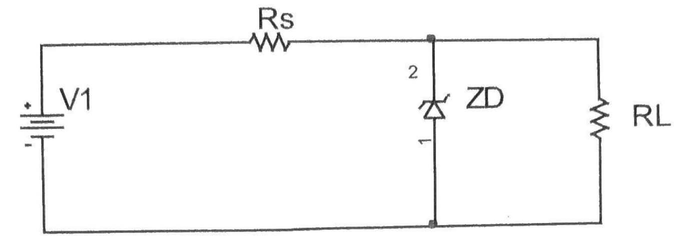
ECSE-2050 **Introduction to Electronics**
Summer 2020 **Name** Saaif Ahmed

Homework 9

Problem 1) Zener Diodes



The above Zener diode has the following Knee voltages and currents,

$V_{Knee} = 5.05V$
$I_{Knee} = 20mA$

Additionally, the following measurements were taken when the diode was in breakdown

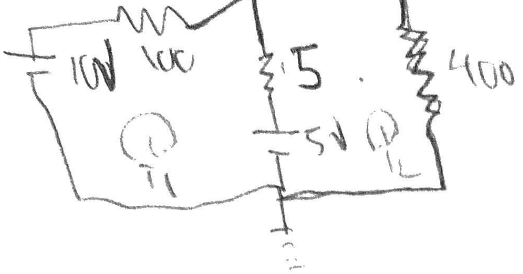
Measurement 1: at $Vz = 5.5V$, $Iz = 100mA$
Measurement 2: at $Vz = 5.6V$, $Iz = 120mA$

a) Based on the above parameters, what is the minimum load voltage such that the Zener diode is in the breakdown region of operation. $V_z \geq 5.1V$
b) Determine the equivalent linear model, r_Z and V_{zo}, when the Zener diode is in breakdown. Sketch the equivalent circuit.
c) For $V1 = 10V$, $Rs = 100\Omega$, $RL = 400\Omega$,
   a. Verify that the diode is in breakdown
   b. Determine the power consumed by the diode and the power consumed by the load RL.
d) For $V1 = 15V$, $Rs = 100\Omega$, $RL = 400\Omega$,
   a. Verify that the diode is in breakdown
   b. Determine the power consumed by the diode and the power consumed by the load RL
e) Qualitatively, what can you say about load power when the circuit is in regulation (when the Zener diode is in breakdown)?
f) If the Zener diode has a maximum current of 100mA, what is the maximum source voltage?

B: $R_z = \frac{5.6-5.5}{(120-100)10^{-3}} = 5$. linear analysis $\rightarrow V_{z0} = 5.0V$

$V_z = 5.1$

C:



$i_1 105 - i_2 5 = 5V$

$-5i_1 + 405 i_2 = 5V$

$i_1 = 0.048$

$i_2 = 0.013$ Verify: $(i_1 - i_2)5 + 5V \geq 5.1$

$5.175 \geq 5.1$

$P_{R_L} = (i_2)^2 R = 0.067\,W$

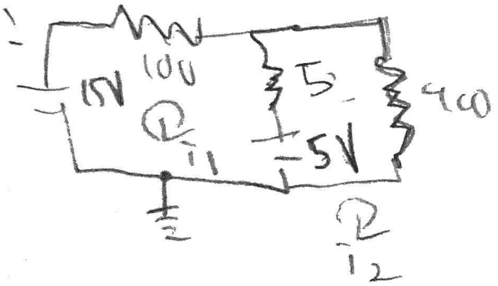
$P_{Diode} = (i_1 - i_2)5 + (i_1 - i_2)^2 5 = 0.181\,W$

$(i_1 - i_2) \geq 20\,mA$

$35\,mA \geq 20\,mA$

diode in breakdown

D:



$105 i_1 - i_2 5 = 10$

$-5i_1 + 405 i_2 = 5V$

$i_1 = 0.1$

$i_2 = 0.014$

$P_{R_L} = (i_2)^2 R = 0.074\,W$

Verify: $(i_1 - i_2)5 + 5V \geq 5.1$

$5.411 \geq 5.1$

$P_{Diode} = (i_1 - i_2)5 + (i_1 - i_2)^2 5 = 0.445\,W$

$(i_1 - i_2) \geq 20\,mA$

$82\,mA \geq 20\,mA$

diode in breakdown

E: Source power is mostly absorbed by the diode and R_s when the zener is in breakdown.

F:

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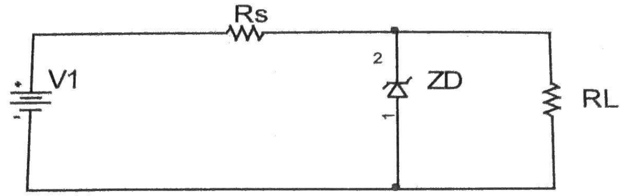
Problem 2) Ripple Voltage



The Zener diode in the above circuit has a Knee voltage of 5.1V, a Knee current of 20mA, and a Zener resistance of 10Ω. You can assume the Knee voltage and current lie on the linear approximation curve of the diode in reverse breakdown.

