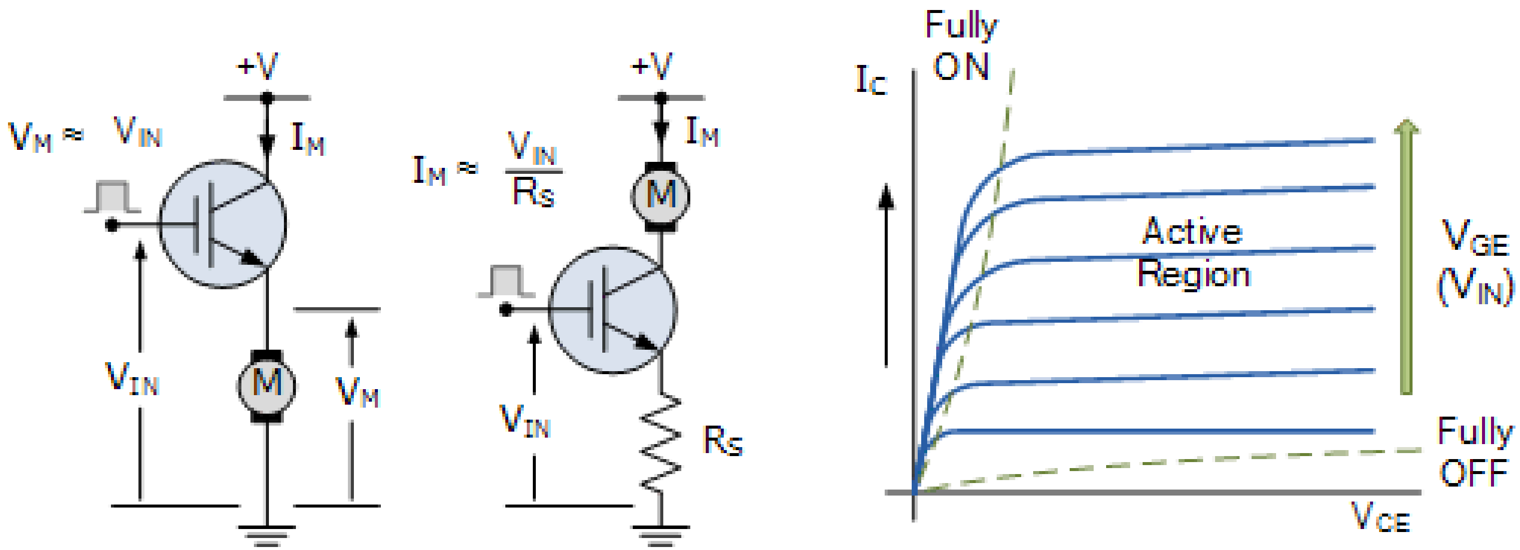


Tranzistorul bipolar cu comanda prin camp

- De ce IGBT ?

