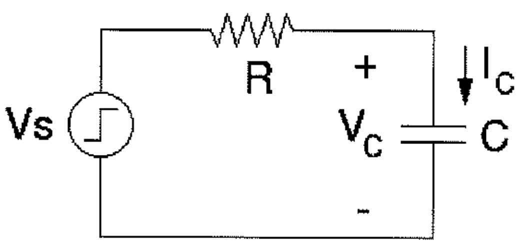
ELE338 **Electronics I** **Exam 1** **F2019**

Name .... Score ....

1) Linear Circuit Theory



Vs is a 5 V step function engaged at t=0.

R=1 kΩ, C=1nF

Assume Vc(t=0) = 0

Recall: $I_C = C\, dV_C/dt$

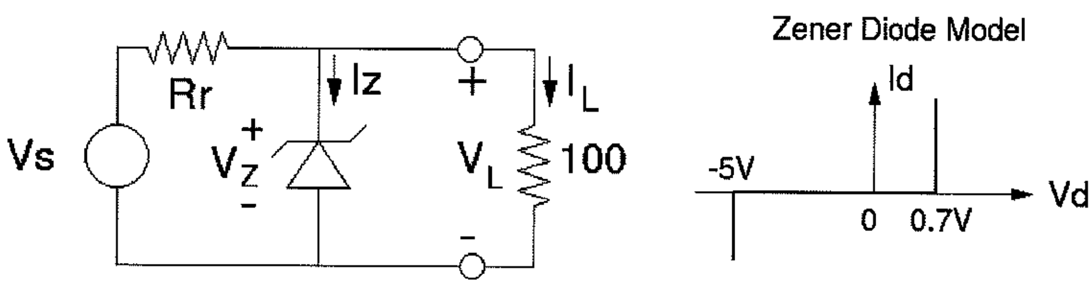
a) Find a value for the current **Ic immediately after** the source Vs stepped up to 5 V.

b) What is the value of **Ic a long time after** the step has been applied (t →∞).

c) Write down the **time-domain KVL** equation for the given circuit and derive a **symbolic solution** for the voltage **Vc(t)** for t≥0.

d) Find a value for the **time t_{90}**, where the **voltage Vc** has reached **90%** of its final value.

2) Voltage Regulator



Vs is an unregulated dc voltage, which varies between 6.3 V and 7.0 V.

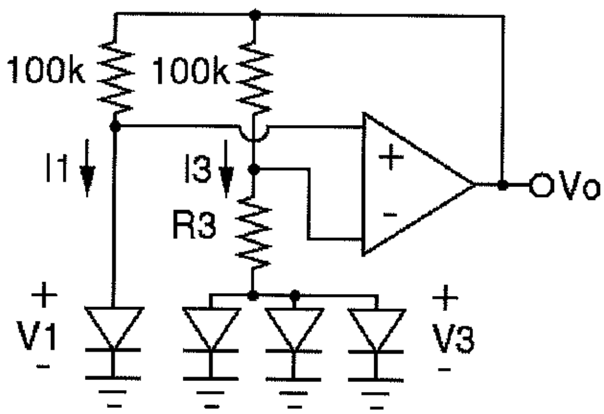
a) What is the **minimum** value of **V_L** if **Rr = 50Ω?** (Hint: Check if the Zener diode is on or off).

b) Find a value for the **maximum** of the Zener diode current **Iz** if **Rr = 16 Ω**.

c) What is the **minimum** of the Zener diode current **Iz** if **Rr = 16 Ω**?

d) Derive a **value** for the **maximum** of **Rr** such that **V_L = V_Z = 5 V** for all values of Vs between **6.3V** and **7.0 V**.

3) Voltage Reference with Diodes



OpAmp is **ideal** and all **diodes** are **identical**

@ T=300K nV_T**=30 mV**

@ T=400K nV_T**=40 mV**

$I_d = I_s \exp(V_d/nV_T)$

$dV_d/dT = -1.7$ **mV/K**

a) Use the given **diode equation** to find a **symbolic expression** for the diode voltage difference $\Delta V_d = V_1 - V_3$.

b) The output **voltage Vo** can be written as $V_o = V_1 + \ldots$ Fill in the missing part of this equation. (Assume that V_1 and all resistor values are known).

