Diodes.

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Lecture 05

Notes

Midterm exam

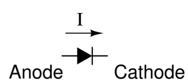
Where: In the lab
When: During the first hour of the lab
Material:

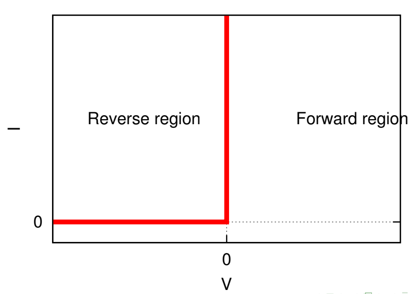
- everything from first 4 weeks of class
- Resistors, capacitors, inductors, and transformers.
- Kirchhoff's laws
- Complex impedances.
- Thévenin's theorem
  - Source impedance and voltage
- Voltage divider in various forms
- Filters

Lab will follow the midterm.
You can skip design exercise preparation prior to the lab. However, at the time of log book submission it must be fully done. Treat it as a home work.

Notes

Ideal diode

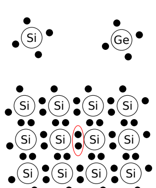




Notes

Semiconductors and doping

Pure semiconductor



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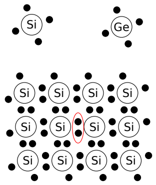
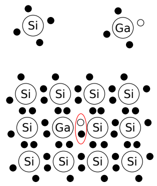


P-doped



Notes

Semiconductors and doping

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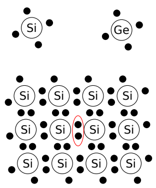
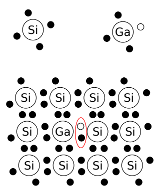
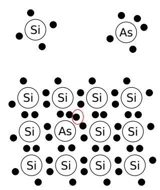


P-doped



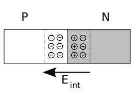
N-doped



Notes

PN-junction

No bias



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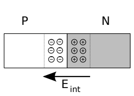
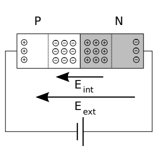


Reverse bias



Notes

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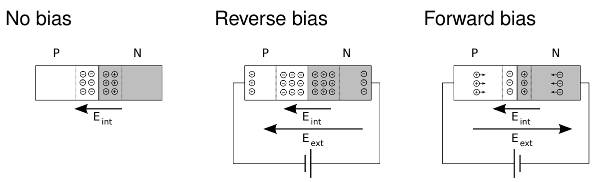
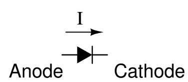


Notes

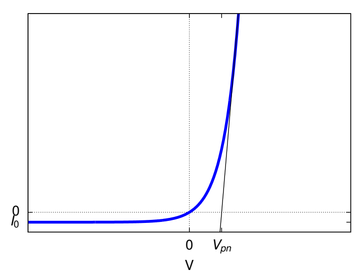
Real diode



$I(V) = I_0 \left(e^{V/(nV_T)} - 1 \right)$

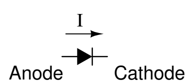
Typical parameters

- saturation current $I_0 = 1$ nA
- thermal voltage $V_T = \frac{kT}{q} =$ 25.85 mV at 300 K
- emission coefficient $n = 1..2$



Notes

Real diode



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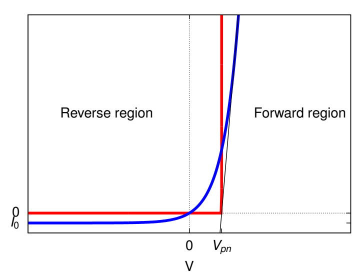
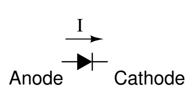


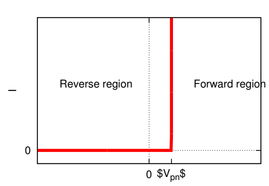
Notes

Simplified diode

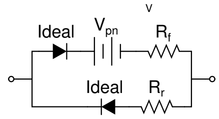


V_{pn} diode P-N junction opening voltage

- $V_{pn} = 0.6$ V for Si
- $V_{pn} = 0.3$ V for Ge



A bit more realistic diode ($R_r \gg R_f$)



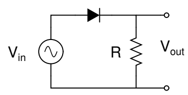
Notes

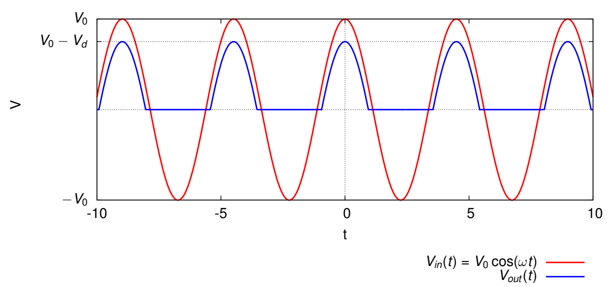
Diodes applications

- Circuit Protection
- Rectification
  - current gate
  - half wave rectifier
  - full wave rectifier
  - Power Supplies
- Frequency manipulation
  - Frequency multiplier
  - Mixers
- and more ...
  - Voltage clamps
  - light emitting diodes (LED)
  - photo-diode

Notes

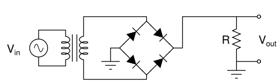
Half-wave rectifier, current gate



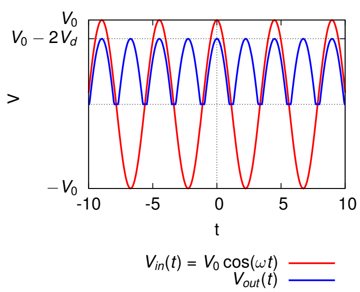


Notes

Full-wave rectifier: $V_{in} \gg V_d \rightarrow V_{out} \approx |V_{in}|$

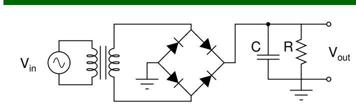


Why
$\max(V_{out}) = V_0 - 2V_d$?



