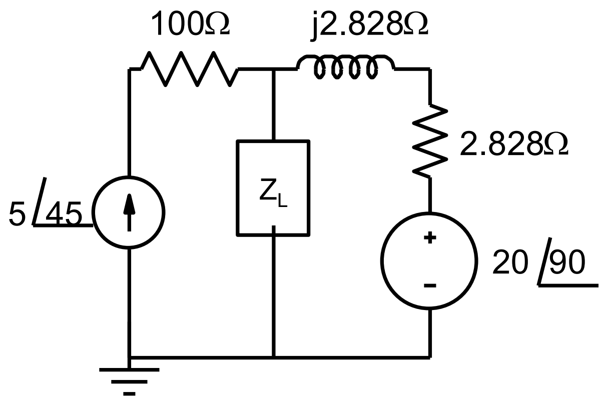
Indian Institute of Technology, Kanpur
Department of Electrical Engineering

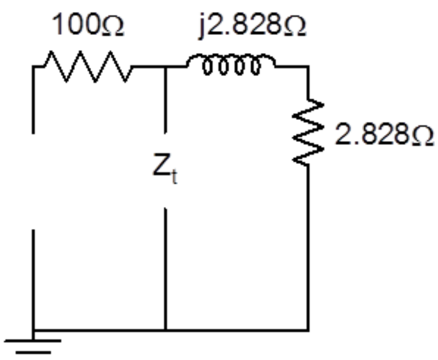
ESC 201A

Midterm Examination
Saturday, 26th Feb, 2022

1 Use Thevenin's theorem to determine Z_L such that maximum power is dissipated in the load impedance Z_L. Determine also the average power dissipated in Z_L and the average power supplied by each source.

(**5 marks**)





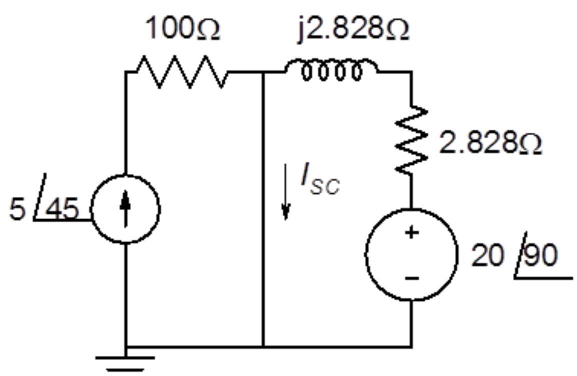
Solution: Thevenin's impedance can be found from the equivalent circuit

$$Z_t = 2.82 + j2.82 = 4\angle 45° \quad [\mathbf{1\ mark}]$$

For maximum power transfer, we should choose:

$$Z_L = \overline{Z_t} = 2.82 - j2.82 = 4\angle -45° \quad [\mathbf{1\ mark}]$$

Thevenin's voltage can be found by first finding the short circuit current:



$$I_{SC} = 5\angle 45° + \frac{20\angle 90°}{2.82 + j2.82} = 10\angle 45°$$

$$V_t = I_{SC} * Z_t = 10\angle 45° * 4\angle 45° = 40\angle 90°$$

$[\mathbf{1\ mark}]$

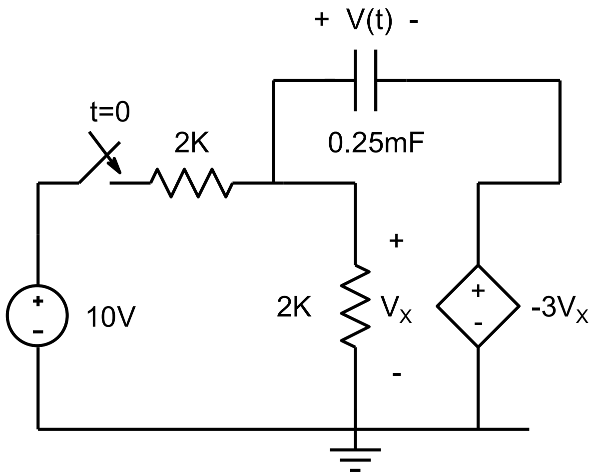
Current through load:

$$I_L = \frac{40\angle 90^\circ}{4\angle 45^\circ + 4\angle -45^\circ} = j5\sqrt{2}$$

$$Re(Z_L) = R_L = 4\cos(-45^\circ) = \frac{4}{\sqrt{2}}$$

$$P_L = \frac{(5\sqrt{2})^2 R_L}{2} = 70.1W \ [\boldsymbol{2\ mark}]$$

2. Assuming that the capacitor does not have any initial charge, determine the voltage across the capacitor V(t) as a function of time after the switch is closed at t = 0. **(5 marks)**



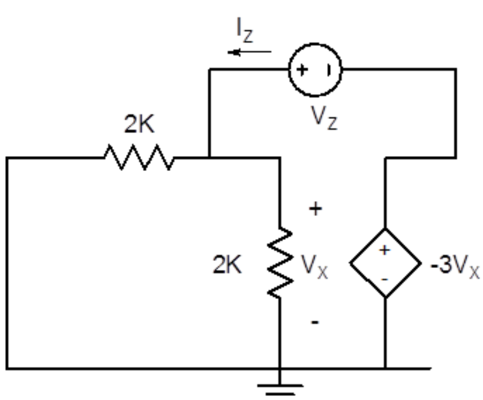
Solution:

$$v(t) = v(\infty) + \{v(0^+) - v(\infty)\}e^{-t/\tau}$$
$$v(0^+) = 0 \ \ [\mathbf{1\ mark}]$$

At $t \to \infty$, the capacitor is open circuit. Therefore,

$$v_X = \frac{2K}{2K + 2K} * 10 = 5V$$
$$v(\infty) = V_X - (-3V_X) = 4V_X = 20V \ \ [\mathbf{1\ mark}]$$
$$\tau = CR_{eq}$$

R_{eq} can be found from the circuit:

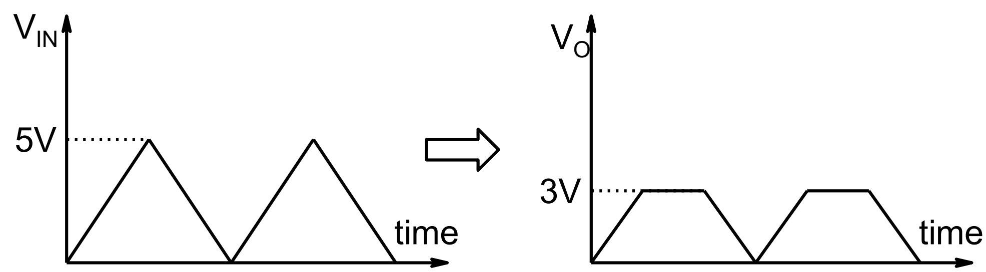


$$R_{eq} = \frac{v_Z}{i_Z}$$
$$v_Z = v_X - -3v_X = 4v_X$$
$$i_Z = \frac{v_X}{1K}$$
$$R_{eq} = \frac{v_Z}{i_Z} = 4K \ \ [\mathbf{1\ mark}]$$

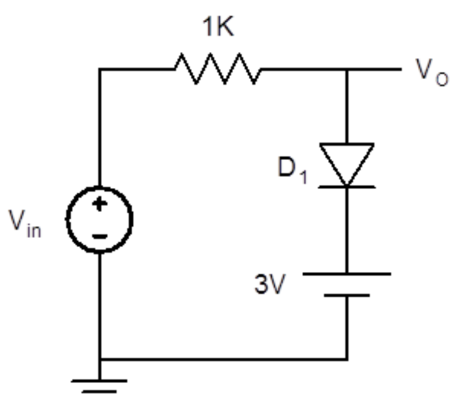
$$\tau = CR_{eq} = 1s \ \ [\mathbf{1mark}]$$
$$v(t) = 20\{1 - e^{-t}\} \ \ [\mathbf{1\ mark}]$$

3. Design a diode circuit to convert the triangular waveform into a trapezoidal waveform as shown below. Give the circuit diagram along with typical component values, and give an explanation for your choice of components. Assume ideal diodes with cut-in voltage of zero volts.