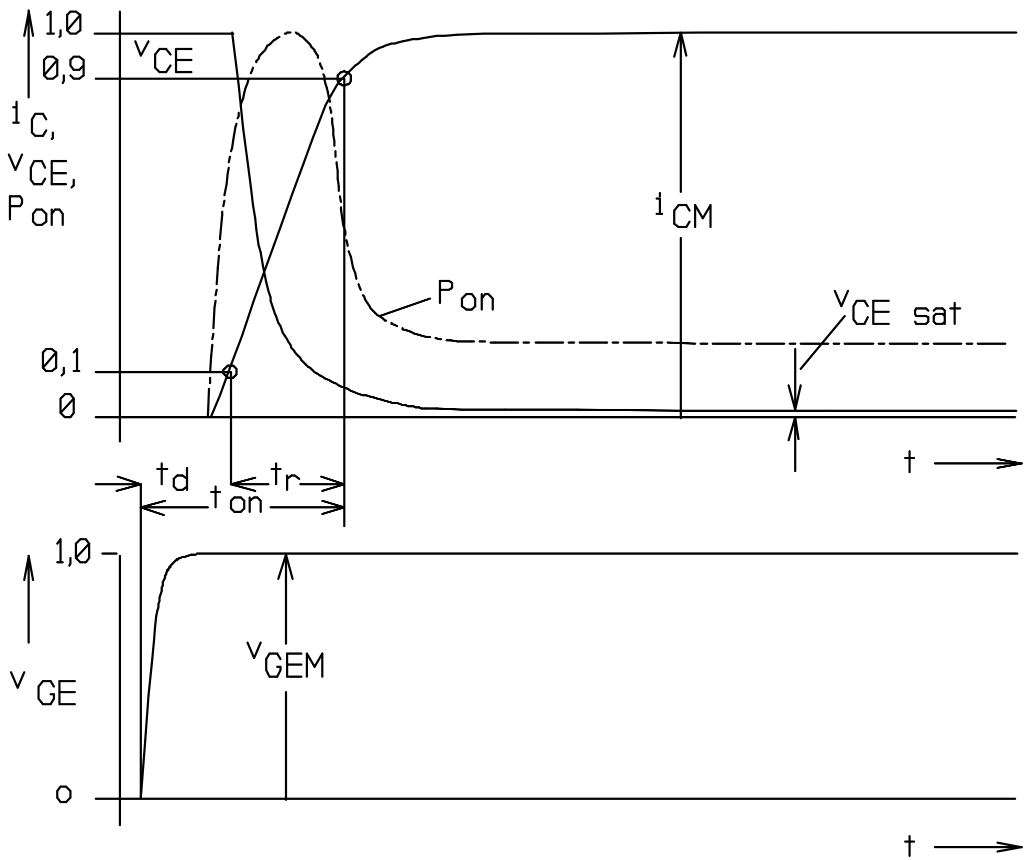
Device Characteristic	Power Bipolar	Power MOSFET	IGBT
Voltage Rating	High <1kV	High <1kV	Very High >1kV
Current Rating	High <500A	Low <200A	High >500A
Input Drive	Current, h_{FE} 20-200	Voltage, V_{GS} 3-10V	Voltage, V_{GE} 4-8V
Input Impedance	Low	High	High
Output Impedance	Low	Medium	Low
Switching Speed	Slow (uS)	Fast (nS)	Medium
Cost	Low	Medium	High

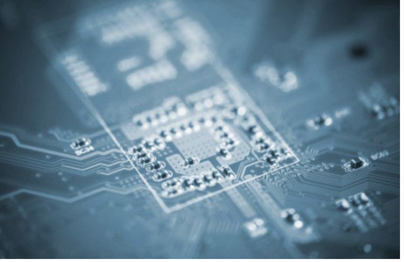
Tranzistorul bipolar cu comanda prin camp



Tranzistorul bipolar cu comanda prin camp

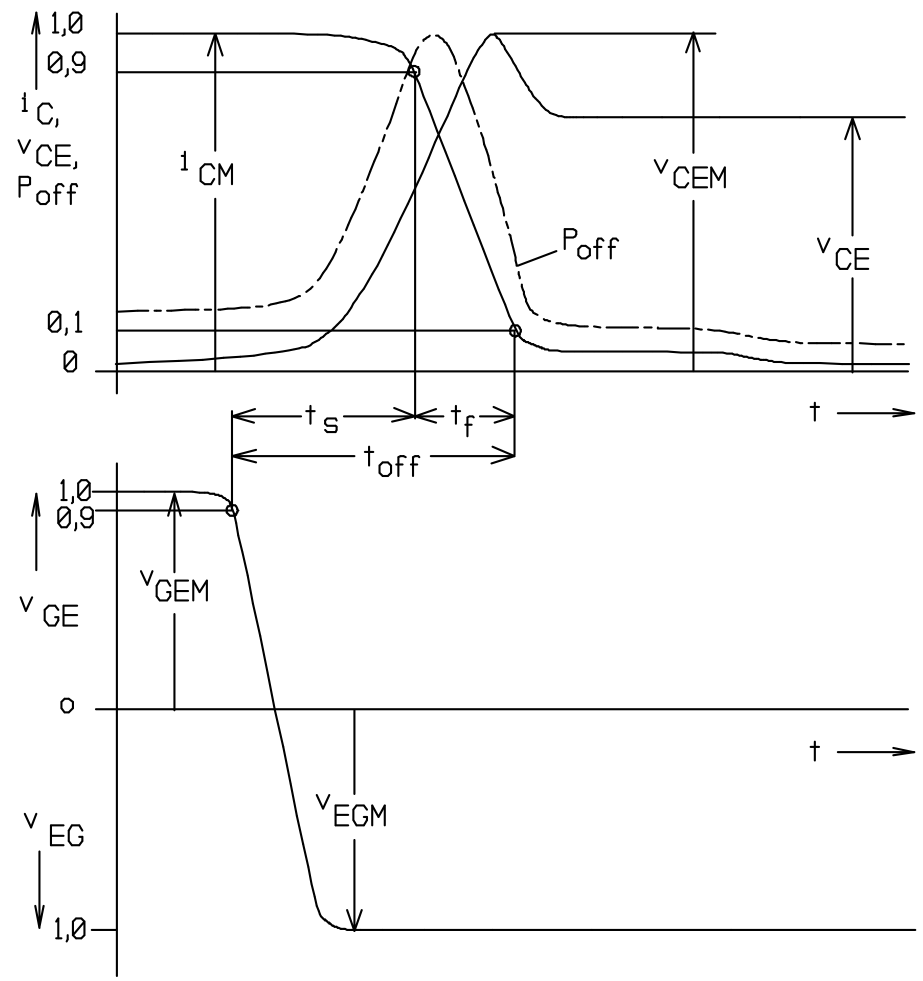
- Comutatia directa a tranzistorului IGBT. Evident comanda se face in tensiune.





