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$\boxed{\text{HW 2a: } 2.62,\ 2.63}$

EXAM I: 25 JUNE 2015

1 SIDE, $8\frac{1}{2}'' \times 11''$ FORMULA SHEET (NO WORKED-OUT PROBLEMS)

- AMPLIFIERS
- OP-AMPS
- DIODES

(UP THROUGH 18 JUNE)

VOLTAGE REGULATOR

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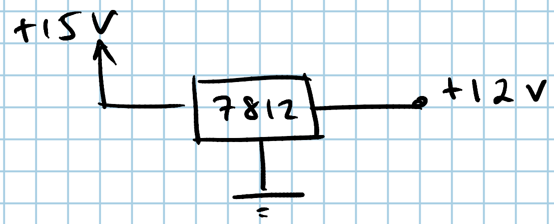
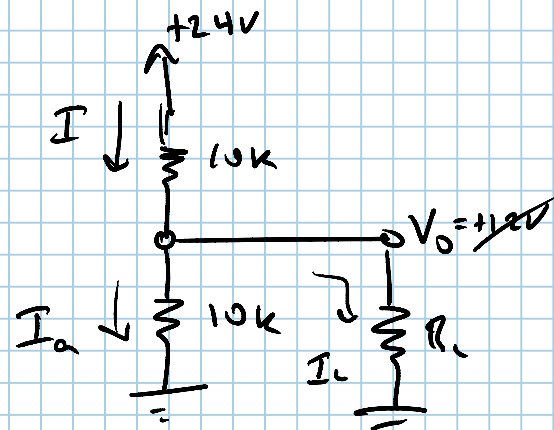
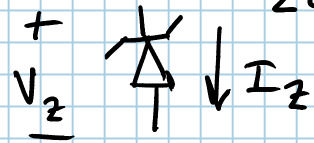
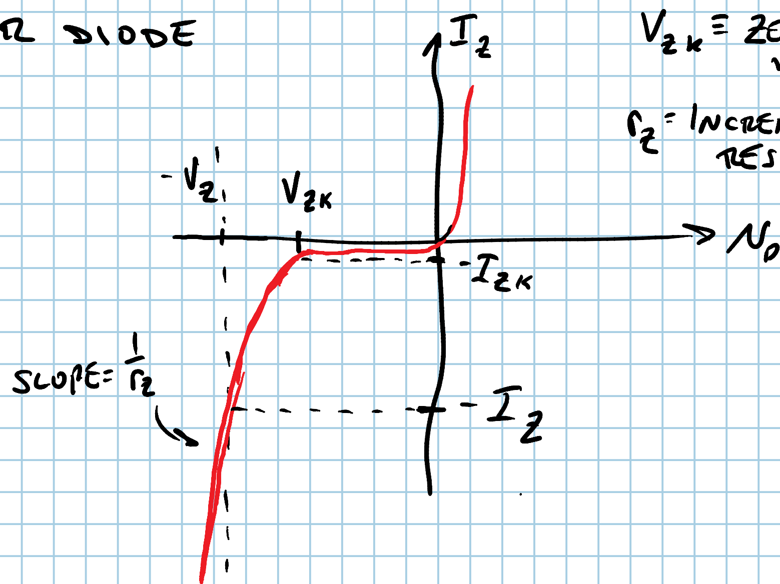




