The junction areas of the four diodes must be related by the same ratios as their currents, thus

$A_4 = 2A_3 = 4A_2 = 8\,A_1$

With $I_1 = 0.1$ mA,

$I = 0.1 + 0.2 + 0.4 + 0.8 = 1.5$ mA

4.27 We can write a node equation at the anodes:

$I_{D2} = I_1 - I_2 = 7$ mA

$I_{D1} = I_2 = 3$ mA

We can write the following equation for the diode voltages:

$V = V_{D2} - V_{D1}$

If D_2 has saturation current I_S, then D_1, which is 10 times larger, has saturation current $10I_S$. Thus we can write

$I_{D2} = I_S e^{V_{D2}/V_T}$

$I_{D1} = 10 I_S e^{V_{D1}/V_T}$

Taking the ratio of the two equations above, we have

$$\frac{I_{D2}}{I_{D1}} = \frac{7}{3} = \frac{1}{10} e^{(V_{D2}-V_{D1})/V_T} = \frac{1}{10} e^{V/V_T}$$

$$\Rightarrow V = 0.025 \ln\left(\frac{70}{3}\right) = 78.7 \text{ mV}$$

To instead achieve $V = 60$ mV, we need

$$\frac{I_{D2}}{I_{D1}} = \frac{I_1 - I_2}{I_2} = \frac{1}{10} e^{0.06/0.025} = 1.1$$

Solving the above equation with I_1 still at 10 mA, we find $I_2 = 4.76$ mA.

4.28 We can write the following node equation at the diode anodes:

$I_{D2} = 10 \text{ mA} - V/R$

$I_{D1} = V/R$

We can write the following equation for the diode voltages:

$V = V_{D2} - V_{D1}$

We can write the following diode equations:

$I_{D2} = I_S e^{V_{D2}/V_T}$

$I_{D1} = I_S e^{V_{D1}/V_T}$

Taking the ratio of the two equations above, we have

$$\frac{I_{D2}}{I_{D1}} = \frac{10 \text{ mA} - V/R}{V/R} = e^{(V_{D2}-V_{D1})/V_T} = e^{V/V_T}$$

To achieve $V = 50$ mV, we need

$$\frac{I_{D2}}{I_{D1}} = \frac{10 \text{ mA} - 0.05/R}{0.05/R} = e^{0.05/0.025} = 7.39$$

Solving the above equation, we have

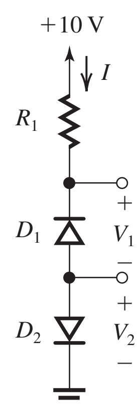
$R = 42\ \Omega$

4.29 For a diode conducting a constant current, the diode voltage decreases by approximately 2 mV per increase of 1°C.

$T = -20$°C corresponds to a temperature decrease of 40°C, which results in an increase of the diode voltage by 80 mV. Thus $V_D = 770$ mV.

$T = +85$°C corresponds to a temperature increase of 65°C, which results in a decrease of the diode voltage by 130 mV. Thus $V_D = 560$ mV.

4.30



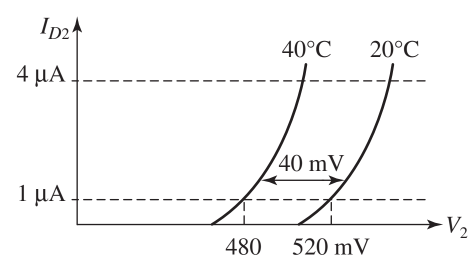
At 20°C:

$V_{R1} = V_2 = 520$ mV

$R_1 = 520$ kΩ

$$I = \frac{520 \text{ mV}}{520 \text{ k}\Omega} = 1\ \mu\text{A}$$

Since the reverse current doubles for every 10°C rise in temperature, at 40°C, $I = 4\ \mu$A



$V_2 = 480 + 2.3 \times 1 \times 25 \log 4$

$= 514.6$ mV

$V_{R1} = 4\ \mu\text{A} \times 520\ \text{k}\Omega = 2.08$ V

At 0°C, $I = \dfrac{1}{4}\ \mu$A

$V_2 = 560 - 2.3 \times 1 \times 25 \log 4$

$= 525.4$ mV

$V_{R1} = \dfrac{1}{4} \times 520 = 0.13$ V

3. $v = 0.7 + 2.3 \times 0.025 \log\left(\frac{0.6255}{1}\right)$

$= 0.6882$ V

$i = \frac{1 - 0.6882}{0.5\ \text{k}\Omega} = 0.6235$ mA

4. $v = 0.7 + 2.3 \times 0.025 \log\left(\frac{0.6235}{1}\right)$

$= 0.6882$ V

$i = \frac{1 - 0.6882}{0.5\ \text{k}\Omega} = 0.6235$ mA

Stop as we are getting the same result.