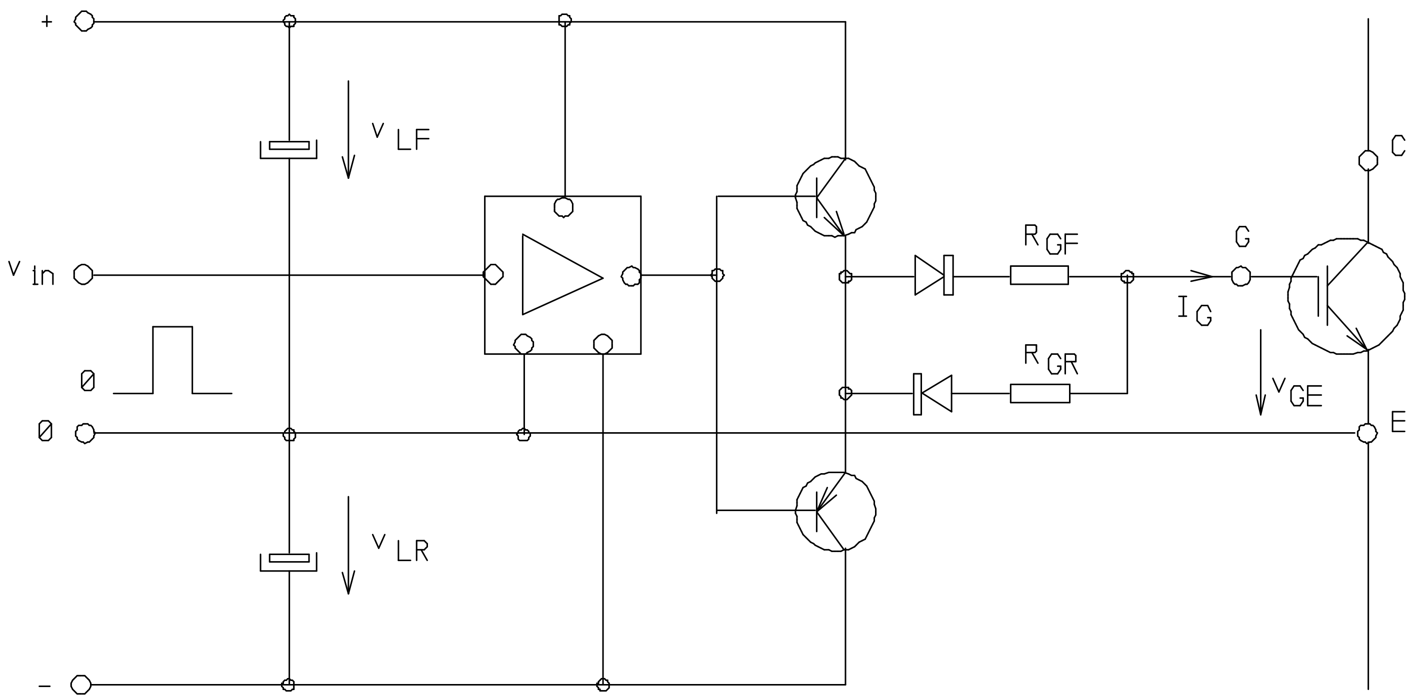
Tranzistorul bipolar cu comanda prin camp

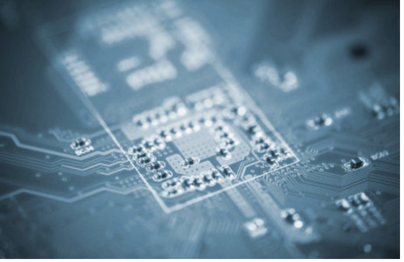
- Comutatia inversa a tranzistorului IGBT.
- Curent de comanda apare numai la incarcarea capacitatii G-E, ca si la tranzistorul MOSFET !



