ECE 65: Components & Circuits Lab

Lecture 5

Zener Diode

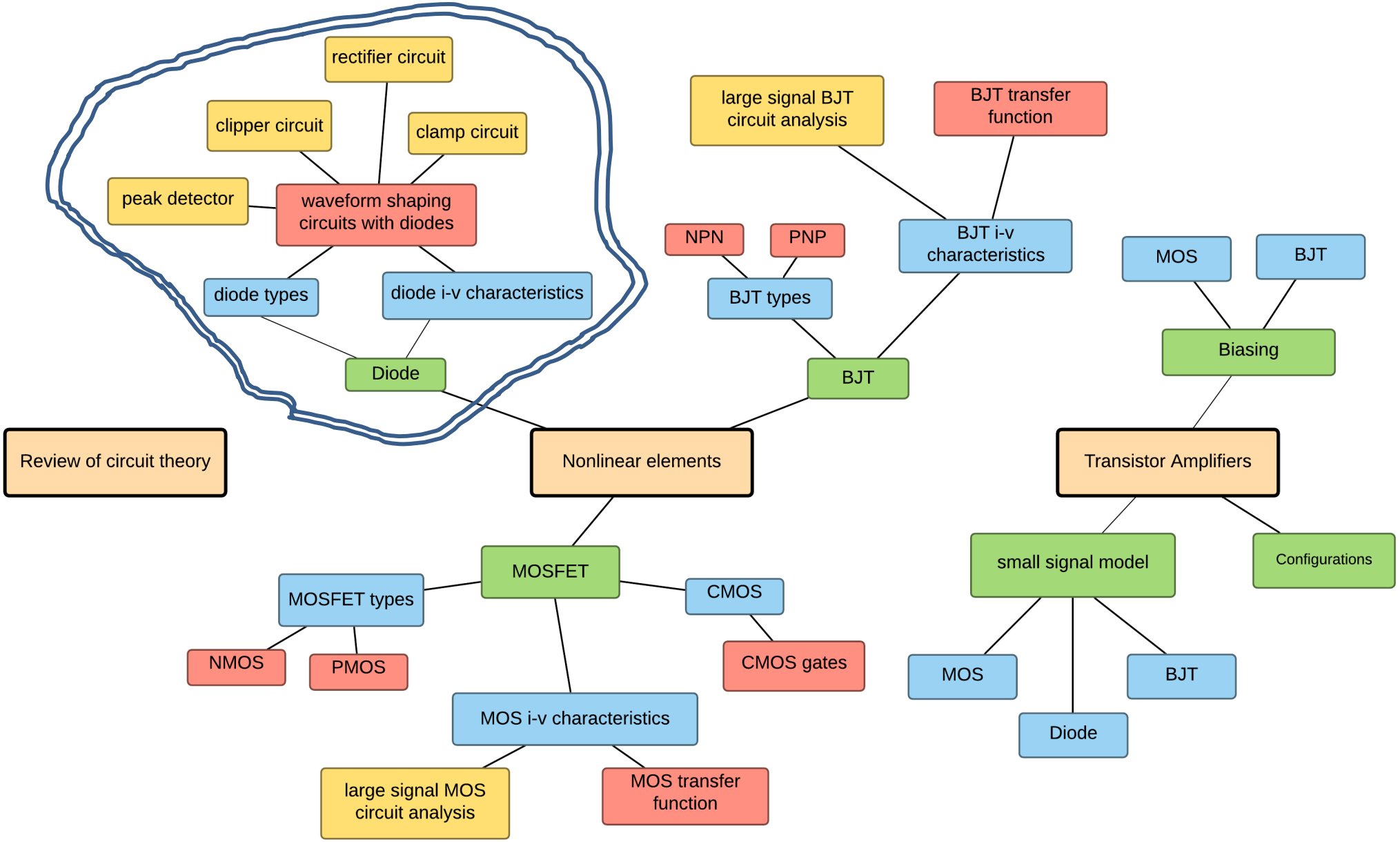
Reference notes: sections 2.1-2.8

Sedra & Smith (7th Ed): sections 4.3-4.4

Saharnaz Baghdadchi

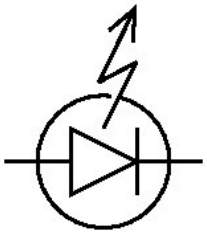
Course map

2. Diodes