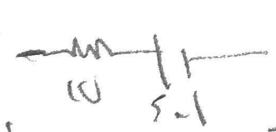
a) Removing the diode from the circuit, for V1 = 10+1sin(ωt) V, Rs = 50Ω, RL = 150Ω, determine the DC voltage and peak-to-peak voltage of the load. Determine the ratio of the ripple voltage to the DC voltage.
b) For the same circuit with the Zener diode included, determine the DC voltage and peak-to-peak voltage of the load. Determine the ratio of the ripple voltage to the DC voltage.
c) Qualitatively, what can you say about the effect of the Zener diode when considering the above ratios.
d) Add a second Zener diode in parallel with the first and verify that both diodes are in regulation. Again determine the ratio of the peak-to-peak voltage to the DC voltage. Did this ratio improve as expected? Why can't we keep adding Zener diode in parallel?

A: $V_L = \frac{(10+1\sin(\omega t))(150)}{200} = 7.5 + .75\sin(\omega t)$ $V_{DCL} = 7.5V$

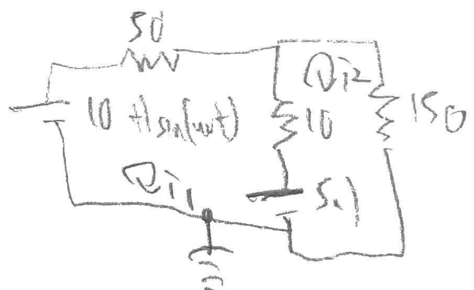
$V_{Rip} = 1.5V$

$\frac{V_{rip}}{V_{DCL}} = .2$

B:



$V_2 = (20mA)10 + 5.1 = 5.3$



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$-10 - 1\sin(\omega t) + i_1 50 + i_1 10 + 5.1 - i_2 10 = 0$ $60i_1 - 10i_2 = 4.9 + 1\sin(\omega t)$

$-5.1 + i_2 10 - i_1 10 + i_2 150 = 0$ $i_1 = 0.082 + 0.017\sin(\omega t) + 0.1$

$160i_2 - i_1 10 = 5.1$ $160i_2 = 2.62 + .17\sin(\omega t)$

$i_2 = 0.016 + .00010625\sin(\omega t)$

B: continued $\quad V_2 = (i_1 - i_2)10 + 5.1$

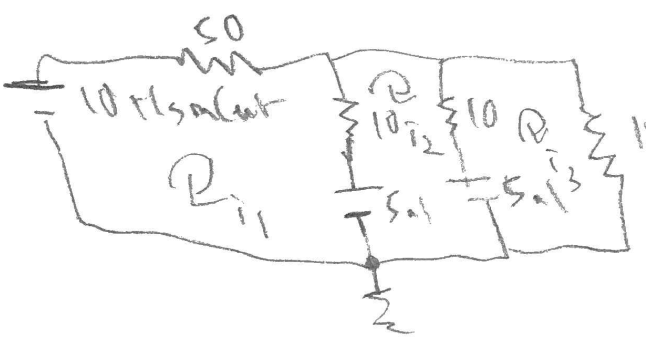
$V_2 = 5.93 + .16\sin(\omega t)$

$V_{OCL} = 5.93 \qquad \frac{V_{rip}}{V_{OCL}} = 0.05$

$V_{rip} = .32$

C: The effect of the zener diode is to reduce ratio of the ripple to the load.

D:



$-10 + i_1 60 - i_2 10 + 5.1 = 0$

$0 + i_2 20 - i_1 10 - i_3 10 = 0$

$-5.1 + i_3 160 - i_2 10 = 0$

$60 i_1 - 10 i_2 = 4.9 + 1\sin(\omega t) \qquad i_1 = 0.082 + 0.017\sin(\omega t) + .17 i_2$

$20 i_2 - 10(0.082 + 0.017\sin(\omega t) + .17 i_2) - i_3 10 = 0$

$20 i_2 - .82 - .17\sin(\omega t) - 1.7 i_2 - i_3 10 = 0 \qquad 18.3 i_2 = .82 + .17\sin(t) + 10 i_3$

$i_2 = 0.045 + 0.1\sin(\omega t) + 0.55 i_3$

$160 i_3 - 10(0.045 + 0.1\sin(\omega t) + 0.55 i_3) = 5.1$

$154.5 i_3 - 0.45 - 1\sin(\omega t) = 5.1 \qquad i_3 = 0.036 + 0.0065\sin(\omega t)$

$R_L \cdot i_3 = V_{out} = 5.4 + 0.97\sin(\omega t)$ → Voltage across all diodes is enough to cause breakdown.

$V_{rip} = \frac{1.94}{5.4} = 0.36.$

The ratio did not improve as expected. This is because each diode has small current draw taking it away from the load.

Hw 9 Prob 1 Part F:

KCL at node Above the Diode.

$$\frac{V_Z - V_1}{100} + 100 * 10^{-3} + \frac{V_Z}{400} = 0$$

$$\frac{5.5}{100} - \frac{V_1}{100} + 100 * 10^{-3} + \frac{5.5}{400} = 0$$

$$V_1 = 16.875V$$