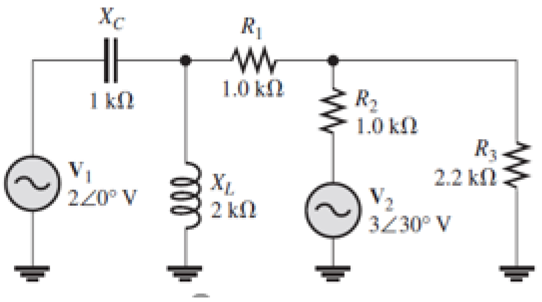
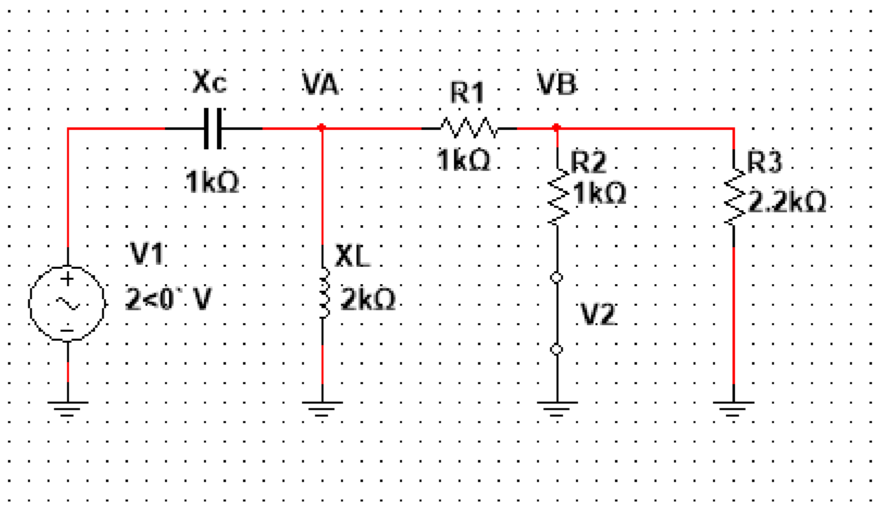
Cálculos de superposición:

1. Con el método de superposición, calcule la corriente a través de R_3 en la figura 19-44.





Nodo VA

$$\frac{V_A - V_1}{-jX_C} + \frac{V_A}{jX_L} + \frac{V_A - V_B}{R_1} = 0$$

$$V_A\left(\frac{1}{-jX_C} + \frac{1}{jX_L} + \frac{1}{R_1}\right) - \frac{V_1}{-jX_C} - \frac{V_B}{R_1} = 0$$