ZENER DIODE

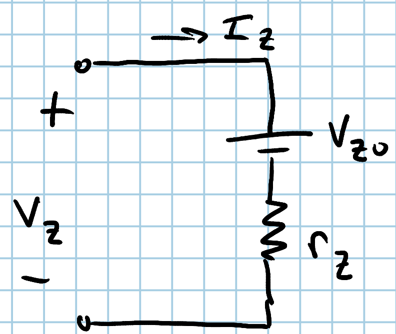




$V_{ZK} \equiv$ ZENER "KNEE" VOLTAGE

r_Z = INCREMENTAL RESISTANCE

ZENER MODEL



V_Z ALMOST EQUAL TO V_{Z0}, BUT $V_Z > V_{Z0}$

$$\boxed{V_Z = V_{Z0} + I_Z r_Z}$$

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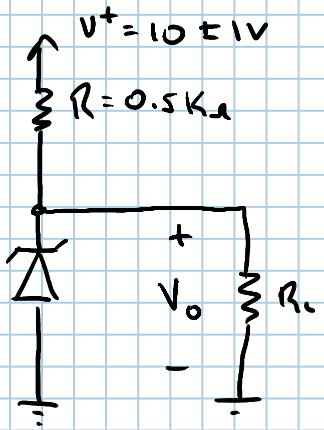
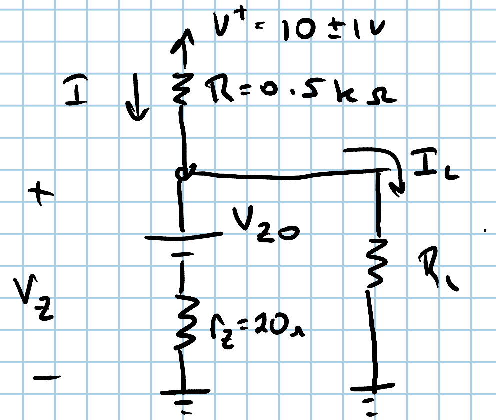
6.8 V ZENER DIODE

$V_Z = 6.8\ V$ @ $I_Z = 5\ mA$

$r_Z = 20\ \Omega$

$I_{ZK} = 0.2\ mA$





FROM EQN. 4.20

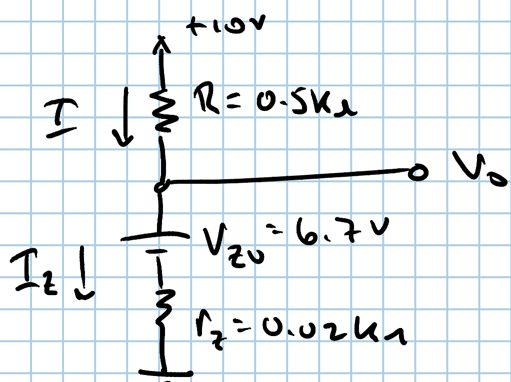
$V_Z = V_{Z0} + I_Z r_Z$

$V_{Z0} = V_Z - I_Z r_Z$

$= 6.8\ V - (5\ mA)(0.02\ k\Omega)$

$\underline{\underline{V_{Z0} = 6.7\ V}}$

a) FIND V_o @ NO LOAD, V^+ @ NOMINAL (+10V)



$I = I_Z \Rightarrow$ KVL

$I R + V_{Z0} + I r_Z = V^+$

$I = \dfrac{V^+ - V_{Z0}}{R + r_Z} = \dfrac{10 - 6.7\ V}{0.5 + 0.02} = \dfrac{3.3\ V}{0.52\ k\Omega}$

$\underline{\underline{I = 6.35\ mA}}$

$V_o = V_{Z0} + I r_Z = 6.7\ V + (6.35\ mA)(0.02\ k\Omega)$

$\boxed{V_o = 6.827\ V}$

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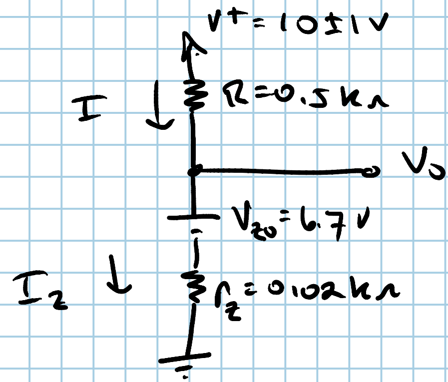
b) FIND ΔV_o FOR ΔV^+ $(10 \pm 1V)$
(NO LOAD) $(11V, 9V)$



$$V_o = V_{Z0} + I r_Z \qquad (I = I_Z)$$

$$I = \frac{V^+ - V_{Z0}}{R + r_Z}$$

$$V_o = V_{Z0} + \underbrace{\left(\frac{V^+ - V_{Z0}}{R + r_Z}\right)}_{I} r_Z$$

