Diodes.

Eugeniy E. Mikhailov
The College of William & Mary

Lecture 05

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.

Ideal diode

Notes

Semiconductors and doping

Pure semiconductor
Semiconductors and doping

Pure semiconductor  P-doped

N-doped

PN-junction

No bias

Reverse bias
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 $n = 1.2$

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 ($R_f \gg R_r$)
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

**Half-wave rectifier, current gate**

\[ V_{in} \rightarrow V_{out} \]

\[ V(t) = V_0 \cos(\omega t) \]

\[ V_{out}(t) = V_0 \cos(\omega t) \]

**Full-wave rectifier:** \( V_{in} \gg V_d \rightarrow V_{out} \approx |V_0| \)

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

\[ V(t) = V_0 \cos(\omega t) \]

\[ V_{out}(t) = V_0 \cos(\omega t) \]

**Full-wave rectifier filtered - power supply**

Ripples size

\[ V(t) = \frac{Q(t)}{C} = \frac{Q_{max} - \int_0^t I dt}{C} \]

\[ = V_{max} - \int_0^t \frac{I}{C} dt \]

\[ \Delta V = V_{max} - V(t) = \int_0^t \frac{I}{C} dt \]

\[ I \leq I_{max} = \frac{V_{max}}{R} \]

\[ t \leq T = \frac{1}{2\pi f_{in}} \]

\[ \Delta V \leq \frac{V_{max}}{\pi RC} \]

Notes

_________________
Full-wave rectifier as Frequency doubler

\[ V_{in}(t) = V_0 \cos(\omega t) \]

\[ V_{out}(\omega) = \cos(2\omega t) \]

FFT \[ \Rightarrow \]

Notes

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Full-wave rectifier as Frequency adder

\[
V_{\text{out}}(t) = |V_{\text{in}}(t)| = \sqrt{V_1^2 + 2V_1V_2\cos(\omega_1 t) + V_2^2}
\]

Assuming \( V_1 \gg V_2 \)

\[
V_{\text{out}}(t) \approx \sqrt{V_1^2 \cos^2(\omega_1 t) + 2V_1V_2\cos(\omega_1 t)\cos(\omega_2 t) + V_2^2 \cos^2(\omega_2 t)}
\]

\[
\approx V_1 \left( \cos(\omega_1 t) + \frac{V_2}{V_1} \cos(\omega_1 t)\cos(\omega_2 t) \right)
\]

\[
\approx V_1 \left( \cos(\omega_1 t) + \frac{V_2}{V_1} \cos((\omega_1 + \omega_2) t) + \cos((\omega_1 - \omega_2) t) \right)
\]