Tranzistorul bipolar cu comanda prin camp

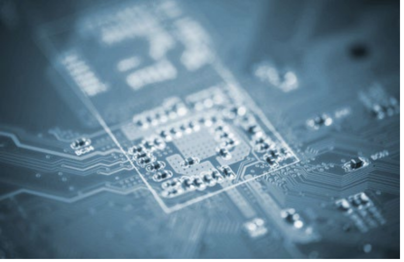
- Un exemplu pentru circuitele de comanda ale tranzistoarelor IGBT.
- Atentie la circuitele de protectie a tranzistoarelor si convertoarelor realizate cu ele !





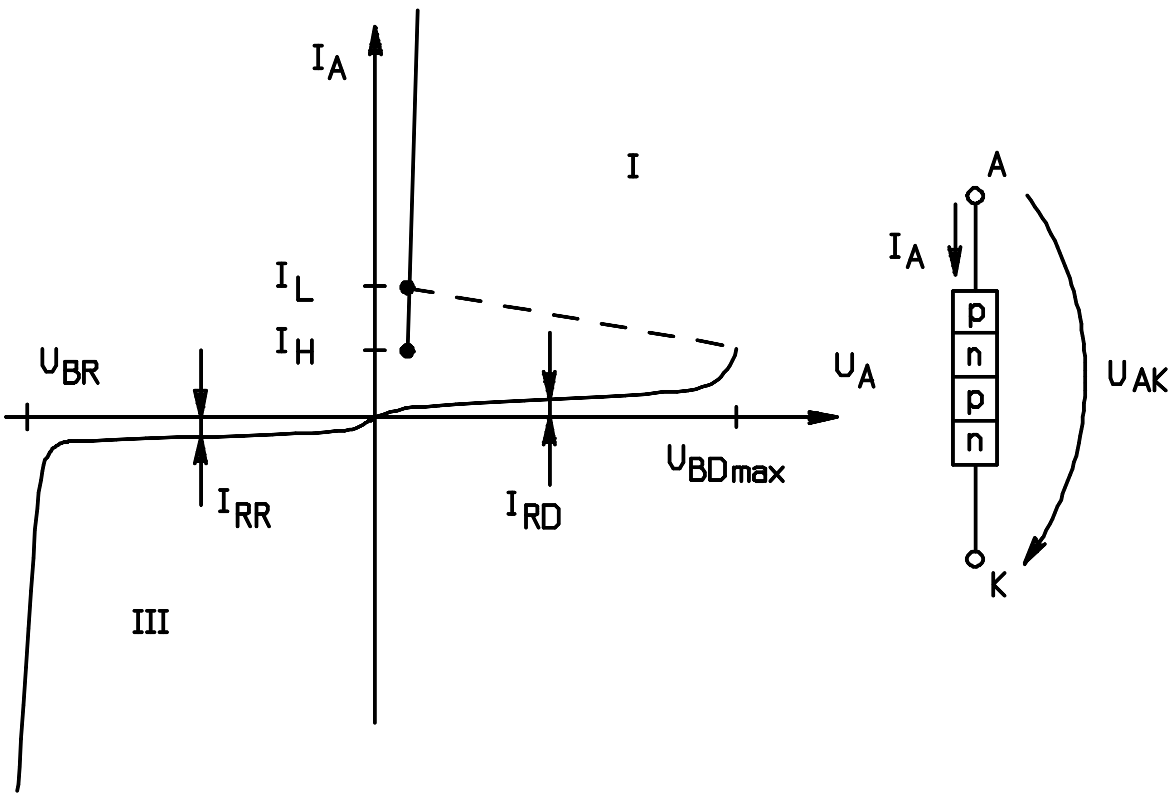
Dispozitive semiconductoare multijonctiune