$$V_o = V_{Z0} + (V^+ - V_{Z0}) \left(\frac{r_Z}{R + r_Z}\right)$$

IF $V^+ = 11V$

$$V_o = 6.7 + (11 - 6.7)\left(\frac{0.02}{0.5 + 0.02}\right) = 6.865\ V$$

IF $V^+ = 9V$

$$V_o = 6.7 + (9 - 6.7)\left(\frac{0.02}{0.5 + 0.02}\right) = 6.788\ V$$

$$\Delta V_o = \pm 0.0385\ V = \pm 38.5\ mV$$

$$\frac{38.5\ mV}{1\ V} = 38.5\ mV/V$$

LINE REGULATION

(c) Find ΔV_o if R_L draws $I_L = 1\,mA$

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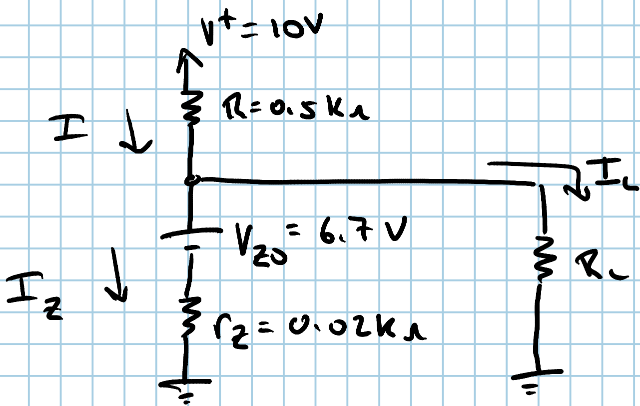


$I \neq I_Z$

I_Z will decrease by $I_L = 1mA$

$I_Z = 6.35mA - 1mA = 5.35mA$

$V_O = V_{Z0} + I_Z r_Z = 6.7 + (5.35mA)(0.02k\Omega)$

$\boxed{V_O = 6.807\,V}$

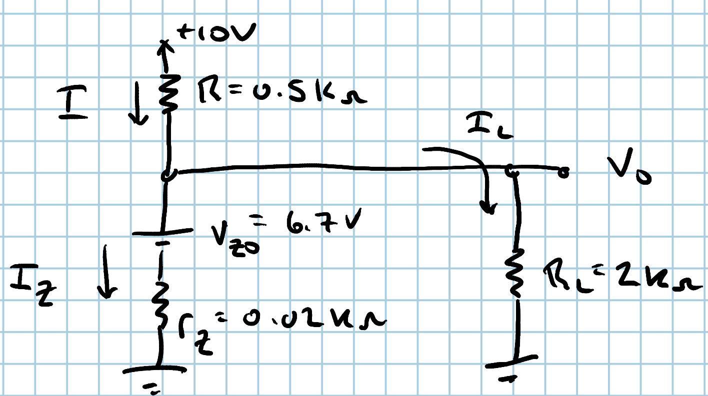
$\Delta V_o = 6.83V - 6.807\,V = 0.02\,V$

$\boxed{\Delta V_O = 20\,mV}$

LOAD REGULATION $\dfrac{\Delta V_O}{\Delta I_Z} = \dfrac{20\,mV}{1mA}$

$= 20\,\frac{mV}{mA}$

(d) Find ΔV_O if $R_L = 2k\Omega$ (No load $V_O = 6.827V$)



$I_L \approx \dfrac{6.8V}{2k\Omega} = 3.4\,mA$

$V_O = V_{Z0} + I_Z r_Z \Rightarrow I_Z = \dfrac{V_O - V_{Z0}}{r_Z}$

$I_L = \dfrac{V_O}{R_L}$

$I = \dfrac{V^+ - V_O}{R}$

KCL: $I = I_Z + I_L$

$\dfrac{10 - V_O}{0.5k\Omega} = \dfrac{V_O - 6.7}{0.02k\Omega} + \dfrac{V_O}{2k\Omega} \Longrightarrow \underline{V_O = 6.762\,V}$