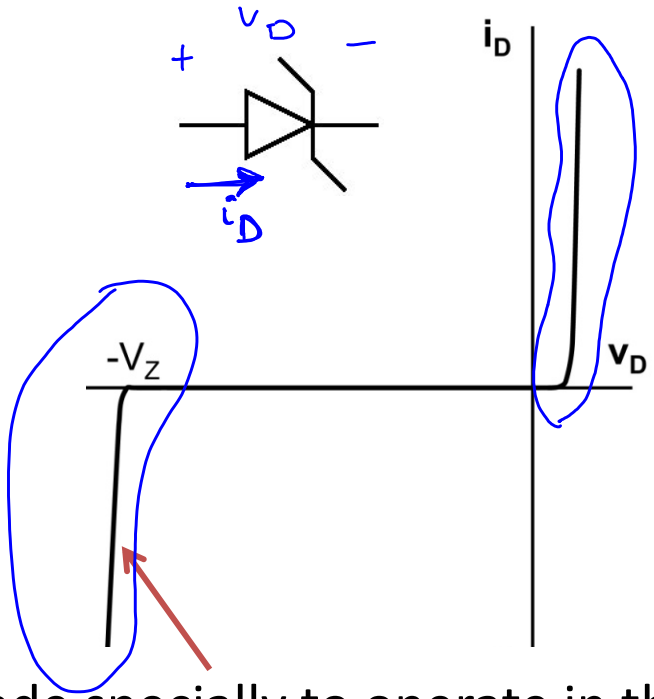
Other types of diodes

Light-emitting diode (LED)



$V_{D0} = 1.7 - 1.9$ V

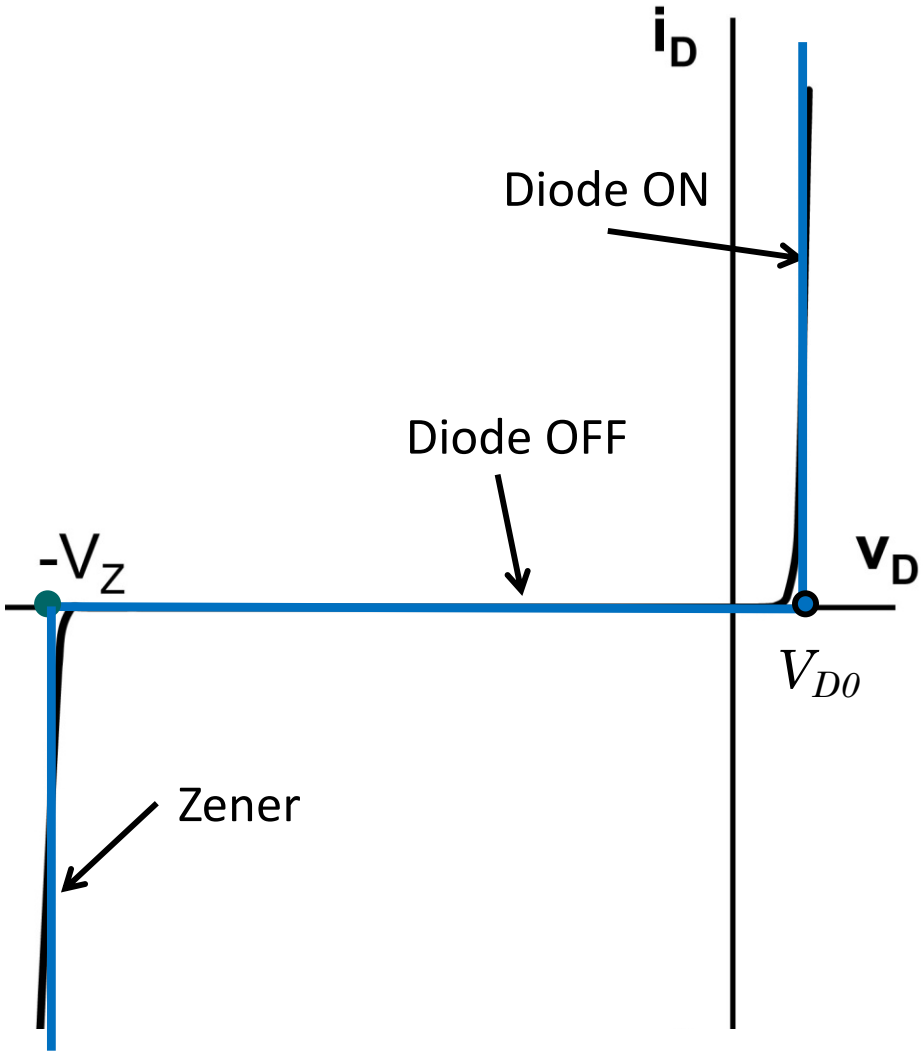
Zener Diode



Made specially to operate in the reverse breakdown region.

Useful as a “reference” voltage in many circuits.

