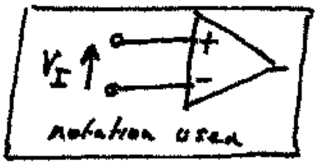
Bioengineering Exam 2016 First Year Electrical Engineering

Answer 1

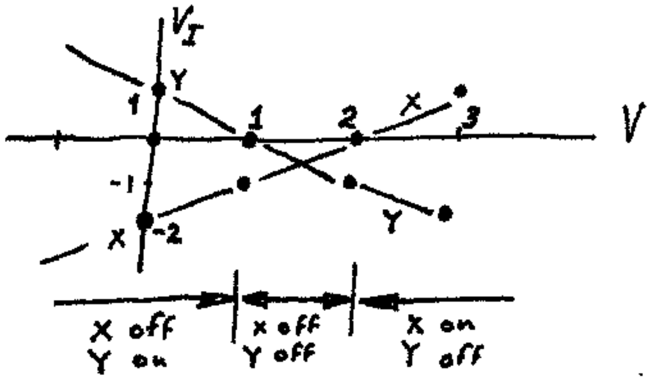
(a) (A) Resistors are irrelevant. Voltage V_I between input terminals (see sketch) is positive, therefore $V = +10$ volts



(B) Circuit is a voltage follower, hence $V = 2$ volts

(C) V_I is negative (−1 volt) hence $V = -10$ volts.

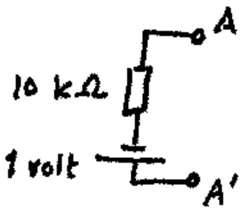
(b) Plot V_I of opamps X and Y versus the voltage V:



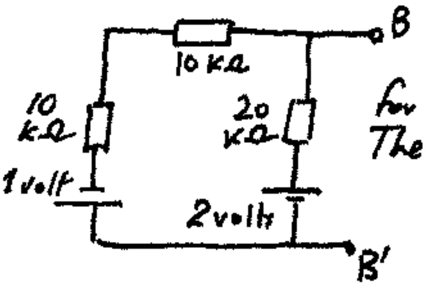
which shows that when V is between 1 volt and 2 volts, the output voltages of both opamps are at −10 volts, and no current flows in the 10 kΩ resistor

(c) The circuit is a Schmitt Trigger, with two stable states.
Assume VA = −10 volts. By voltage divider action the voltage at the + input is −6 volts. So as V decreases, VA → 10 volts as V reaches −6 volts. Therefore, with $V = -8^V$, VA must be at 10 volts. At that value of VA the threshold voltage at the + terminal is 6 volts. So the voltage VA changes from +10 volts to −10 volts when V reaches 6 volts

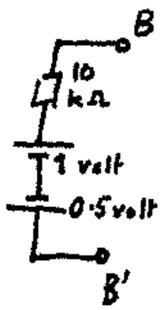
(d) To the left of AA′ the Thevenin model is as shown immediately below:



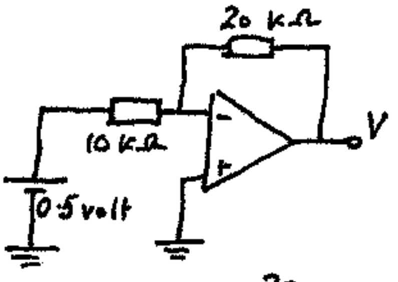
So that the circuit to the left of BB′ is:



for which the Thevenin model is:



which when connected to the circuit to the right of BB′ gives an inverter circuit:



Solving, $V = -\frac{20}{10} \times 0.5$
$= -1$ volt

Bioengineering Exam 2016 First Year Electrical Engineering

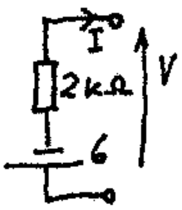
Answer 2

(a) Left circuit: current in $1\,k\Omega = (20-5)/1 = 15\,mA$. Current in $2\,k\Omega$ is $5/2 = 2.5\,mA$
Therefore current flows in Zener, $V = 5$ volt. Power dissipation $= 5 \times (15-2.5)$ $= 62.5\,mW$

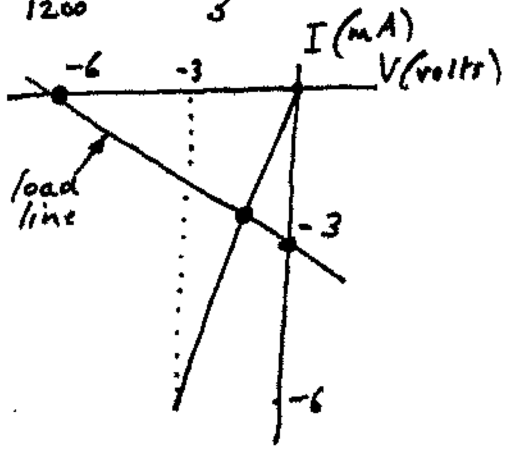
Middle circuit: Current in Zener $= 15\,mA$, $V = 5$ volts, Power dissipation $= 5 \times 15 = 75\,mW$