$$V_A(1 + 0.5j) - jV_1 - V_B = 0$$

Nodo VB

$$\frac{V_B - V_A}{R_1} + \frac{V_B}{R_2} + \frac{V_B}{R_3} = 0$$

$$V_B\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_A}{R_1} = 0$$

$$V_B(2.45) - V_A = 0$$

$$V_A = 2.45V_B$$

$$2.45V_B(1 + 0.5j) - jV_1 - V_B = 0$$

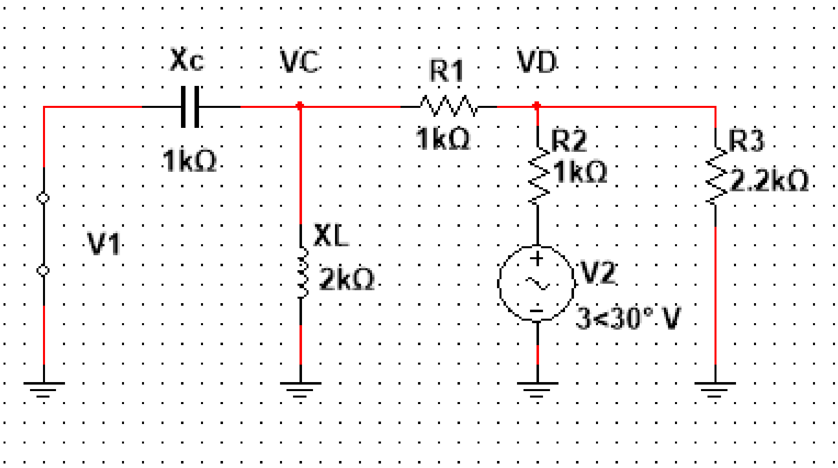
$$(1.45 + 1.23j)V_B = jV_1$$

$$V_B = \frac{(1 < 90°)(2 < 0°)}{(1.45 + 1.23j)}$$

$$V_B = (1.05 < 49.7°)V$$

$$I_{V1} = \frac{(1.05 < 49.7°)}{2200}$$

$$I_{V1} = (0.48 < 49.7°)mA$$



Nodo VC

$$\frac{V_C}{-jX_C} + \frac{V_C}{jX_L} + \frac{V_C - V_D}{R_1} = 0$$

$$V_C\left(\frac{1}{-jX_C} + \frac{1}{jX_L} + \frac{1}{R_1}\right) - \frac{V_D}{R_1} = 0$$

$$V_C(1 + 0.5j) = V_D$$

Nodo VD

$$\frac{V_D - V_C}{R_1} + \frac{V_D - V_2}{R_2} + \frac{V_D}{R_3} = 0$$

$$V_D\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) - \frac{V_C}{R_1} - \frac{V_2}{R_2} = 0$$

$$V_D(2.45) - V_C - V_2 = 0$$

$$2.45V_D - \frac{V_C}{1 + 0.5j} - V_2 = 0$$

$$(1.65 + 0.4j)V_D = V_2$$

$$V_D = \frac{(3 < 30°)}{(1.65 + 0.4j)}$$

$$V_D = (1.8 < 16.4°)V$$

$$I_{V2} = \frac{(1.8 < 16.4°)}{2200}$$

$$I_{V2} = (0.8 < 16.4°)mA$$

$$I_{V1} = (0.31 + j0.36)mA$$

$$I_{V2} = (0.76 + j0.22)mA$$

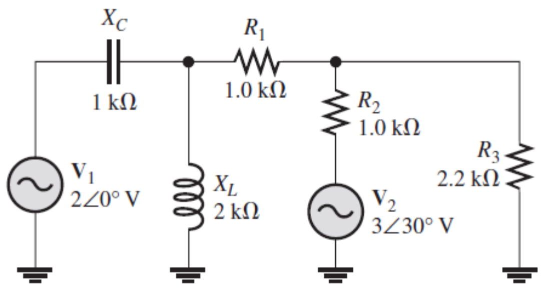
$$I_{R3} = I_{V1} + I_{V2}$$

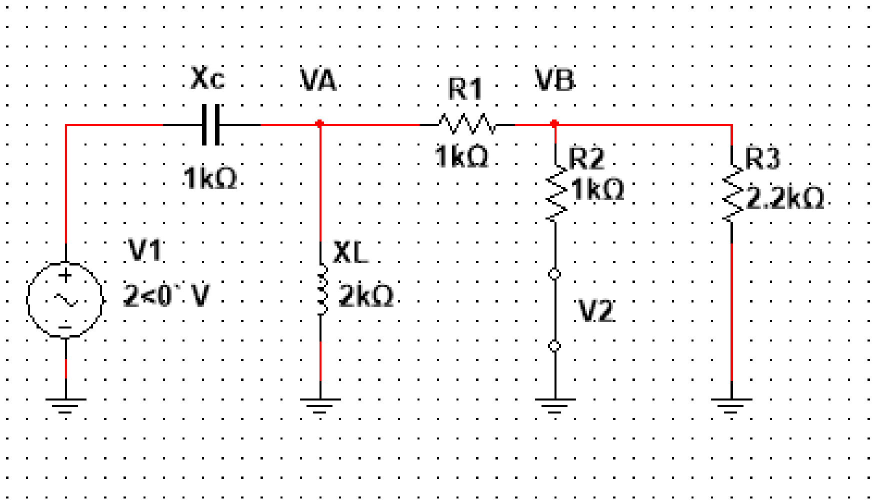
$$I_{R3} = (1.07 + j0.59)mA$$

$$I_{R3} = (1.23 < 28.77°)mA$$

2. Use el teorema de superposición para determinar la corriente y el voltaje a través de la rama R_2 de la figura 19-44.

▶ **FIGURA 19–44**





$$V_A\left(\frac{1}{-jX_C}+\frac{1}{jX_L}+\frac{1}{R_1}\right)-\frac{V_1}{-jX_C}-\frac{V_B}{R_1}=0$$