Zener Diode piecewise-linear model



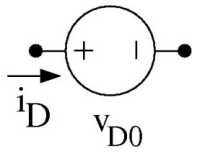
Diode ON: $v_D = V_{D0}$ and $i_D \geq 0$

Diode OFF: $i_D = 0$ and $-V_Z < v_D < V_{D0}$

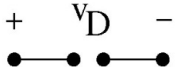
Zener: $v_D = -V_Z$ and $i_D \leq 0$

Circuit Models:

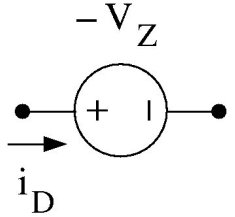
ON:



OFF:

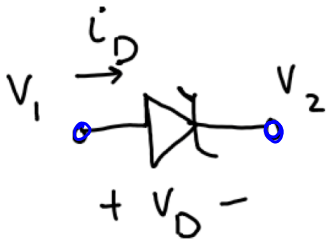


Zener:



Zener Diode piecewise-linear model

Assume Zener diode with $V_D = 0.7\ V$ and $V_Z = 5\ V$.



(A) When $0 < V_1 - V_2 < 0.7$, diode is forward-biased, but it's not ON, yet. $\Rightarrow i_D = 0$

(B) When $-5 < V_1 - V_2 < 0$, diode is reverse-biased, but it's not in the Zener region, so it's off. $\Rightarrow i_D = 0$

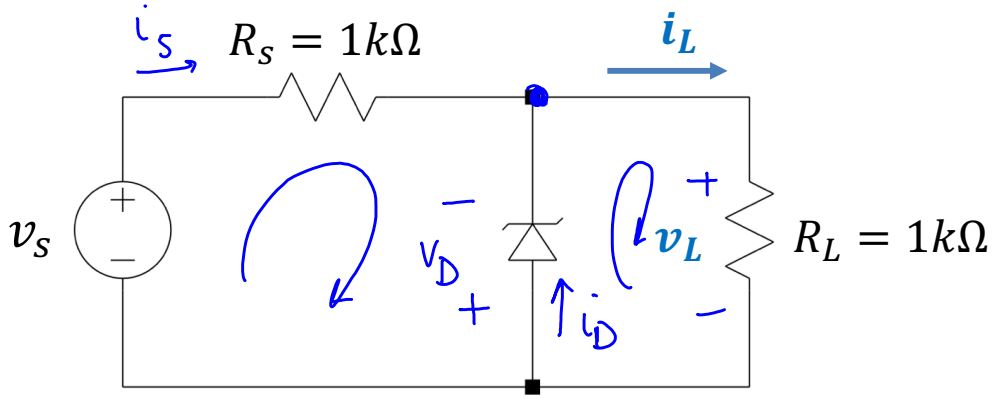
(C) When $V_1 - V_2 = 0.7$, diode is forward-biased and it's ON $\Rightarrow i_D \geq 0$ and $V_D = V_{D_0} = 0.7\ V$.

(D) When $V_1 - V_2 = -5\ V$, diode is in Zener region, it conducts,

$\Rightarrow i_D \leq 0$ and $V_D = -V_2 = -5\ V$

Example:

In the following circuit, find i_L and v_L for $v_s = 10\ V$. For what range of v_s and R_L the Zener diode will be in the Zener region and the circuit can operate as a voltage regulator? $(V_Z = 3\ V, V_{D0} = 0.7\ V)$



KCL:

$$i_s + i_D - i_L = 0$$

KVL:

$$V_s = R_s i_s - V_D$$

$$V_D + V_L = 0 \rightarrow V_L = -V_D$$

Assume the diode is in the Zener region:

$V_D = -V_Z$, $i_D < 0$

$V_L = V_Z = 3V$

$i_L = \frac{V_L}{R_L} = \frac{3V}{1k} = 3mA$, $i_L = 3mA$

$$i_s = \frac{V_s + V_D}{R_s} = \frac{10V - 3V}{1k}$$

$i_s = 7mA$

$i_D = i_L - i_s = 3mA - 7mA$

$= -4mA < 0$

when the diode is in the Zener region, $i_D \leq 0$.