$\Delta V_O = 6.827 - 6.762 = 0.065V$

$\boxed{\Delta V_O = 65\,mV}$

(e) FIND V_o IF $R_L = 0.5\,k\Omega$

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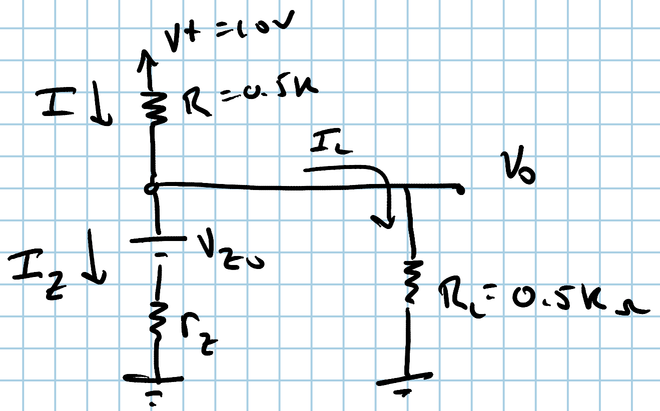
(SMALLER R_L, LARGER LOAD)



$$I_L \approx \frac{V_o}{R_L} \approx \frac{6.8\,V}{0.5\,k\Omega} = 13.6\,mA$$

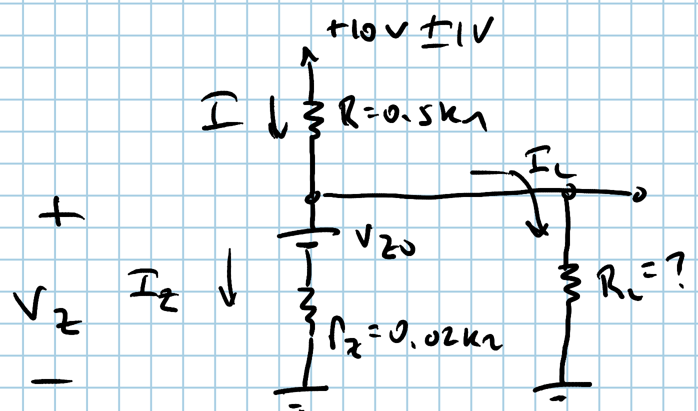
$$I_{(NO\ LOAD)} \approx \frac{10-6.8}{0.5\,k\Omega} = \frac{3.2}{0.5\,k} = 6.4\,mA$$

$I_L >> I_{(NO\ LOAD)}$

CAN'T HAPPEN

(f) FIND SMALLEST R_L (LARGEST LOAD) FOR WHICH THE DIODE OPERATES IN BREAKDOWN.

