Homework 3, solution

4.60 (a) Three 6.8-V zeners provide $3 \times 6.8 = 20.4$ V with $3 \times 10 = 30\text{-}\Omega$ resistance. Neglecting R, we have

Load regulation $= -30$ mV/mA.

(b) For 5.1-V zeners we use 4 diodes to provide 20.4 V with $4 \times 25 = 100\Omega$ resistance.

Load regulation $=$ - 100 mV/mA

4.62 $V_Z = V_{Z0} + I_{ZT} r_Z$

$9.1 = V_{Z0} + 0.02 \times 10$

$\Rightarrow V_{Z0} = 8.9$ V

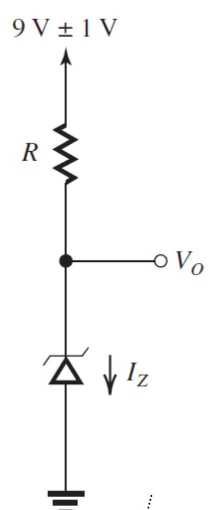
At $I_Z = 10$ mA,

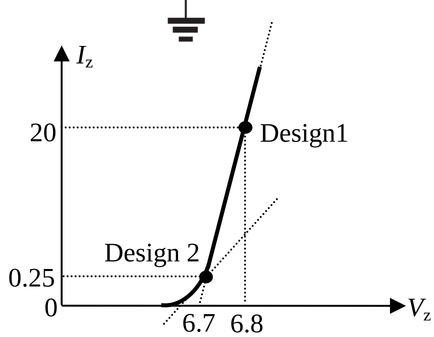
$V_Z = 8.9 + 0.01 \times 10 = 9.0$ V

At $I_Z = 50$ mA,

$V_Z = 8.9 + 0.05 \times 10 = 9.4$ V

4.64





GIVEN PARAMETERS

$V_Z = 6.8\text{V}, r_z = 5\ \Omega$

$I_Z = 20$ mA

At knee,

$I_{ZK} = 0.25$ mA

$r_z = 750\ \Omega$

FIRST DESIGN: 9-V supply can easily supply current

Let $I_Z = 20$ mA, well above knee.

$$\therefore \quad R = \frac{8-6.8}{20} = 60\Omega$$

$$\text{Line regulation} = \frac{\Delta V_O}{\Delta V_S} = \frac{r_Z}{r_Z + R}$$

$$= \frac{5}{5+60} = 76.9\frac{mV}{V}$$

Used lowest possible voltage 8V here because source voltage is 9±1V

SECOND DESIGN: limited current from 9-V supply

$I_Z = 0.25$ mA

$V_Z = V_{ZK} \simeq V_{ZO}$ – calculate V_{Z0} from

$V_Z = V_{Z0} + r_Z I_{ZT}$

$6.8 = V_{Z0} + 5 \times 0.02$

$V_{Z0} = 6.7$ V

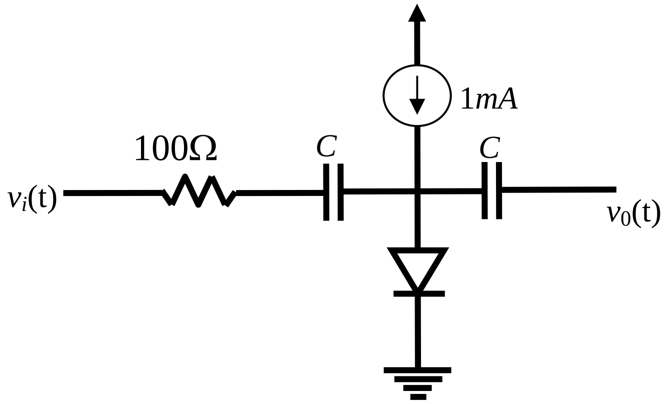
$$\therefore R = \frac{8 - 6.7}{0.25} = 5.2\ \text{k}\Omega$$

$$\text{LINE REGULATION} = \frac{\Delta V_O}{\Delta V_S} = \frac{750}{750 + 5200}$$

$$= 126\ \frac{\text{mV}}{\text{V}}$$

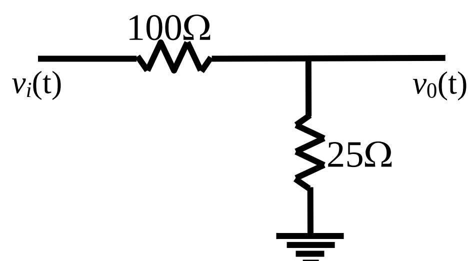
Handout problems:

1, For the following circuit, the diode has $I_s = 10^{-12}A$, $nV_T = 25mV$. The DC current source has 1mA constant current, and $v_s(t)$ is a small *AC* voltage signal. All capacitors are very big which pass *AC* and block *DC* signals. Use small signal analysis, please find the ratio between the output *AC* voltage $v_0(t)$ and the input *AC* voltage $v_i(t)$.



