Solution Homework-06 ENGR 117

5 Questions 20 points each

Q-1 Design an op amp-based low-pass filter with a cutoff frequency of 2500 Hz and a passband gain of 5 using a 10 nF capacitor. The input to the low-pass filter is 3.5 cos ωt V.

a) Draw your circuit, labeling the component values and output voltage.

b) If the value of the feedback resistor in the filter is changed but the value of the resistor in the forward path is unchanged, what characteristic of the filter is changed?

c) Find the output voltage when $\omega = \omega_c$.

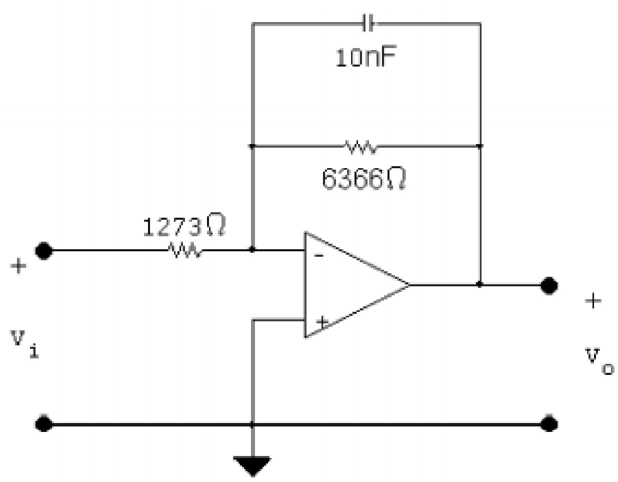
d) Find the output voltage when $\omega = 0.125\,\omega_c$.

e) Find the output voltage when $\omega = 8\,\omega_c$.

Note: vi = 3.5 $\angle$ 0 ====➔ Vi(jω) = 3.5 $\angle$ 0

[a] $$\omega_c = \frac{1}{R_2C} \quad \text{so} \quad R_2 = \frac{1}{\omega_c C} = \frac{1}{2\pi(2500)(10\times10^{-9})} = 6366\,\Omega$$

$$K = \frac{R_2}{R_1} \quad \text{so} \quad R_1 = \frac{R_2}{K} = \frac{6366}{5} = 1273\,\Omega$$



[b] Both the cutoff frequency and the passband gain are changed.

[c] $$H(j\omega) = \frac{-5(2\pi)(2500)}{j\omega + 2\pi(2500)}$$

$$H(j5000\pi) = \frac{-5(5000\pi)}{5000\pi + j5000\pi} = \qquad \frac{5}{\sqrt{2}}\underline{/135^\circ} = \frac{Vo}{Vi}$$

$$V_o = \frac{17.5}{\sqrt{2}}\underline{/135^\circ} \qquad \text{so} \quad v_o(t) = 12.37\cos(5000\pi t + 135^\circ)\,\text{V}$$

[d] $$H(j625\pi) = \frac{-5(5000\pi)}{5000\pi + j625\pi} = 4.96\underline{/172.9^\circ} \qquad = \frac{Vo}{Vi}$$

$$V_o = 17.36\underline{/172.9^\circ} \qquad \text{so} \quad v_o(t) = 17.36\cos(625\pi t + 172.9^\circ)\,\text{V}$$

[e] $$H(j40{,}000\pi) = \frac{-5(5000\pi)}{5000\pi + j40{,}000\pi} = 0.62\underline{/97.1^\circ} \qquad = \frac{Vo}{Vi}$$

$$V_o = 2.2\underline{/97.1^\circ} \qquad \text{so} \quad v_o(t) = 2.2\cos(40{,}000\pi t + 97.1^\circ)\,\text{V}$$

Q-2 Write the relationship and draw phasor between phase and line quantities for a balanced 3 phase system if:

a. Star Connection (phasor diagram for phase voltages and Line voltages).
b. Delta Connection (phasor diagram for phase currents and Line currents).

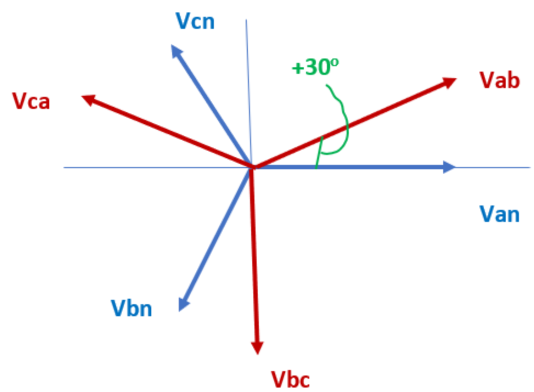
[a] **STAR: (Positive sequence)**

I(phase) = I(Line) It means:

$I_{an} = I_\varphi \angle 0$ $\quad$ $I_a = I_\varphi \angle 0$

$I_{bn} = I_\varphi \angle -120$ $\quad$ $I_b = I_\varphi \angle -120$

$I_{cn} = I_\varphi \angle +120$ $\quad$ $I_c = I_\varphi \angle +120$



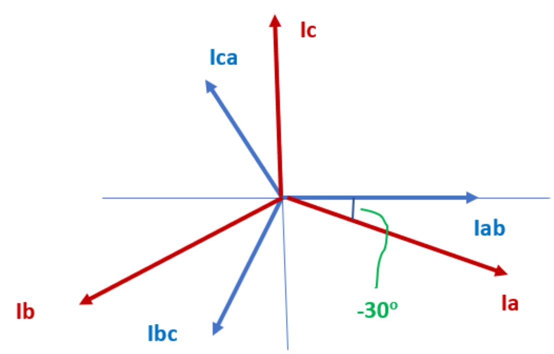
V(Line) = $(\sqrt{3} \angle +30^\circ)$ **V(phase)** It means:

$V_{an} = V_\varphi \angle 0^\circ$ then $V_{ab} = (\sqrt{3} \angle +30^\circ)(V_\varphi \angle 0) = \sqrt{3}\, V_\varphi \angle 30^\circ$

$V_{bn} = V_\varphi \angle -120^\circ$ then $V_{bc} = (\sqrt{3} \angle +30^\circ)(V_\varphi \angle -120) = \sqrt{3}\, V_\varphi \angle -90^\circ$

$V_{cn} = V_\varphi \angle +120^\circ$ then $V_{ca} = (\sqrt{3} \angle +30^\circ)(V_\varphi \angle +120) = \sqrt{3}\, V_\varphi \angle 150^\circ$

[b] **DELTA: (Positive sequence)**



V(phase) = V(Line) It means:

$V_{ab} = V_\varphi \angle 0$ $\quad$ $V_{ab} = I_\varphi \angle 0$

$V_{bc} = V_\varphi \angle -120$ $\quad$ $V_{bc} = V_\varphi \angle -120$

$V_{ca} = V_\varphi \angle +120$ $\quad$ $V_{ca} = V_\varphi \angle +120$

I(Line) = $(\sqrt{3} \angle -30^\circ)$ **I(phase)** It means:

$I_{ab} = I_\varphi \angle 0^\circ$ then $I_a = (\sqrt{3} \angle -30^\circ)(I_\varphi \angle 0) = \sqrt{3}\, I_\varphi \angle -30^\circ$

$I_{bc} = I_\varphi \angle -120^\circ$ then $I_b = (\sqrt{3} \angle -30^\circ)(I_\varphi \angle -120) = \sqrt{3}\, I_\varphi \angle -150^\circ$

$I_{ca} = I_\varphi \angle +120^\circ$ then $I_c = (\sqrt{3} \angle -30^\circ)(I_\varphi \angle +120) = \sqrt{3}\, I_\varphi \angle 90^\circ$

Q-3 For each set of voltages, state whether or not the voltages form a balanced three-phase set. If the set is balanced, state whether the phase sequence is positive or negative. If the set is not balanced, explain why?

a) $v_a = 48\cos(314t - 45^\circ)$ V,

$v_b = 48\cos(314t - 165^\circ)$ V,

$v_c = 48\cos(314t + 75^\circ)$ V.

b) $v_a = 188\cos(250t + 60^\circ)$ V,

$v_b = -188\cos 250t$ V,

$v_c = 188\cos(250t - 60^\circ)$ V.

c) $v_a = 426\cos 100t$ V,

$v_b = 462\cos(100t + 120^\circ)$ V,

$v_c = 426\cos(100t - 120^\circ)$ V.

d) $v_a = 1121\cos(2000t - 20^\circ)$ V,

$v_b = 1121\sin(2000t - 50^\circ)$ V,

$v_c = 1121\cos(2000t + 100^\circ)$ V.

e) $v_a = 540\sin 630t$ V,

$v_b = 540\cos(630t - 120^\circ)$ V,

$v_c = 540\cos(630t + 120^\circ)$ V.

f) $v_a = 144\cos(800t + 80^\circ)$ V,

$v_b = 144\sin(800t - 70^\circ)$ V,

$v_c = 144\sin(800t + 50^\circ)$ V.

