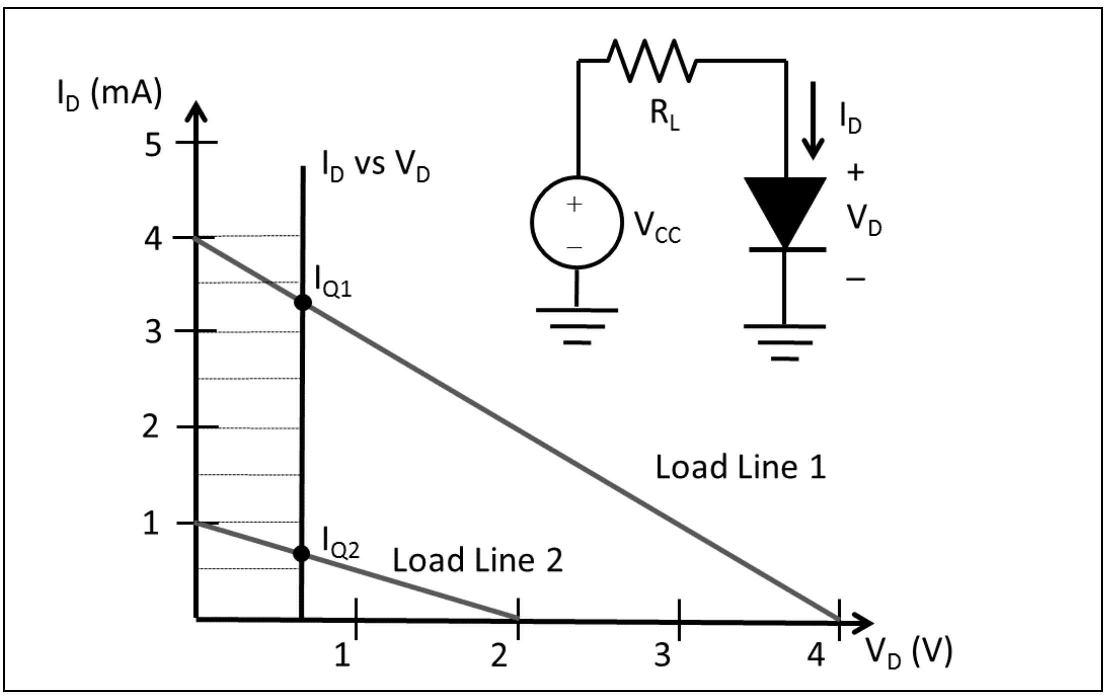
ECE 255 Spring 2019

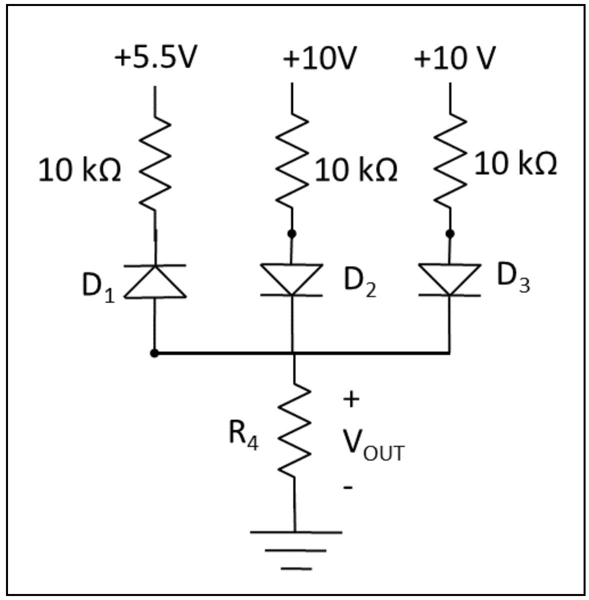
Homework 3

Due 5:00 PM Monday, Jan 28 in MSEE 180 Dropbox

1. Consider a silicon diode that follows an "ideal diode" equation ($I = I_0 (\exp(V/V_T) - 1)$, with I_0 = 1e-14 A. Consider forward-biased operation at room temperature (V_T = 0.026V). (Note that this is the region that we typically approximate as $V_D \sim 0.7$ in circuit analysis).
   a. Determine the current range over which the diode voltage is between 0.65 and 0.75 V. Your solution should include a plot of the current-voltage relationship on a semilog scale (log I versus linear V).
   b. Determine the ratio between the largest and smallest current calculated in part a).
2. Consider the resistor/diode circuit shown below. The I-V plot shows: i) the diode current-voltage relationship (using the $V_D \sim 0.7$ V approximation) and ii) load lines 1 and 2, representing different values of V_{CC} and R_L.
   a. For load line 1, find the values of V_{CC} and R_L.
   b. For load line 1, find I_D by reading it off the graph (to the nearest 0.1 mA)
   c. For load line 1, find I_D by expressing the load line equation in the form $y = ax + b$ and using the $V_D \sim 0.7$ V approximation.
   d. Repeats parts a) and b) for load line 2.

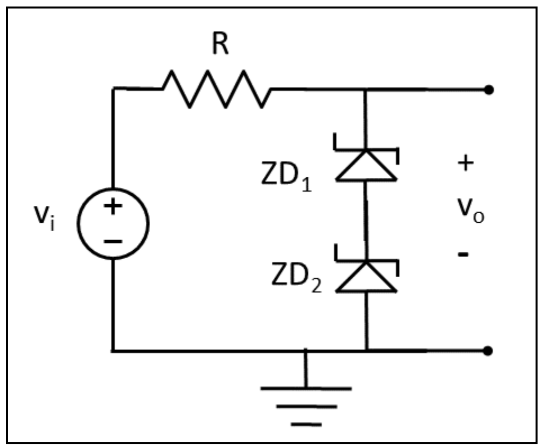