Solution:
For DC analysis, both capacitors are open circuits, so that the DC current flowing through the diode is $I_D = 1mA$. Then, the small-signal equivalent resistance of the diode is

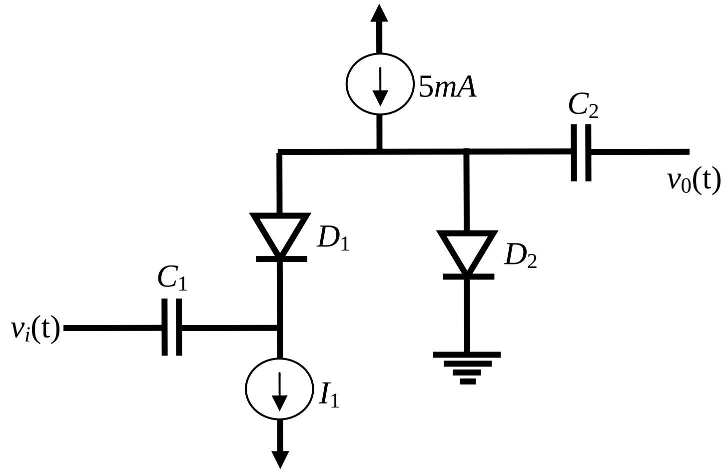
$$r_d = nV_T / I_D = 25mV / 1mA = 25\Omega$$



The small-signal equivalent circuit shown on the right is a simple voltage divider, so that

$$v_0(t) = v_i(t)\frac{25\Omega}{100\Omega + 25\Omega} = 0.2v_i(t)$$

2, For the following circuit, the two diode are identical with $I_s = 10^{-12}A$, $nV_T = 25mV$. All capacitors are very big which pass *AC* and block *DC* signals. $v_s(t)$ is a small *AC* voltage signal. Please find the DC current I_1 at which $v_0(t)/v_i(t) = 0.5$.



Solution:

Both DC and AC equivalent circuits are shown below.

For DC circuit analysis: $I_{D1} = I_1$, and $I_{D2} = 5mA - I_1$.

The small-signal equivalent resistances of the two diodes are

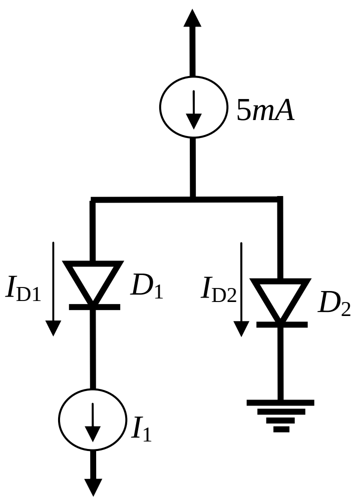
$r_{d1} = \frac{nV_T}{I_1} = \frac{25mV}{I_1}$ and $r_{d2} = \frac{nV_T}{I_2} = \frac{25mV}{5mA - I_1}$

The small-signal circuit analysis indicates that

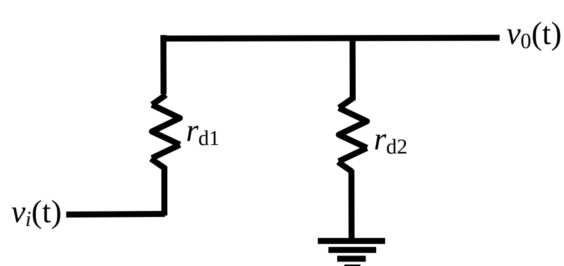
$$v_0(t) = v_i(t)\frac{r_{d2}}{r_{d1} + r_{d2}}$$

For $\frac{v_0(t)}{v_i(t)} = 0.5$, we must have $\frac{r_{d2}}{r_{d1} + r_{d2}} = 0.5$. That is, $r_{d1} = r_{d2}$ and $\frac{25mV}{I_1} = \frac{25mV}{5mA - I_1}$

The solution is: $I_1 = 2.5mA$



DC circuit



AC circuit