[a] $\mathbf{V}_a = 48\underline{/-45^\circ}$ V

$\mathbf{V}_b = 48\underline{/-165^\circ}$ V

$\mathbf{V}_c = 48\underline{/75^\circ}$ V

Balanced, positive phase sequence

[b] $\mathbf{V}_a = 188\underline{/60^\circ}$ V

$\mathbf{V}_b = -188\underline{/0^\circ}$ V $= 188\underline{/180^\circ}$ V

$\mathbf{V}_c = 188\underline{/-60^\circ}$ V

Balanced, negative phase sequence

[c] $\mathbf{V}_a = 426\underline{/0^\circ}$ V

$\mathbf{V}_b = 462\underline{/120^\circ}$ V

$\mathbf{V}_c = 426\underline{/-120^\circ}$ V

Unbalanced due to unequal amplitudes

[d] $\mathbf{V}_a = 1121\underline{/-20^\circ}$ V

$\mathbf{V}_b = 1121\underline{/-140^\circ}$ V

$\mathbf{V}_c = 1121\underline{/100^\circ}$ V

Balanced, positive phase sequence

[e] $\mathbf{V}_a = 540\underline{/-90^\circ}$ V

$\mathbf{V}_b = 540\underline{/-120^\circ}$ V

$\mathbf{V}_c = 540\underline{/120^\circ}$ V

Unbalanced due to unequal phase separation

[f] $\mathbf{V}_a = 144\underline{/80^\circ}$ V

$\mathbf{V}_b = 144\underline{/-160^\circ}$ V

$\mathbf{V}_c = 144\underline{/-40^\circ}$ V

Balanced, negative phase sequence

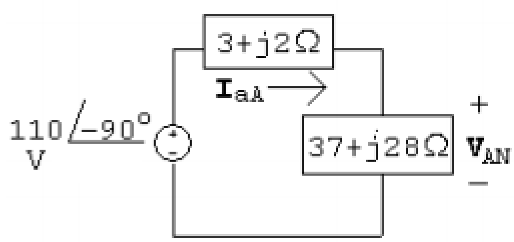
Q-4 A balanced three-phase circuit has the following characteristics.

- Y-Y connected;
- The line voltage at the source, $\mathbf{V}_{ab}$, is $110\sqrt{3}\,\underline{/-60^\circ}$ V;
- The phase sequence is positive;
- The line impedance is $3 + j2\ \Omega/\phi$;
- The load impedance is $37 + j28\ \Omega/\phi$;

a) Draw the single-phase equivalent circuit for the a-phase.
b) Calculated the line currents for each phase.
c) Calculated the line voltages at the load in each phase.

[a] $\mathbf{V}_{an} = 1/\sqrt{3}\underline{/-30^\circ}\mathbf{V}_{ab} = 110\underline{/-90^\circ}$ V

The a-phase circuit is



[b] $\mathbf{I}_{aA} = \dfrac{110\underline{/-90^\circ}}{40 + j30} = 2.2\underline{/-126.87^\circ}$ A

[c] $\mathbf{V}_{AN} = (37 + j28)\mathbf{I}_{aA} = 102.08\underline{/-89.75^\circ}$ V

$$\mathbf{V}_{AB} = \sqrt{3}\underline{/30^\circ}\mathbf{V}_{AN} = 176.81\underline{/-59.75^\circ}\ \text{V}$$

I_{bB}= 2.2 ***L*** –246.87° A

I_{cC}= 2.2 ***L*** –6.87° A

V_{BC}= 176.81 ***L*** –179.75° V

V_{CA}= 176.81 ***L*** +60.25° V

Q-5 A balanced, three-phase circuit is characterized as follows:

- Y-Δ connected;
- Source voltage in the b-phase is $150\underline{/135^\circ}$ V;
- Source phase sequence is acb;
- Line impedance is $2 + j3\ \Omega/\phi$;
- Load impedance is $129 + j171\ \Omega/\phi$.

a) Draw the single phase equivalent for the a-phase.

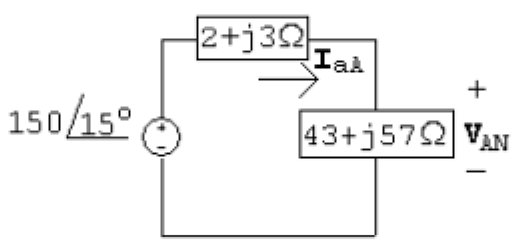
b) Calculate the a-phase line current.

c) Calculate the a-phase line voltage for the three-phase load.

[a] $\mathbf{V}_{\text{an}} = \mathbf{V}_{\text{bn}} - 1\underline{/120^\circ} = 150\underline{/15^\circ}\ \text{V}$

$$Z_y = Z_\Delta/3 = 43 + j57\,\Omega$$

The a-phase circuit is



[b] $\mathbf{I}_{\text{aA}} = \dfrac{150\underline{/15^\circ}}{45 + j60} = 2\underline{/-38.13^\circ}\ \text{A}$

[c] $\mathbf{V}_{\text{AN}} = (43 + j57)\mathbf{I}_{\text{aA}} = 142.8\underline{/14.84^\circ}\ \text{V}$

$$\mathbf{V}_{\text{AB}} = \sqrt{3}\underline{/-30^\circ}\mathbf{V}_{\text{AN}} = 247.34\underline{/-15.16^\circ}\ \text{V}$$

V_{BC}= 247.34 ***L*** +104.84° V

V_{CA}= 247.34 ***L*** -135.16° V