3. Consider the circuit shown below. The diodes are all identical, and are general purpose diodes with reverse breakdown voltage V_Z > 10V. In forward bias, each diode can be modeled using a "constant voltage drop" approximation (V_D = 0.7V).



   a. Consider the case in which R_4 = 5 kΩ and D_1 is off. What is the value of the output voltage (V_{OUT})?
   b. Consider the same circuit as in part a), except for the value of R_4. What is the minimum value of R4 required in order for D_1 to become forward biased (i.e. for V_{D1} to be 0.7V or greater, in the polarity corresponding to forward bias)?

4. Consider the clipper circuit shown below, employing two Zener diodes. In forward bias, each diode can be modeled as a standard diode using a constant voltage drop model with V_D =0.7V. The Zener voltages for the two diodes are V_{Z1} = 4.5V and V_{Z2} = 5.5V. You can assume that the series resistance in the Zener region is negligible.

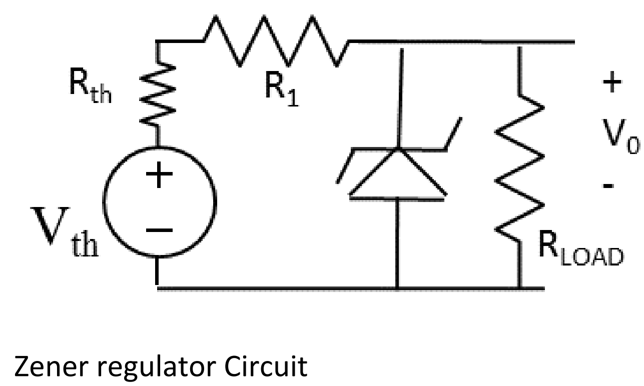


   a. Consider the case in which v_1 is a DC bias voltage varying from -12V to +12 V. Find and plot/sketch the output voltage (v_o) versus input voltage (v_1). You should state the minimum and maximum output voltages.
   b. Next, consider the case in which v_1 is a sinusoidal voltage v_1 = 12V sin (ωt). Plot/sketch the input and output (v_o) waveforms versus time for two periods of the input sinusoid.