@ EDGE OF THE BREAKDOWN REGION, $I_Z = I_{ZK} = 0.2\,mA$



$V_Z = V_{Z0} + I_Z r_Z = 6.7\,V + (0.2\,mA)(0.02\,k\Omega)$

$V_Z = V_o = 6.696\,V \approx V_{Z0}$

$$I\Big|_{WORST\ CASE} = \frac{9 - 6.7}{0.5} = 4.6\,mA \qquad (10 - 1V)$$

$I_L = I - I_Z = 4.6\,mA - 0.2\,mA = 4.4\,mA$

$$R_L = \frac{V_o}{I_L} = \frac{6.696\,V}{4.4\,mA} \approx 1.5\,k\Omega$$

RECTIFIER CIRCUITS

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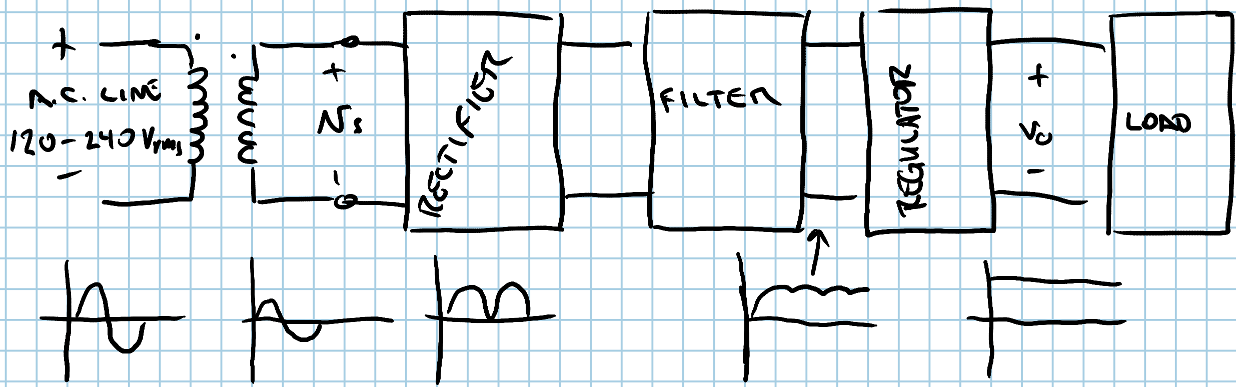
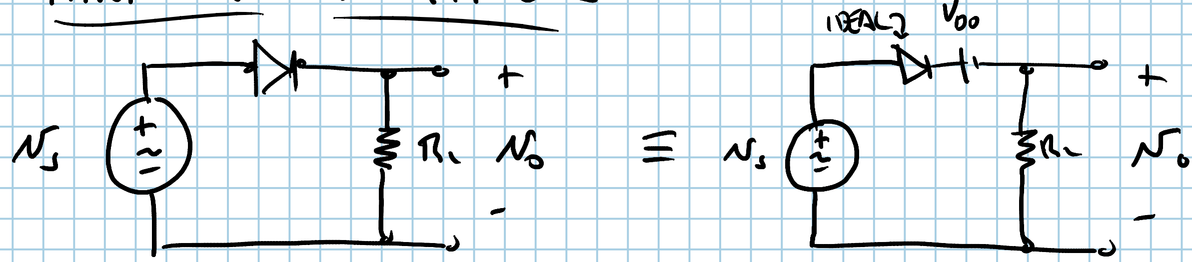
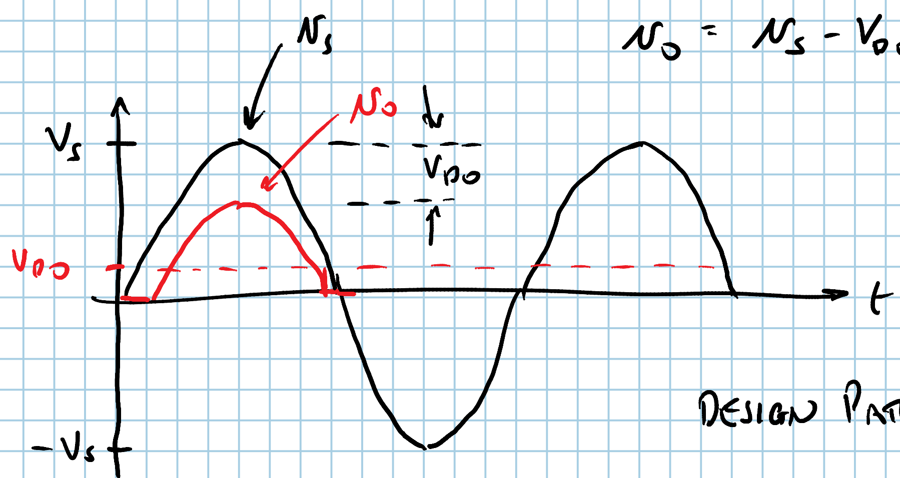


HALF-WAVE RECTIFIERS





$v_o = v_s - V_{DO}$; $v_s \geq V_{DO}$

($V_{DO} = 0.7\text{ V or } 0.8\text{ V}$)

DESIGN PARAMETERS: DIODE CURRENT
PEAK INVERSE VOLTAGE

WHEN v_s IS NEGATIVE, DIODE IS CUT-OFF (OPEN),
$\therefore$ PIV = v_s, BUT, OVER-SPECIFY FOR SAFETY & RELIABILITY.