4.37 We first find the value of I_S for the diode, given by $I_S = I_D e^{-V_D/V_T}$ with $I_D = 1$ mA and $V_D = 0.75$ V. This gives $I_S = 9.36 \times 10^{-17}$ A.

In order to have 3.3 V across the 4 series-connected diodes, each diode drop must be 0.825 V. Applying this voltage to the diode gives current $I_D = 20.1$ mA. We can then find the resistor value using

$$R = \frac{15\ \text{V} - 3.3\ \text{V}}{20.1\ \text{mA}} = 582\ \Omega$$

4.38 Constant voltage drop model:

Using $v_D = 0.7\ \text{V}, \Rightarrow i_{D1} = \frac{V - 0.7}{R}$

Using $v_D = 0.6\ \text{V}, \Rightarrow i_{D2} = \frac{V - 0.6}{R}$

For the difference in currents to be only 1%,

$\Rightarrow i_{D2} = 1.01 i_{D1}$

$V - 0.6 = 1.01\,(V - 0.7)$

$V = 10.7$ V

For $V = 3$ V and $R = 1$ kΩ:

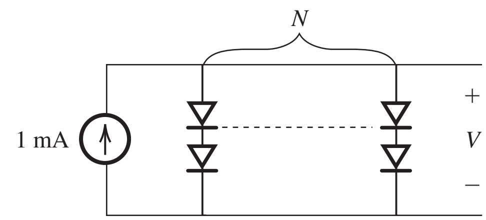
At $V_D = 0.7$ V, $\quad i_{D1} = \frac{3 - 0.7}{1} = 2.3$ mA

At $V_D = 0.6$ V, $\quad i_{D2} = \frac{3 - 0.6}{1} = 2.4$ mA

$\frac{i_{D2}}{i_{D1}} = \frac{2.4}{2.3} = 1.04$

Thus the percentage difference is 4%.

4.39 Available diodes have 0.7 V drop at 2 mA current since $2V_D = 1.4$ V is close to 1.3 V, use N parallel pairs of diodes to split the 1 mA current evenly, as shown in the figure next.



The voltage drop across each pair of diodes is 1.3 V. ∴ Voltage drop across each diode

$= \frac{1.3}{2} = 0.65$ V. Using

$I_2 = I_1 e^{(V_2 - V_1)/V_T}$

$= 2e^{(0.65-0.7)/0.025}$

$= 0.2707$ mA

Thus current through each branch is 0.2707 mA.

The 1 mA will split in $= \frac{1}{0.2707} = 3.69$ branches.

Choose $N = 4$.

There are 4 pairs of diodes in parallel.

∴ We need 8 diodes.

Current through each pair of diodes

$= \frac{1\ \text{mA}}{4} = 0.25$ mA

∴ Voltage across each pair

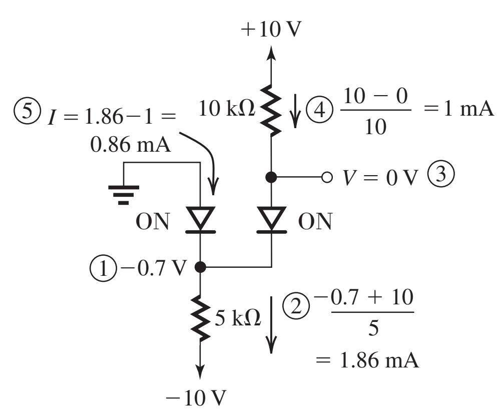
$= 2\left[0.7 + 0.025\ \ln\left(\frac{0.25}{2}\right)\right]$

$= 1.296$ V

SPECIAL NOTE: There is another possible design utilizing only 6 diodes and realizing a voltage of 1.313 V. It consists of the series connection of 4 parallel diodes and 2 parallel diodes.