- Au aparut in deceniul 6 al secolului trecut pentru a satisface cerintele din electronica de putere, unde performantele in tensiune si curent ale tranzistoarelor bipolare si cu efect de cimp nu permiteau rezolvarea problemelor ridicate de aplicatiile industriale.
- Elementul care sta la baza realizarii dispozitivelor semiconductoare multijonctiune este structura cu patru straturi, “pnpn”, dezvoltata de Shockley, care a permis punerea la punct in anul 1958 a primului tiristor, de catre firma General Electric.
- Dispozitivele multijonctiune au dominat electronica de putere aproape o jumatate de secol !



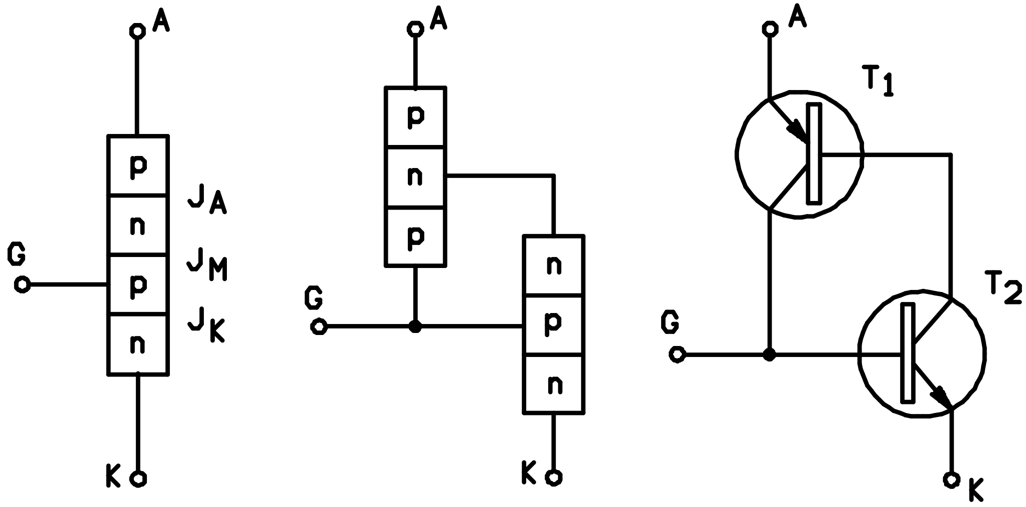
Dispozitive semiconductoare multijonctiune

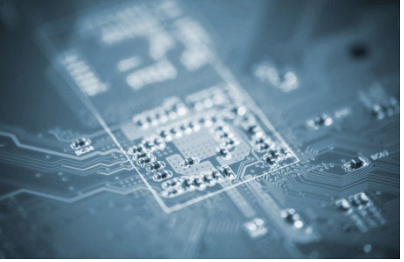
- Caracteristica statica a structurii “pnpn”.
  - Discontinua. Neliniara.