$$V_A\left(\frac{1}{-j1000}+\frac{1}{j2000}+\frac{1}{1000}\right)-\frac{2<0°}{-j1000}-\frac{V_B}{1000}=0$$

$$V_A(j-j0.5+1)-j2-V_B=0$$

$$V_A(j0.5+1)-V_B=j2$$

$$\frac{V_B-V_A}{R_1}+\frac{V_B}{R_2}+\frac{V_B}{R_3}=0$$

$$V_B\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)-\frac{V_A}{1000}=0$$

$$2.45V_B=V_A$$

$$2.45V_B(j0.5+1)-V_B=j2$$

$$V_B(j1.23+1.45)=j2$$

$$V_B=\frac{j2}{j1.23+1.45}$$

$$V_B=\frac{2<90°}{1.9<40.15°}$$

$$V_B=1.05<49.84°\,V$$

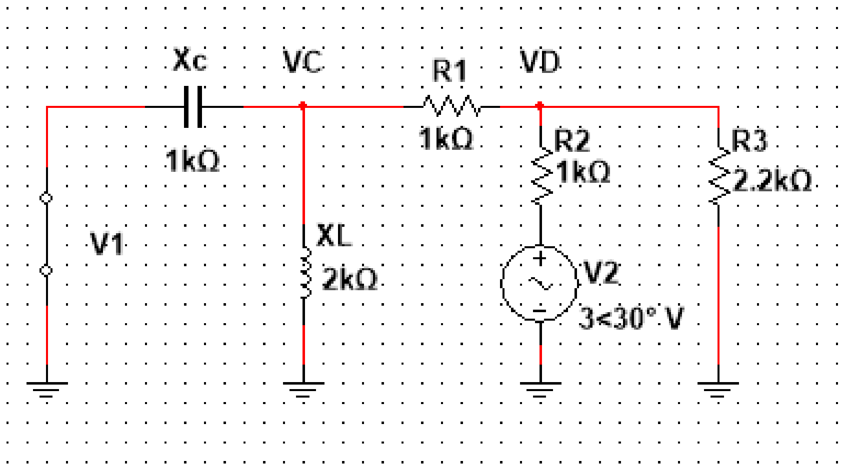
$$V_B=0.67+j0.8\,V$$

$$I_{V1}=\frac{V_B}{R_2}$$

$$I_{V1}=\frac{1.05<49.84°\,V}{1000}$$

$$I_{V1}=1.05<49.84°\,mA$$

$$I_{V1}=0.67+j0.8\,mA$$



$$\frac{V_C}{-jX_C}+\frac{V_C}{jX_L}+\frac{V_C-V_D}{R_1}=0$$

$$V_C\left(\frac{1}{-jX_C}+\frac{1}{jX_L}+\frac{1}{R_1}\right)-\frac{V_D}{R_1}=0$$

$$V_C\left(\frac{1}{-j1000}+\frac{1}{j2000}+\frac{1}{1000}\right)-\frac{V_D}{1000}=0$$

$$V_C(j-j0.5+1)-V_D=0$$

$$V_C=\frac{V_D}{1+j0.5}$$

$$\frac{V_D-V_C}{R_1}+\frac{V_D-V_2}{R_2}+\frac{V_D}{R_3}=0$$

$$V_D\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)-\frac{V_C}{R_1}-\frac{V_2}{R_2}=0$$

$$V_D\left(\frac{1}{1000}+\frac{1}{1000}+\frac{1}{2200}\right)-\frac{V_C}{1000}-\frac{3<30°}{1000}=0$$