Right circuit: If $V = 5$ volts, current in $200\,\Omega$ would be $25\,mA$, which exceeds that available through the $1\,k\Omega$ resistor. Therefore zero current in Zener, Power dissipation $= 0$ and, by voltage divider action, $V = \frac{200}{1200} \times 20 = \frac{10}{3}$ volts.

b) Thevenin Equivalent circuit to left of X is



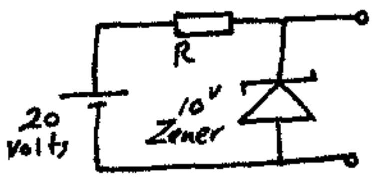
whose current-voltage relation can be plotted on the same graph as for the device X.
Intersects at $V = 0, I = -3\,mA$
$I = 0, V = -6$ volts



See plot at right.
Intersection occurs at $V = -2$ volts
$I = -3\,mA$

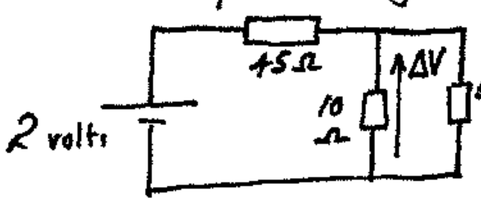
With reference to Figure 2b, if $V = -2$ then $VA = 7$ volts.

(c) Use the circuit shown at right, where the Zener diode has a Zener voltage of 10 volts.

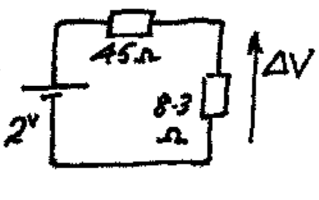


When current drawn is 200 mA there must be at least 200 mA in R. We choose to have 220 mA flowing in R, giving $R = 10\,\text{volts}/220\,mA = 45\,\Omega$

d) If 200 mA is being drawn from the circuit, it corresponds to a resistance of 50 ohms. The required change circuit is therefore



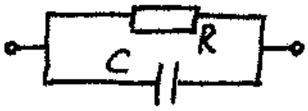
equivalent to



giving $\Delta V = \frac{8.3}{53.3} \times 2 = 0.31$ volt

Thus, with a 2 volt variation in the 20 volt source there is a 0.31 volt change in the nominal voltage of 10 volts.

Answer 3



(a)

$$Z = R + j\omega L$$

$$Y = \frac{1}{Z} = \frac{1}{R + j\omega L}$$

$$Y = 1/R + j\omega C$$

$$Z = \frac{1}{Y} = \frac{R}{1 + j\omega CR}$$

(b) X $V_o = \dfrac{V_{in}}{R_1 + \frac{1}{j\omega C}} \times R_2$

$$\frac{V_o}{V_{in}} = \frac{R_2}{R_1} \cdot \frac{1}{\left(1 + \frac{1}{j\omega CR_1}\right)}$$

Y $V_o = \dfrac{V_{in}}{R_1} \times (R_2 + j\omega L)$

$$\frac{V_o}{V_{in}} = \frac{R_2}{R_1} \cdot (1 + j\omega L/R_2)$$

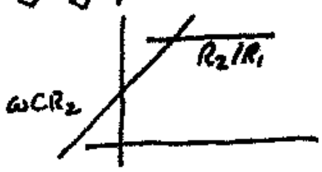
Z $V_o = \dfrac{V_{in}}{R_1} \cdot \dfrac{R_2}{1 + j\omega CR_2}$

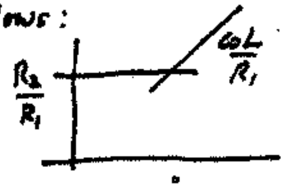
$$\frac{V_o}{V_{in}} = \frac{R_2}{R_1} \cdot \frac{1}{1 + j\omega CR_2}$$

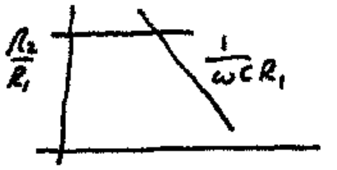
(c) $\omega \to 0$ $\left|\dfrac{V_o}{V_{in}}\right| \to \omega CR_2$ | $\omega \to 0$ $\left|\dfrac{V_o}{V_{in}}\right| \to \dfrac{R_2}{R_1}$ | $\omega \to 0$ $\left|\dfrac{V_o}{V_{in}}\right| \to \dfrac{R_2}{R_1}$

$\omega \to \infty$ $\left|\dfrac{V_o}{V_{in}}\right| \to \dfrac{R_2}{R_1}$ | $\omega \to \infty$ $\left|\dfrac{V_o}{V_{in}}\right| \to \dfrac{\omega L}{R_1}$ | $\omega \to \infty$ $\left|\dfrac{V_o}{V_{in}}\right| \to \dfrac{1}{\omega CR_1}$

