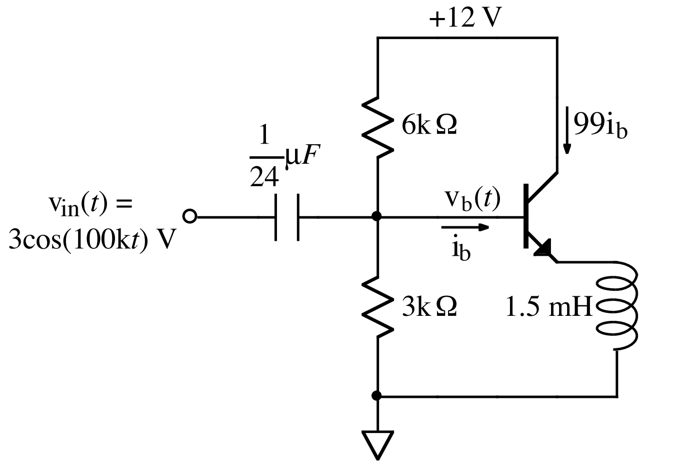
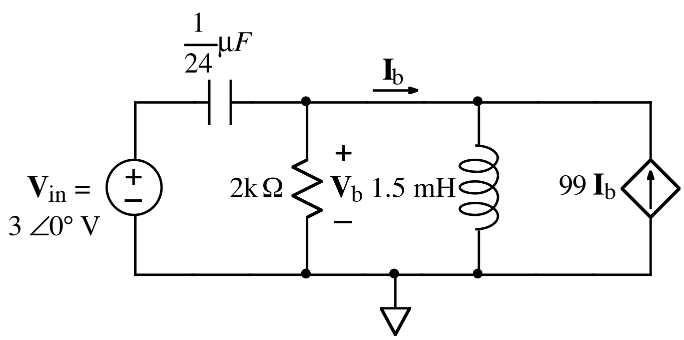
HOMEWORK #17 prob 5 solution

Ex:



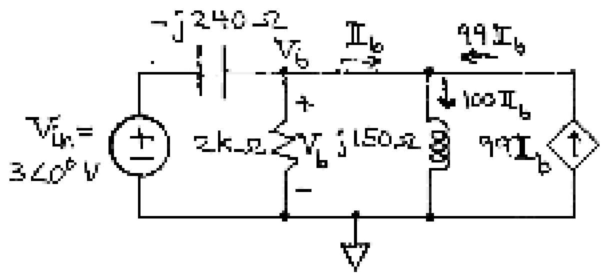


The above circuit diagrams show an emitter-follower amplifier and its high-frequency equivalent circuit. Find $v_b(t)$.

soln: The bottom diagram uses a mixed notation in that the C and L values are shown instead of Z_C and Z_L. We first compute Z_C and Z_L using $\omega = 100k$ from the top circuit.

$$Z_C = \frac{1}{j\omega C} = \frac{-j}{\omega C} = \frac{-j}{100k \cdot \frac{1}{24}\mu} \Omega = -j\,240\ \Omega$$

$Z_L = j\omega L = j\,100k \cdot 1.5\,mH = j150\,\Omega$



A straightforward solution approach is to use the node-voltage method with V_b on the top rail.

$$\frac{V_b - V_{in}}{-j240\,\Omega} + \frac{V_b}{2k\,\Omega} + \frac{V_b}{j150\,\Omega} \cdot \frac{1}{100} = 0\,A$$

or $$V_b\left(\frac{1}{-j240\,\Omega} + \frac{1}{2k\,\Omega} + \frac{1}{j1.5k\,\Omega}\right) = \frac{V_{in}}{-j240\,\Omega}$$

or $$V_b = \frac{V_{in}}{-j240\,\Omega} \cdot -j240\,\Omega \,\|\, 2k\,\Omega \,\|\, j1.5k\,\Omega$$

or $$V_b = V_{in} \cdot 1 \,\Big\|\, \frac{2k}{-j240} \,\Big\|\, \frac{-1.5k}{240}$$