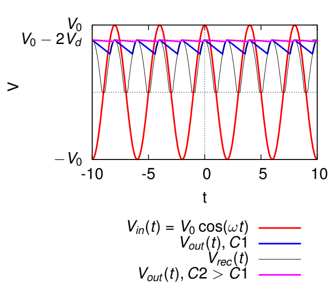
Notes

Full-wave rectifier filtered - power supply



Ripples size

$$V(t) = \frac{Q(t)}{C} = \frac{Q_{max} - \int_0^t I dt}{C}$$
$$= V_{max} - \int_0^t \frac{I}{C} dt$$
$$\Delta V = V_{max} - V(t) = \int_0^t \frac{I}{C} dt$$
$$I \leq I_{max} = \frac{V_{max}}{R}$$
$$t \leq T = \frac{1}{2f_{in}}$$

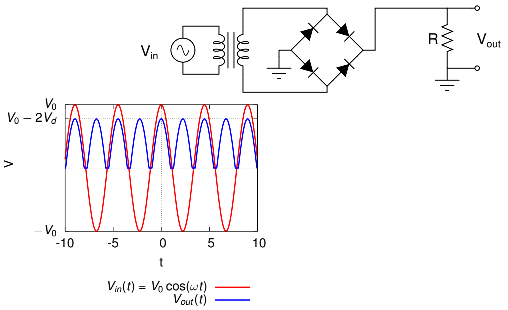


$T \ll RC$

$$\Delta V \leq \frac{V_{max}}{2RCf_{in}}$$

Notes

Full-wave rectifier as Frequency doubler



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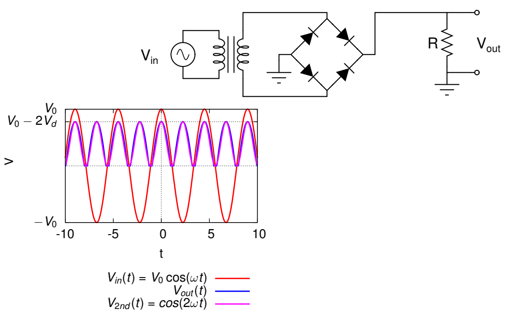

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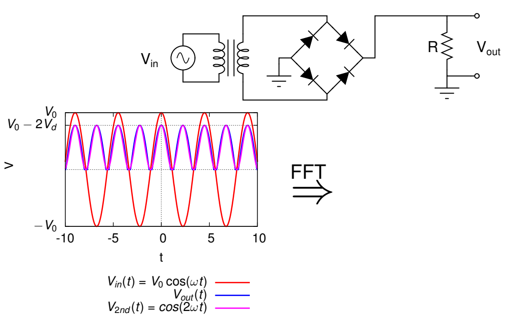

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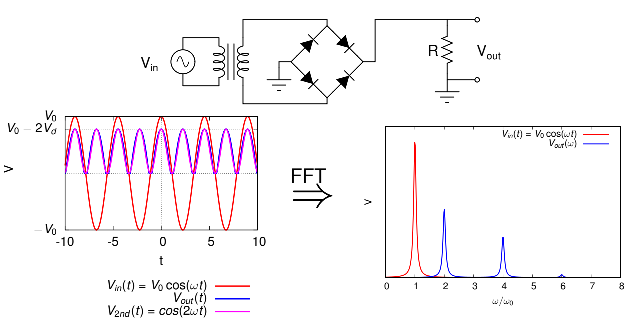
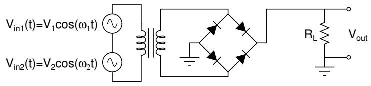


Notes

Full-wave rectifier as Frequency adder



$$V_{out}(t) = |V_{in}(t)| = \sqrt{V_{in}^2(t)} = \sqrt{(V_1 \cos(\omega_1 t) + V_2 \cos(\omega_2 t))^2}$$
$$= \sqrt{V_1^2 \cos^2(\omega_1 t) + 2V_1 V_2 \cos(\omega_1 t)\cos(\omega_2 t) + V_2^2 \cos^2(\omega_2 t)}$$

Assuming $V_1 \gg V_2$

$$V_{out}(t) \approx \sqrt{V_1^2 \cos^2(\omega_1 t) + 2V_1 V_2 \cos(\omega_1 t)\cos(\omega_2 t) + \cancel{V_2^2 \cos^2(\omega_2 t)}}$$
$$\approx V_1 \left(\cos(\omega_1 t) + \frac{V_2}{V_1}\cos(\omega_1 t)\cos(\omega_2 t)\right)$$
$$\approx V_1 \left(\cos(\omega_1 t) + \frac{V_2}{V_1}\frac{\cos((\omega_1+\omega_2)t) + \cos((\omega_1-\omega_2)t)}{2}\right)$$

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