$$i_D = i_L - i_s \leq 0 \longrightarrow \boxed{i_s \geq i_L}$$

$$V_L = V_Z \quad , \quad \boxed{i_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L}}$$

$$\boxed{i_s = \frac{V_s - V_Z}{R_s}}$$

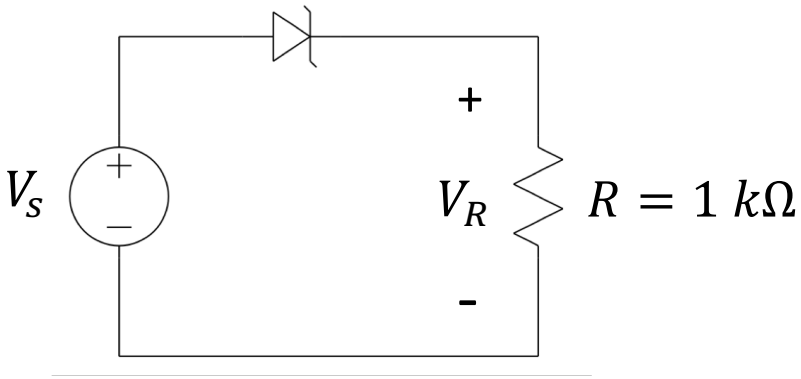
$$\boxed{\frac{V_s - V_Z}{R_s} \geq \frac{V_Z}{R_L}}$$

$$\frac{V_s}{R_s} \geq V_Z \left(\frac{1}{R_L} + \frac{1}{R_s} \right) \longrightarrow \underline{\underline{V_s \geq V_Z \left(1 + \frac{R_s}{R_L} \right)}}$$

$$\frac{V_s/V_Z - 1}{R_s} \geq \frac{1}{R_L} \longrightarrow R_L \geq \boxed{\frac{R_s}{V_s/V_Z - 1}}$$

Lecture 5 reading quiz

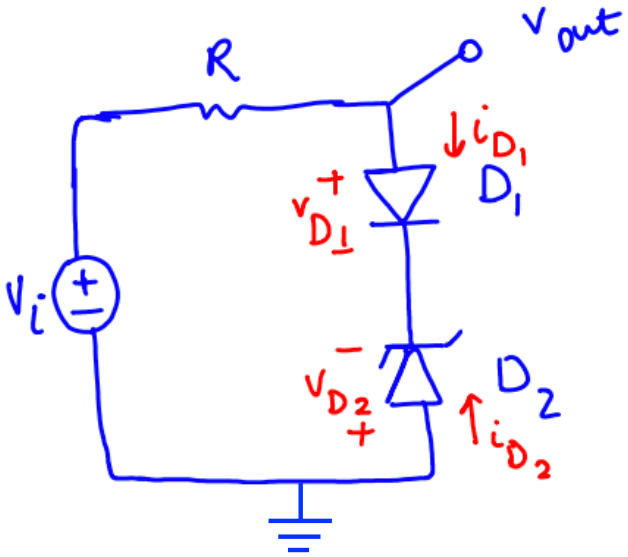
In the following circuit, find V_R for $V_s = +5\ V$ and $V_s = -5\ V$. Assume $V_Z = 3\ V$ and $V_{Do} = 0.7\ V$.



Discussion question 1.

In the below circuit find the range of v_i for which D_1 is ON and D_2 is in the Zener region. Calculate v_{out}.

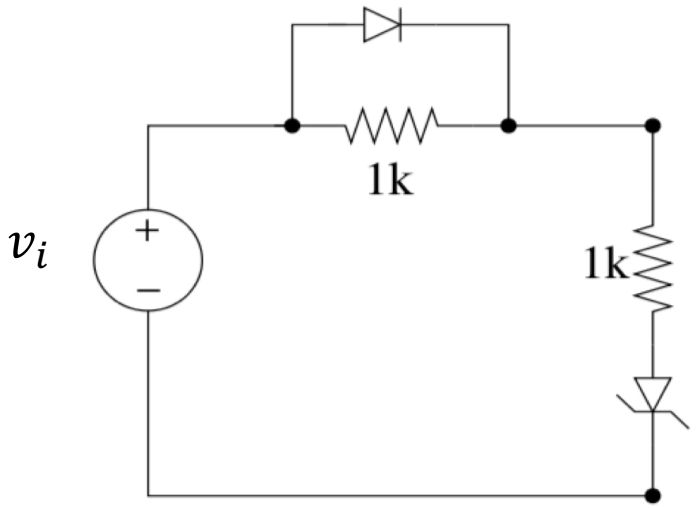
Are there any other possible states at which D_1 and D_2 can operate? Assume $V_{D0} = 0.7\ V$ and $V_Z = 5\ V$.



Extra activity: find v_{out} for all ranges of v_i (solve the circuit parametrically).

Clicker question 1:

What is the range of v_i for which both diodes are ON? Assume $V_Z = 4\ V$ and $V_{Do} = 0.7\ V$.



A. $v_i \geqslant 2.1$ V

B. $v_i \geqslant 1.4$ V

C. $v_i \geqslant 0.7$ V

D. Both diodes cannot be ON simultaneously.