5. (Derived from S&S Problem 4.70). A half-wave rectifier circuit (see Fig. 4.23) with a 1 kΩ load operates from a 120-V (rms) 60 Hz household supply through a 12-to-1 step-down transformer. In forward bias, the silicon diode can be modeled using a 0.7-V drop for any current.
   a) What is the peak voltage of the rectified output?
   b) For what fraction of the cycle does the diode conduct?
   c) What is the average output voltage?
   d) What is the average current in the load?
   e) Suppose that we place a capacitor (C_1) in parallel with the resistor. What value of C_1 is required in order to realize an RC time constant equal to twice the time

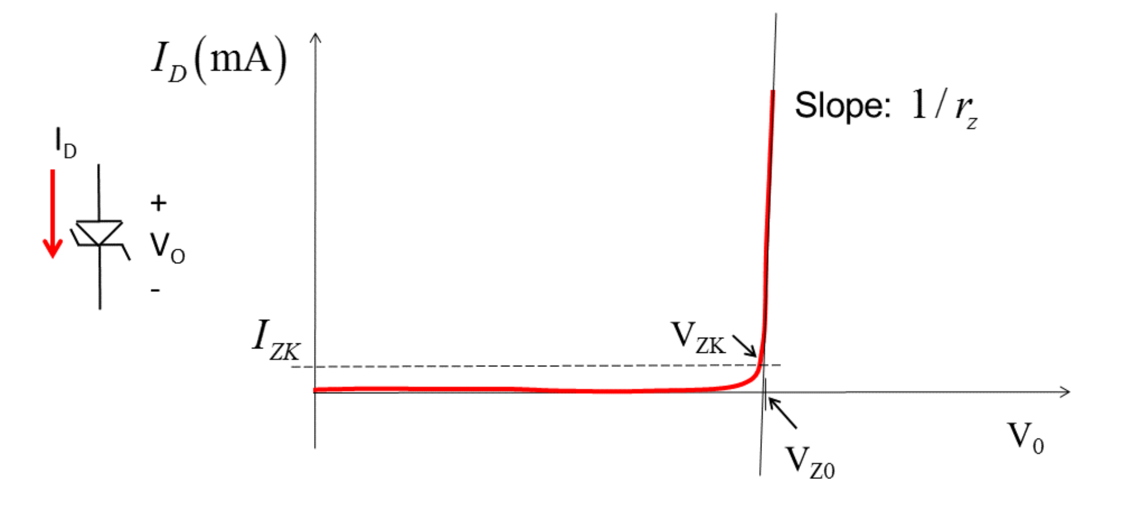
interval over which the diode is "off" (determined from your analysis in parts a)-d)). For "R", you should use 1 kΩ.

6. Consider a Zener diode in a regulator circuit, as discussed in S&S Example 4.7. The Zener diode has V_{Z0} = 10V and r_Z = 25 Ω. R_1 = 400 Ω. To be consistent with Ex. 4.7, an R_{LOAD} is shown, but $R_{LOAD} = \infty$ throughout this problem. The source represents the output of a diode regulator circuit, with V_{th} = (16 +/_ 1) V.



Zener regulator Circuit

   a) First consider the case in which R_{th} = 0. Find the min and max values of V_O (corresponding to $V_{th.min}$ = 15V and $V_{th,max}$ = 17V, respectively).
   b) Next, consider the case in which R_{th} is not zero. What is the maximum value of R_{th} for which the Zener diode is operating with a current of at least 2 mA over the full range of V_{th}? You may assume that the corresponding knee voltage is ~ V_{Z0}.
   c) The regulating action of the Zener diode can be illustrated using appropriate load lines. Plot/sketch the Zener diode current-voltage relationship in the reverse-bias region – since the diode is "upside down" in the circuit, you can plot this in the first quadrant (i.e. current and voltage are both positive quantities). Plot/sketch load lines corresponding to i) the $V_{th,min}$ and $V_{th,max}$ points from part a) and ii) the V_{th_min} point from part b).



Zener I-V Shown reflected into first quadrant, for Prob. 6c.