$$2.45V_D-V_C=2.59+j1.5$$

$$V_D=\frac{2.59+j1.5}{1.65+j0.4}$$

$$V_D=\frac{3<30°}{1.7<13.59°}$$

$$V_D=1.69+j0.49\ V$$

$$V_D=1.76<16.4°\ V$$

$$I_{V2}=\frac{-0.9-j}{1000}$$

$$I_{V2} = -0.9 - j\ mA$$

$$I_{V2} = 1.35 < -132.15°\ mA$$

$$I_{R2} = I_{V1} + I_{V2}$$

$$I_{R2} = -0.22 - j0.2\ mA$$

$$I_{R2} = 0.3 < -138.1°\ \ mA$$

$$V_{R2} = R_2 * I_{R2}$$

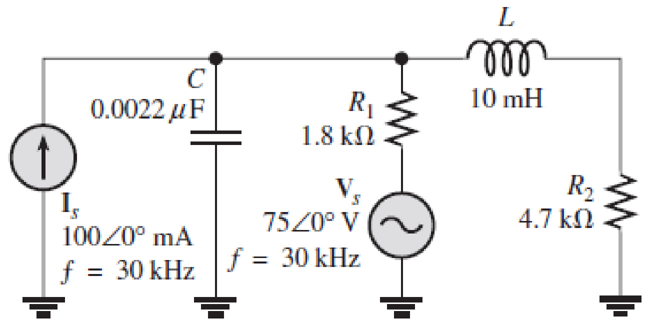
$$V_{R2} = 1000 * 0.3 < -138.1°\ mA$$

$$V_{R2} = 0.3 < -138.1°\ V$$

$$V_{R2} = -0.22 - j0.2\ V$$

3. Con el teorema de superposición, calcule la corriente a través de R_1 en la figura 19-45.

▶ FIGURA 19–45



$$X_C = \frac{1}{2\pi f C}$$

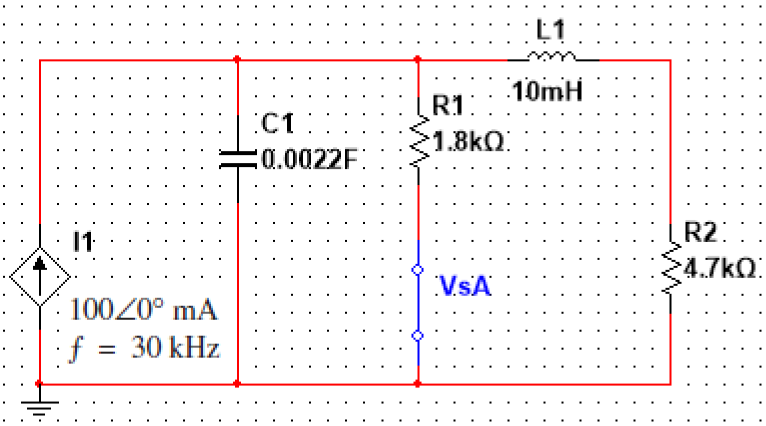
$$X_C = \frac{1}{2\pi(30x10^3)(0.0022)}$$

$$X_C = 2.41\ k\Omega$$

$$X_L = 2\pi f L$$

$$X_L = 2\pi(30x10^3)(10x10^{-3})$$

$$X_L = 1884\ \Omega$$

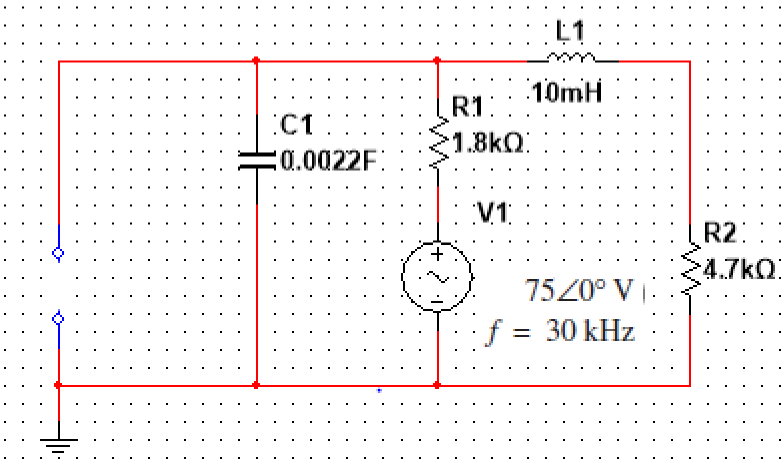


$$100x10^{-3} < 0° + \frac{V_1}{2411 < -90°} + \frac{V_1}{1.8\ k\Omega} + \frac{V_1}{1884 < 90°\Omega + 4.7k\Omega} = 0$$