Dispozitive semiconductoare multijonctiune

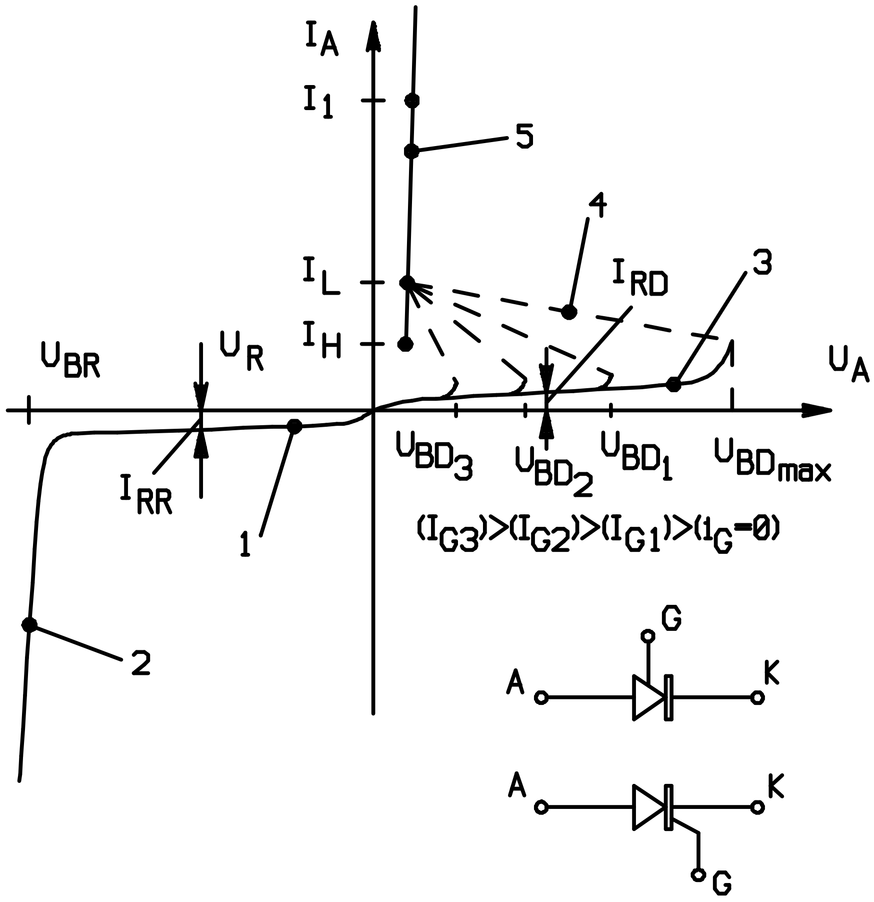
- Schema echivalenta cu tranzistoare bipolare a tiristorului de putere. Structura Shockley, prevazuta cu grila de comanda pe partea catodica.

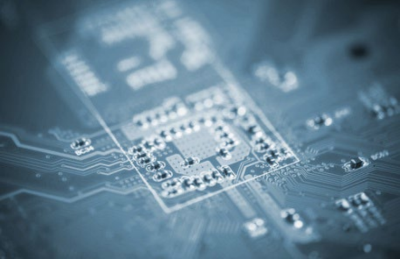




Dispozitive semiconductoare multijonctiune

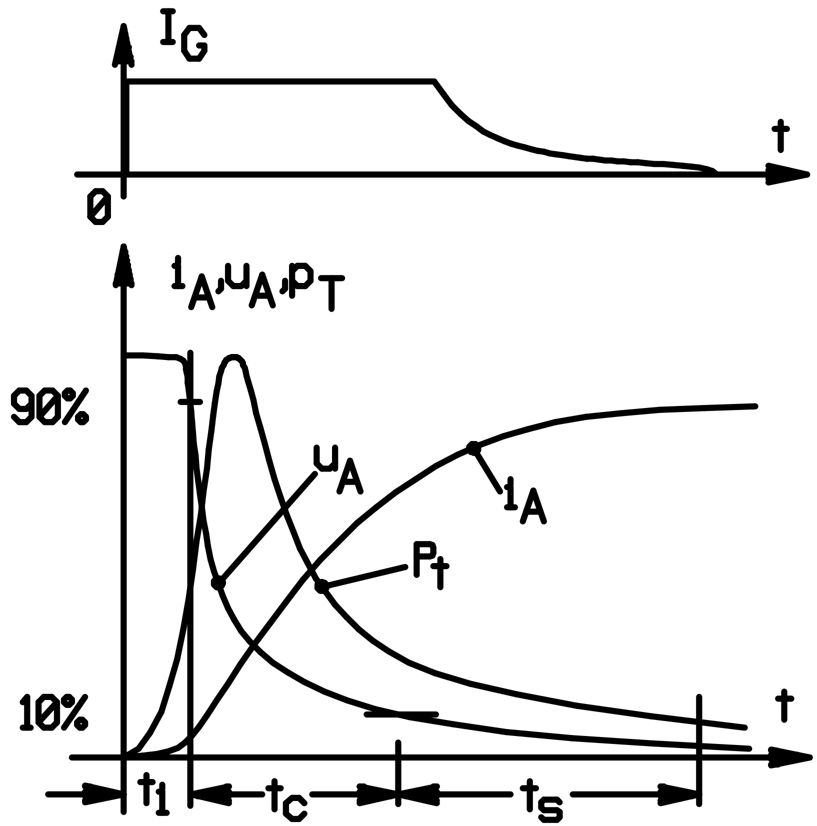
- Simbolul si caracteristica statica a tiristorului de putere.