Now $$1 \,\Big\|\, \frac{-1.5k}{240} = \frac{1\left(\frac{-1.5k}{240}\right)}{1 + \frac{-1.5k}{240}} = \frac{-1.5k}{240 - 1.5k}$$

$$'' = \frac{1.5k}{14.76k} = \frac{1.5}{14.76}$$

$$V_b = V_{in} \cdot \frac{1.5}{14.76} \,\Big\|\, \frac{2k}{-j240}$$

$$= V_{in} \cdot \frac{1.5}{14.76} \,\Big\|\, \frac{j25}{3}$$

$$= 3\angle 0^\circ \text{ V} \cdot \frac{\frac{1.5}{14.76} \cdot j\frac{25}{3}}{\frac{1.5}{14.76} + j\frac{25}{3}}$$

$$= 3\angle 0^\circ \text{ V} \cdot \frac{j1.5(25)}{3(1.5) + j25(14.76)}$$

$$= 3\angle 0^\circ \text{ V} \cdot \frac{j3(25)}{3\cdot 3 + j5(14.76)}$$

$$= 3\angle 0^\circ \text{ V} \cdot \frac{j75}{9 + j73.8}$$

$$= \frac{225\angle 90^\circ \text{ V}}{\sqrt{9^2 + 73.8^2}\angle \tan^{-1}\frac{73.8}{9}}$$

$$= \frac{225\angle 90^\circ \text{ V}}{74.3\angle 83.0^\circ}$$

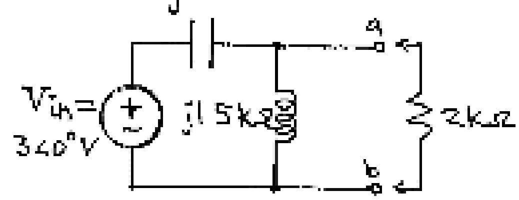
$$\approx 3.02\angle 90^\circ - 83.0^\circ \text{ V}$$

$$V_b \doteq 3\angle 7^\circ \text{ V}$$

$$\therefore v_b(t) \doteq 3\cos(100kt + 7^\circ) \text{ V}$$

An alternate approach begins with the observation that the L and the dependent source may be replaced by $j\omega L \cdot 100$. This concept is called "impedance multiplication."

Then we remove the 2kΩ resistor and find the Thevenin equivalent of the circuit with respect to the terminals where the 2kΩ resistor is attached.



$$V_{Th} = V_{a,b \text{ no load}}$$

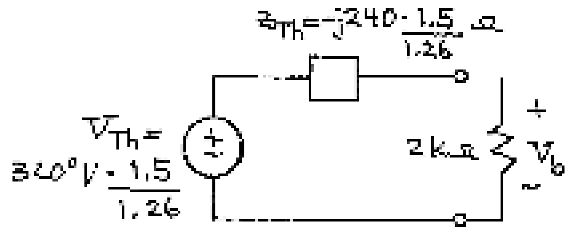
$$= V_{in} \cdot \frac{j1.5k\Omega}{j1.5k\Omega - j240\,\Omega}$$

$$V_{Th} = 3\angle 0°\,V \cdot \frac{1.5}{1.476}$$

Z_{Th} = Z seen looking into a,b with V_{in} off (= wire)

$$Z_{Th} = -j240 \| j1.5k\ \Omega$$

$$Z_{Th} = \frac{240(1.5k)}{j(1.5k - 240)}\,\Omega = -j240 \cdot \frac{1.5}{1.476}\ \Omega$$



$$\mathbf{V}_b = \mathbf{V}_{Th} \cdot \frac{2k\Omega}{2k\Omega + Z_{Th}}$$

$$= 3\angle 0^\circ V \cdot \frac{15}{14.76} \cdot \frac{2k\Omega}{2k\Omega - j240 \cdot \frac{15}{14.76}\,\Omega}$$

$$= 3\angle 0^\circ V \cdot \frac{15\,(2k\Omega)}{14.76\,(2k\Omega) - j\,240\,(15)\,\Omega}$$

$$= 3\angle 0^\circ V \cdot \frac{30k}{29.52k - j\,3.6k}$$

$$= 3\angle 0^\circ V \cdot \frac{30}{29.52 - j\,3.6}$$

$$= 3\angle 0^\circ V \; \frac{1}{0.984 - j0.12}$$

$$= \frac{3\angle 0^\circ V}{0.99\angle -6.95^\circ}$$

$$\mathbf{V}_b \doteq 3\angle 7^\circ V$$

$$\therefore v_b(t) = 3\cos(100kt + 7^\circ)\ V$$