$$V_1 = 122.86 < 155.2°\ V$$

$$I_1 = \frac{122.86 < 155.2°}{1800}$$

$$I_1 = 68.26 < 155.2°\ mA$$



$$\frac{V_2}{2.41 < -90°\ k\Omega} + \frac{V_2 - 75 < 0°}{1.8\ k\Omega} + \frac{V_2}{1884 < 90°\Omega + 4.7k\Omega} = 0$$

$$V_2 = 51.2 < -24.79°\ V$$

$$V_2 = I_2 R_1 + V_S$$

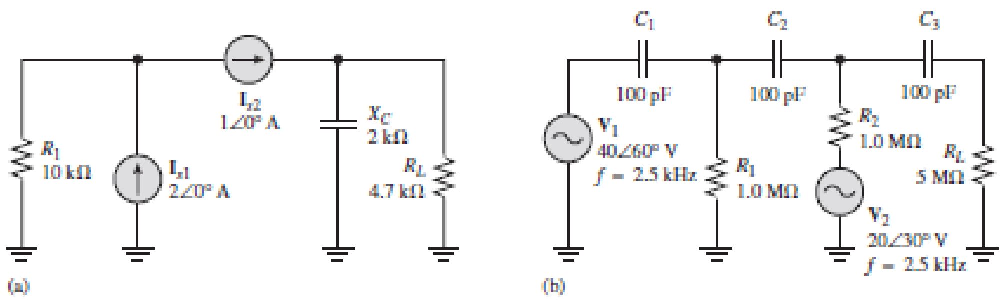
$$I_2 = \frac{V_2 - V_S}{R_1}$$

$$I_2 = 19.83 < -143°\ mA$$

$$I = I_1 + I_2$$

$$I = 80 < -12.07°\ mA$$

4. Con el teorema de superposición, determine la corriente a través de R_L en cada circuito de la figura 19-46.



▲ **FIGURA 19–46**

a)

$$1 < 0° + \frac{V_1}{2x10^3 < -90°} + \frac{V_1}{4.7\ k\Omega} = 0$$

$$V_1\left(\frac{< 90°}{2x10^3} + \frac{1}{4700}\right) = -1 < 0°$$

$$V_1 = 1841.62 < -67.023°\ V$$

$$V_1 = I_{RL2}\ R_L$$

$$I_{RL2} = \frac{1841.62 < -67.023°}{4700}$$

$$I_{RL2} = 391.83 < -67.023°\ mA$$

$$I_L = I_{RL1} + \ I_{RL2}$$

$$I_L = 0 < 0° + 391.83 < -67.023°$$

$$I_L = 391.83 < -67.023°$$

b)

$$X_{C1} = \frac{1}{2\pi f C_1}$$

$$X_{C1} = 0.63\ M\Omega$$

$$X_{C2} = \frac{1}{2\pi f C_2}$$

$$X_{C2} = 0.63\ M\Omega$$

$$X_{C3} = \frac{1}{2\pi f C_3}$$

$$X_{C3} = 0.63\ M\Omega$$

$$\frac{V_3 - 40 < 60°}{0.63\ M\Omega < -90°} + \frac{V_3}{1\ M\Omega} + \frac{V_3 - V_4}{0.63\ M\Omega < -90°} = 0$$