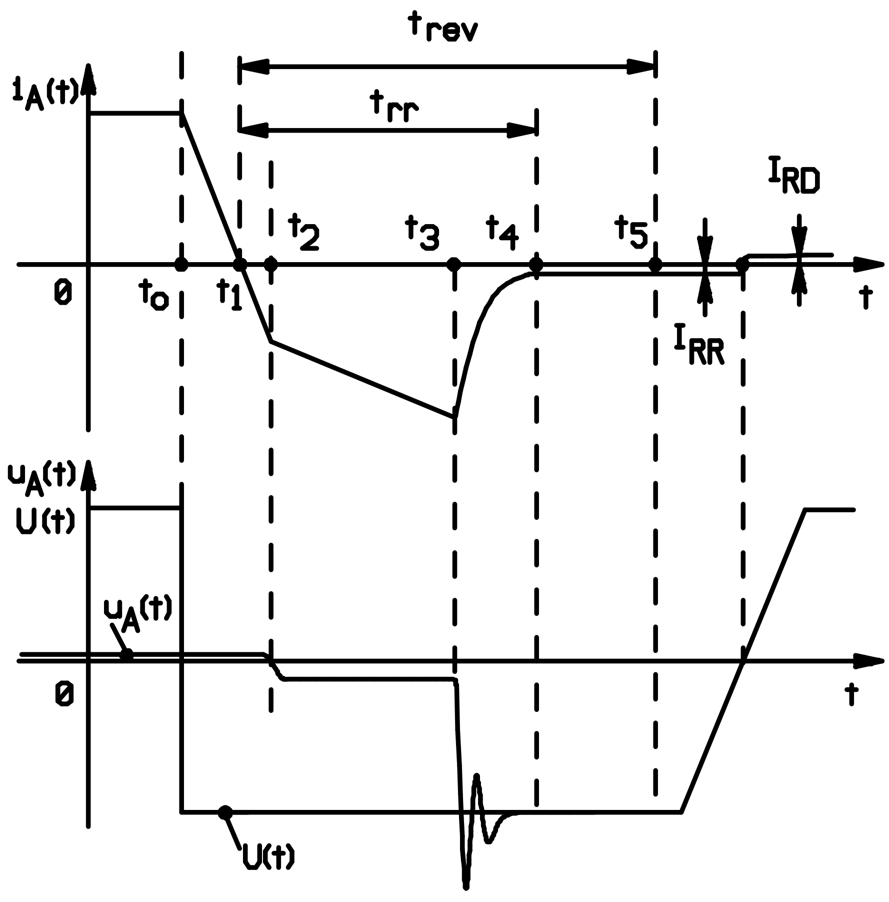
Dispozitive semiconductoare multijonctiune

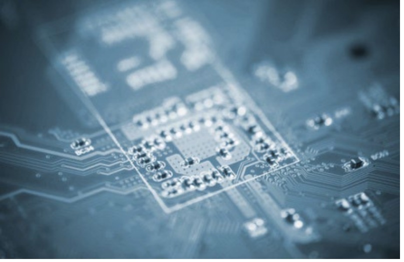
- Comutatia directa - amorsarea - tiristorului de putere.



Dispozitive semiconductoare multijonctiune

- Comutatia inversa - blocarea - tiristorului de putere.

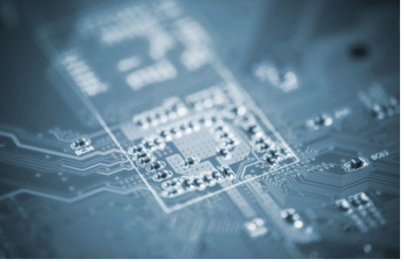




Dispozitive semiconductoare multijonctiune

Citeva concluzii importante !

- Tiristorul de putere functioneaza numai in regim de comutatie. Nu prezinta o zona activa de functionare.
- Amorsarea se poate face prin mai multe mijloace. Singura metoda aplicabila este comanda pe orizontala. Control de faza. Control in functie de timp. Conditii pentru amorsare sigura.
- Blocarea tiristorului impune scaderea controlata a curentului anodic sub valoarea sa de mentinere. Se face in partea de putere. Procesul depinde de sursa tensiunii de comutatie, (retea de intrare, de iesire, intern). Amanunte la Electronica de putere.



Dispozitive semiconductoare multijonctiune

- Triacul.
  - Structura. Simboluri uzuale. Caracteristica statica