4.40 Refer to Example 4.2.

(a)



$$\frac{i_{D2}}{i_{D1}} = e^{5/25} = 1.221$$

% change

$$= \frac{i_{D2} - i_{D1}}{i_{D1}} \times 100 = \frac{1.221 - 1}{1} \times 100$$

$$= 22.1\%$$

For –5 mV change we obtain

$$\frac{i_{D2}}{i_{D1}} = e^{-5/25} = 0.818$$

$$\% \text{ change} = \frac{i_{D2} - i_{D1}}{i_{D1}} \times 100 = \frac{0.818 - 1}{1} \times 100$$

$$= -18.1\%$$

Maximum allowable voltage signal change when the current change is limited to $\pm 10\%$ is found as follows:

The current varies from 0.9 to 1.1

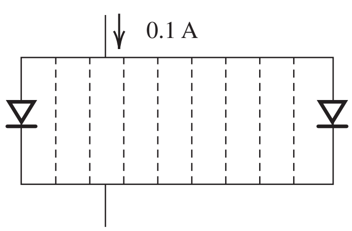
$$\frac{i_{D2}}{i_{D1}} = e^{\Delta V / V_T}$$

For 0.9, $\Delta V = 25 \ln(0.9) = -2.63$ mV

For 1.1, $\Delta V = 25 \ln(1.1) = +2.38$ mV

For $\pm 10\%$ current change the voltage signal change is from –2.63 mV to +2.38 mV

4.47



Ten diode connected in parallel and fed with a total current of 0.1 A. So the current through each diode $= \frac{0.1}{10} = 0.01$ A

Small signal resistance of each diode

$$= \frac{V_T}{i_D} = \frac{25 \text{ mV}}{0.01 \text{ A}} = 2.5\ \Omega$$

Equivalent resistance, R_{eq}, of 10 diodes connected in parallel is given by

$$R_{eq} = \frac{2.5}{10} = 0.25\ \Omega$$

If there is one diode conducting 0.1 A current, then the small signal resistance of this diode

$$= \frac{25 \text{ mV}}{0.1 \text{ A}} = 0.25\ \Omega$$

This value is the same as of 10 diodes connected in parallel.

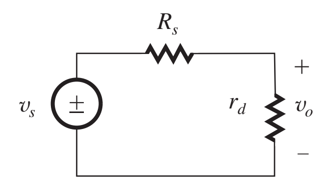
If 0.2 Ω is the resistance for making connection, the resistance in each branch $= r_d + 0.2 = 2.5 + 0.2 = 2.7\ \Omega$

For a parallel combination of 10 diodes, equivalent resistance, R_{eq}, is

$$R_{eq} = \frac{2.7}{10} = 0.27\ \Omega$$

If there is a single diode conducting all the 0.1 A current, the connection resistance needed for the single diode will be $= 0.27 - 0.25 = 0.02\ \Omega$.

4.48 The dc current I flows through the diode giving rise to the diode resistance $r_d = \frac{V_T}{I}$ and the small-signal equivalent circuit is represented by



$$v_o = v_s \times \frac{r_d}{r_d + R_S} = v_s \frac{V_T/I}{\frac{V_T}{I} + R_S} = v_s \frac{V_T}{V_T + IR_S}$$

$$\text{Now, } v_o = 10 \text{ mV} \times \frac{25 \text{ mV}}{25 \text{ mV} + 10^3 I}$$

I	v_o
1 mA	0.24 mV
0.1 mA	2.0 mV
1 μA	9.6 mV

$$\text{For } v_o = \frac{1}{2} v_s = v_s \times \frac{0.025}{0.025 + 10^3 I}$$

$$\Rightarrow I = 25\ \mu\text{A}$$

4.49 As shown in Problem 4.48,

$$\frac{v_o}{v_i} = \frac{V_T}{V_T + R_S I} = \frac{0.025}{0.025 + 10^4 I} \qquad (1)$$

Here $R_S = 10$ kΩ

The current changes are limited $\pm 10\%$. Using exponential model, we get

$$\frac{i_{D2}}{i_{D1}} = e^{\Delta v / V_T} = 0.9 \text{ to } 1.1$$

$$\Delta v = 25 \times 10^{-3} \ln\left(\frac{i_{D2}}{i_{D1}}\right) \text{ and here}$$