$$V_3(3.29x10^{-6} < 72.33°) - V_4(1.57x10^{-6} < 90°) = 62.8x10^{-6} < 150°$$

$$V_4 = (0.79 < 36.71°)V_3$$

$$V_3 = 22.83 < 99.17°$$

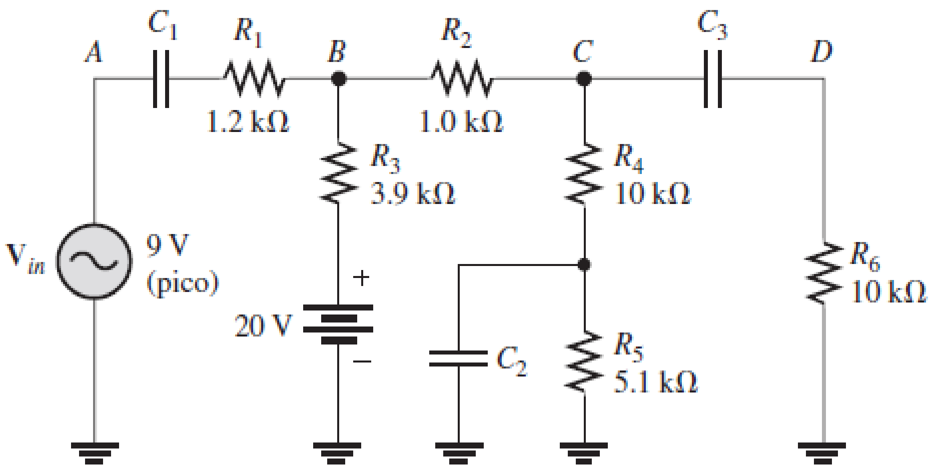
$$V_4 = 18.08 < 135.88°$$

$$I_{RL} = \frac{V_4}{0.63\ M\Omega < -90° + 5\ M\Omega}$$

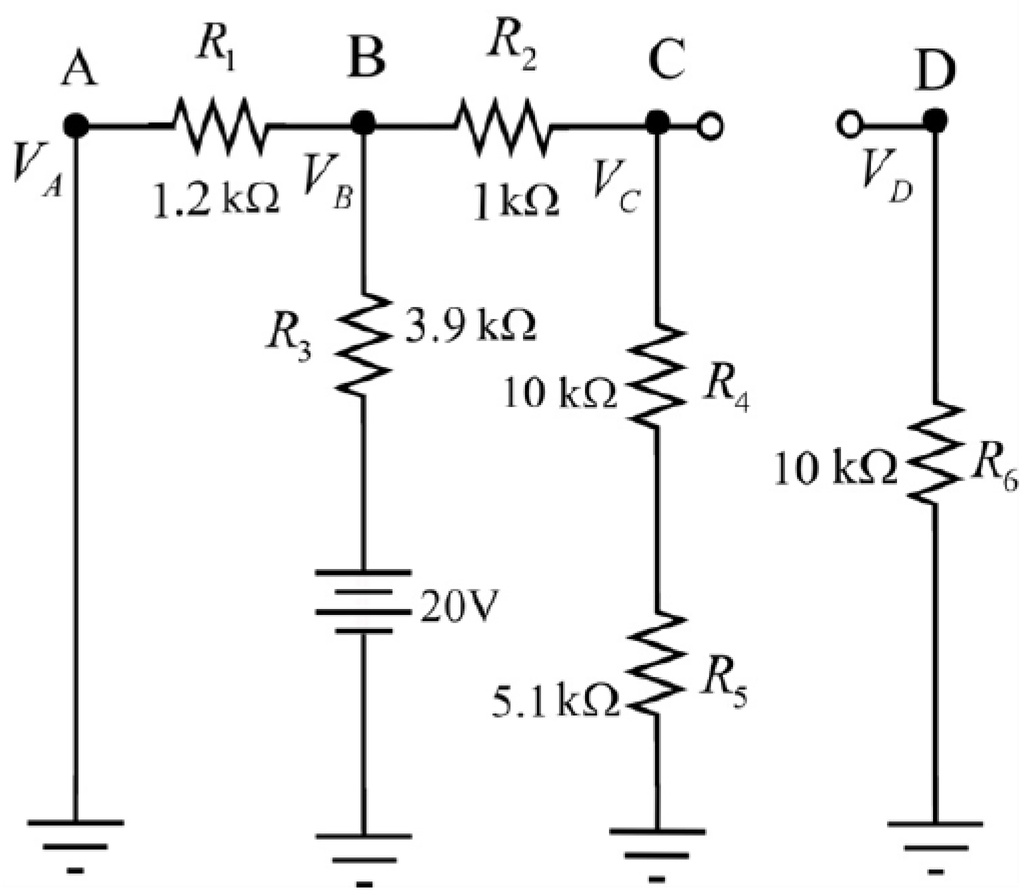
$$I_{RL} = 3.56x10^{-6} < 143.12°\ A$$

$$I_L = 2.47x10^{-6} < 103.81°\ A$$

***5.** Determine el voltaje en cada punto (*A*, *B*, *C*, *D*) señalado en la figura 19-47. Suponga $X_C = 0$ para todos los capacitores. Trace las formas de onda de voltaje en cada punto.