c) If $R_3 = 1.5\ \mathrm{k\Omega}$ and $V_1 = 670$ **mV** at **T=300 K,** find the values of **Vo** at the 2 temperatures i) $T_1 = 300$ **K,** and ii) $T_2 = 400$ **K,** respectively.

d) Derive a value for R_3 such that the output **voltage Vo** becomes approximately **temperature independent** (i.e. remains constant), between $T_1 = 300$ **K** and $T_2 = 400$ **K.**

ELE 338 Exam 1 Fall 2019

1) a) $\| I_c(t=0^+) = \frac{V_{step}}{R} = 5\,mA \|$ 2

b) $\| I_c(t \to \infty) = 0 \|$ 2

c) $| V_s = I_c R + V_c = C \cdot R \frac{dV_c}{dt} + V_c |$ 1

for $t \geq 0$ $| V_s = V_{step} |$

$\therefore \| V_c(t) = V_{step}(1 - e^{-\frac{t}{RC}}) \|$ $t \geq 0$ 3

d) $| V_c(t_{90}) = V_{step}(1 - e^{-\frac{t_{90}}{RC}}) = 0.9\,V_{step} |$

$\therefore | e^{-\frac{t_{90}}{RC}} = 0.1 |$ 2

$\| t_{90} = RC \cdot \ln(10) = 2.3\,\mu s \|$ 2

12

2) a) $V_{S\,Min} = 6.5V$

If zener is on $I_r = \frac{V_{S\,Min} - V_Z}{R_r} = 26mA$

$\therefore I_r < I_L = 50mA$ for proper operation

$\therefore$ |Zener is off|

$\| V_{L\,Min} = V_{S\,Min} \cdot \frac{R_L}{R_r + R_L} = 4.2V \|$ 3

b) zener is on $\therefore | I_{r\,Max} = \frac{V_{S\,Max} - V_Z}{R_r} = 125mA |$

$| I_L = 50mA |$

$\therefore \| I_Z = I_{r\,Max} - I_L = 75mA \|$ 3

c) zener is on: $| I_{r\,Min} = \frac{V_{S\,Min} - V_Z}{R_r} = 81.25mA |$

$I_L = 50mA$

$\therefore \| I_{Z\,Min} = I_{r\,Min} - I_Z = 31.25mA \|$ 3

d) zener turn on: $| V_L = 5V ; I_Z = 0 |$

$\therefore | I_{r\,Min} = \frac{V_{S\,Min} - V_Z}{R_{r\,Max}} = I_L |$

$\therefore \| R_{r\,Max} = \frac{V_{S\,Min} - V_Z}{I_L} = 26\Omega \|$ 3

12

3) a) $V_1 - V_3 = nV_T \ln\left(\frac{I_1}{I_S}\right) - nV_T \ln\left(\frac{I_3}{I_S \cdot 3}\right)$

$= nV_T \ln\left(\frac{I_1}{I_S} \frac{3 I_S}{I_3}\right)$

Ideal OpAmp $\therefore I_1 \cdot 100k = I_3 \cdot 100k$

$\therefore \| \Delta V_d = V_1 - V_3 = nV_T \ln(3) \|$ 3

b) $|V_o = V_1 + 100k \cdot I_1 = V_1 + 100k \cdot I_3|$

$|I_3 R_3 = \Delta V_d|$

$\therefore I_3 = \frac{\Delta V_d}{R_3}$

$\therefore \| V_o = V_1 + \frac{100k}{R_3} \Delta V_d = V_1 + \frac{100k}{R_3} nV_T \ln(3) \|$ 3

c) i) $\| V_{o1} = 0.67V + \frac{100}{1.5} 0.03 \ln(3) V = 2.867V \|$ 1

ii) $\| V_{o2} = 0.5V + \frac{100}{1.5} 0.04 \ln(3) V = 3.430V \|$ 1

d) $\left| \frac{dV_o}{dT} = 0 \right| \therefore \left| \frac{dV_1}{dT} + n \frac{V_T}{T} \ln(3) \cdot \frac{100k}{R_3} = 0 \right|$

$\left| R_3 = -100k \cdot \frac{nV_T}{T} \ln(3) \cdot \frac{1}{dV_1/dT} \right|$

$\| R_3 |_{T=300k} = 100k \cdot \ln(3) \cdot \frac{0.1mV}{1.7mV} = 6.46k\Omega \|$ 4

12