Log-log plots are as follows:







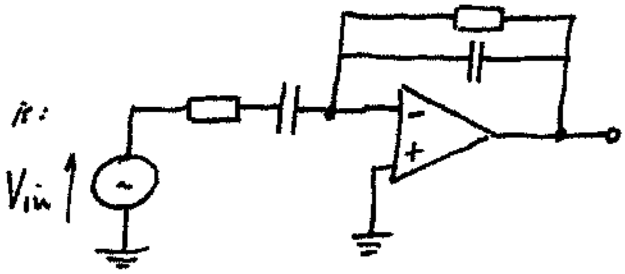
and correspond to

A B C

(d) See the log-log plots of (c) above. Asymptote intersections are given by

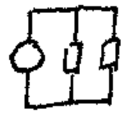
X $\omega = \dfrac{1}{CR_1}$ Y $\omega = \dfrac{R_2}{L}$ Z $\omega = \dfrac{1}{CR_2}$

(e) Suggested circuit is:

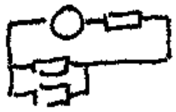


Bioengineering Exam First Year 2016 Electrical Engineering

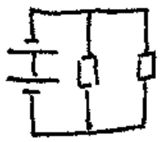
Answer 4

(a) 

Parallel connection of $6\,k\Omega$ and $3\,k\Omega$ equivalent to $2\,k\Omega$. By Ohms Law, $V = 6$ volts. Hence $I = 6/3 = 2\,mA$



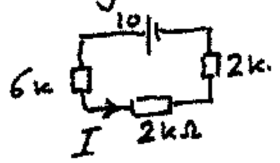
By Ohm's Law, $V = -4$ volts. Parallel connection of $6\,k\Omega$ and $3\,k\Omega$ is equivalent to $2\,k\Omega$, so voltage across $3\,k\Omega$ is $2 \times 2 = 4$ volts and current through $3\,k\Omega$ is $4/3\,mA$ ($1.33\,mA$)



By Ohms Law, current in $17\,k\Omega$ is $-(20-3)/17 = -1\,mA$
$V = -17$ volts.

Whatever the voltage across the source, voltage dividers ensure that $V = 0$.
Parallel connection of $10\,k\Omega$ and $20\,k\Omega$ is equivalent to $200/30\,k\Omega$ so voltage across the source will be $(200/30) \times 3 = 20$ volts so that $I = 2\,mA$

(b) With only 10^V source

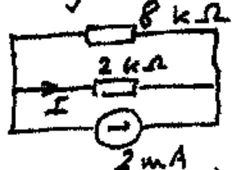


I current in horizontal $2\,k\Omega$ is $1\,mA$

With only 1 mA source

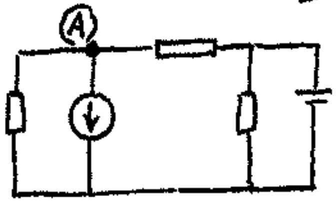
Parallel connection of $6\,k\Omega$ & $4\,k\Omega$ is $2.4\,k\Omega$ so voltage across $2.4\,k\Omega$ is 2.4 volts and $I = \frac{2.4}{4} = 0.6\,mA$

With only 2 mA source



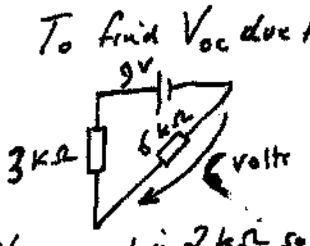
Parallel connection of $8\,k\Omega$ and $2\,k\Omega$ is $1.6\,k\Omega$ so voltage across the $2\,k\Omega$ is 3.2 volts and $I = -\frac{3.2}{2} = -$

Therefore, by Superposition,
$I = 1 + 0.6 - 1.6 = 0\,mA$

(c) 

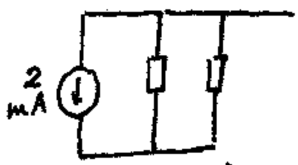
KCL at A (OUT) gives $\dfrac{V_A}{10} + \dfrac{(V_A - 5)}{2} + 0.2(5 - V_a) = 0$
which simplifies to $V_a = 15/4$ volts.

(d) To find V_{oc} due to 9 volts



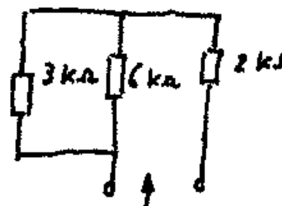
No current in $2\,k\Omega$ so $V_{oc} = 6$ volts (A more positive)

To find V_{oc} due to 2mA



$6\,k\Omega$ and $3\,k\Omega$ in parallel equivalent to $2\,k\Omega$ so $V_{oc} = 4$ volts (A more positive)

To find R_o



$R_o = 4\,k\Omega$

$\therefore$ Actual $V_{oc} = 10$ volts (by Superposition)

So the Thevenin model is