(5 marks)



Solution:



For input voltage less than 3V, diode is OFF so $V_o = V_{in}$. For larger input voltage, the diode turns on and acts like a short circuit. Thus, $V_o = 3V$. $[\boldsymbol{2\ marks}]$

$circuit$: $[\boldsymbol{3\ marks}]$ $(\boldsymbol{1\ mark\ per\ component})$

4 An amplifier has a transfer function of the form:

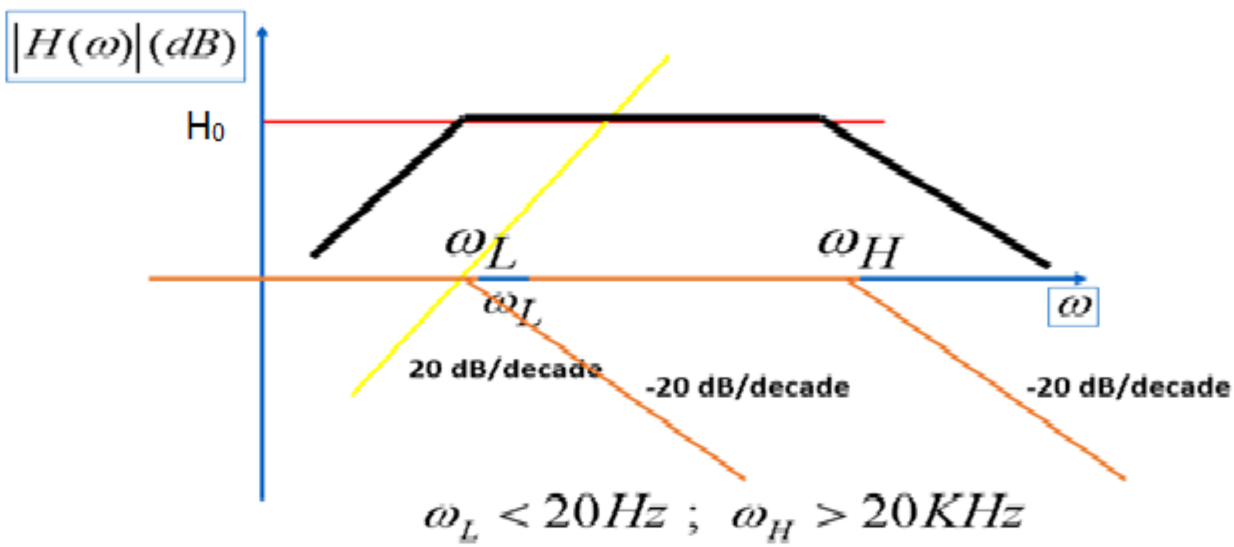
$$G(\omega) = \frac{V_O(\omega)}{V_{in}(\omega)} = \frac{100 \times j(\omega/\omega_L)}{\{1 + j(\omega/\omega_L)\}\{1 + j(\omega/\omega_H)\}}$$

Sketch Bode plot of the transfer function and determine suitable values for corner frequencies such that amplifier can amplify audio frequencies in the range 20-20KHz equally well. **(5 marks)**

Solution:

$$20\log_{10}(|G(\omega)|) = 40 + 20\log_{10}(\frac{\omega}{\omega_L}) - 10\log_{10}\left(1 + \left(\frac{\omega}{\omega_L}\right)^2\right) - 10\log_{10}(1 + (\frac{\omega}{\omega_H})^2)$$

$$H_0 = 40dB$$



Plot: [$\boldsymbol{3\ marks}$]

$\boldsymbol{\omega_L, \omega_H}$: [$\boldsymbol{1 + 1 = 2\ marks}$]