For 0.9, $\Delta v = -2.63$ mV

For 1.1, $\Delta v = 2.38$ mV

The variation is –2.63 mV to 2.38 mV for $\pm 10\%$ current variation. Thus the largest symmetrical output signal allowed is 2.38 mV in amplitude. To

At $I_Z = 2I_{ZT} = 0.01$ A,

$V_Z = 17.6 + 0.01 \times 80 = 18.4$ V

$P = 18.4 \times 0.01 = 0.184$ W $= 184$ mW

(e) $7.5 = V_{Z0} + 0.2 \times 1.5$

$\Rightarrow V_{Z0} = 7.2$ V

At $I_Z = 2I_{ZT} = 0.4$ A,

$V_Z = 7.2 + 0.4 \times 1.5 = 7.8$ V

$P = 7.8 \times 0.4 = 3.12$ W

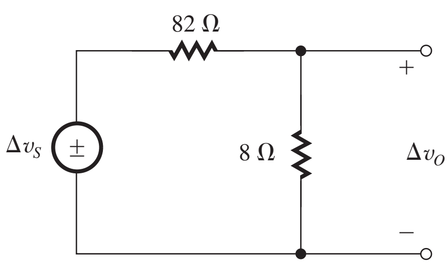
4.60 (a) Three 6.8-V zeners provide $3 \times 6.8 = 20.4$ V with $3 \times 10 = 30$-Ω resistance. Neglecting R, we have

Load regulation $= -30$ mV/mA.

(b) For 5.1-V zeners we use 4 diodes to provide 20.4 V with $4 \times 30 = 120$-Ω resistance.

Load regulation $= -120$ mV/mA

4.61



Small-signal model

From the small-signal model we obtain

$$\frac{\Delta v_O}{\Delta v_S} = \frac{8}{8+82} = \frac{8}{90}$$

Now $\Delta v_S = 1.0$ V.

$$\therefore \Delta v_O = \frac{8}{90}\Delta v_S = \frac{8}{90} \times 1.0$$

$= 88.9$ mV

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

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

$\Rightarrow V_{Z0} = 8.9$ V

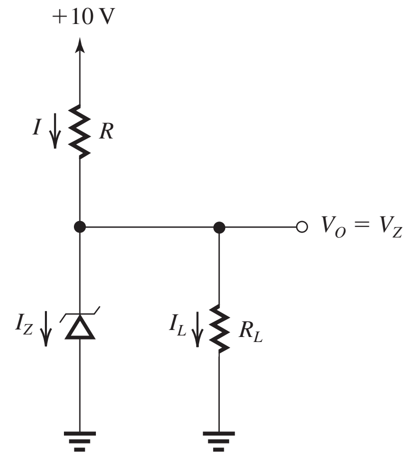
At $I_Z = 10$ mA,

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

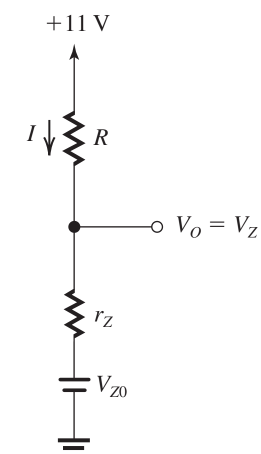
At $I_Z = 50$ mA,

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

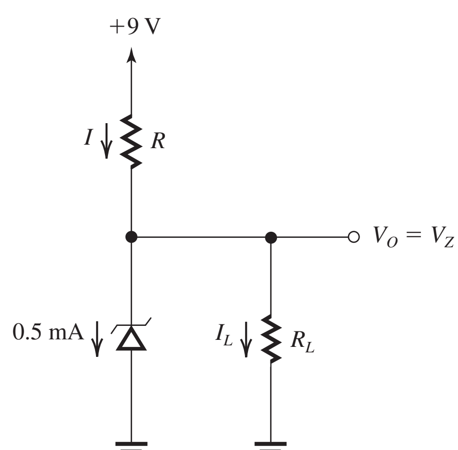
4.63



(a)



(b)



(c)