▲ FIGURA 19–47



Nodo B

$$\frac{V_B}{3900}+\frac{V_B-V_C}{1000}=0$$

$$1.25\,V_B-V_C=5.12$$

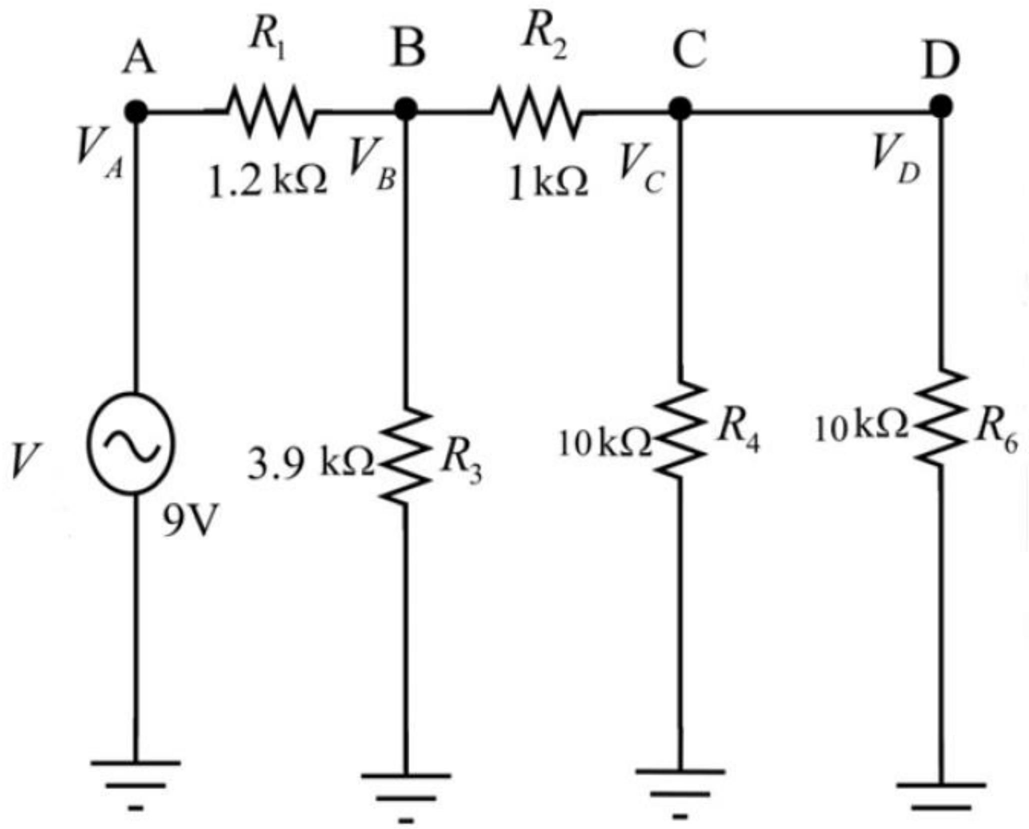
Nodo C

$$\frac{V_c}{15100}+\frac{V_C-V_B}{1000}=0$$

$$1.06\,V_C=V_B$$

$$V_C=15.17\,V$$

$$V_B=16.17\,V$$



Nodo B

$$2.08\ V_B - V_C = 7.5$$

Nodo C

$$1.2\ V_C - V_B = 0$$

$$V_B = 5.97\ V$$

$$V_C = 4.97\ V$$

$$V_C = V_D$$

$$V_D = 4.97\ V$$

El voltaje desarrollado en los puntos A, B, C y D debido a la fuente de voltaje de CC es el siguiente:

$$V_A = 0V$$

$$V_B = 16.17V$$

$$V_C = 15.17V$$

$$V_D = 0V$$

El voltaje desarrollado en los puntos A, B, C y D debido a la fuente de voltaje de CA es el siguiente:

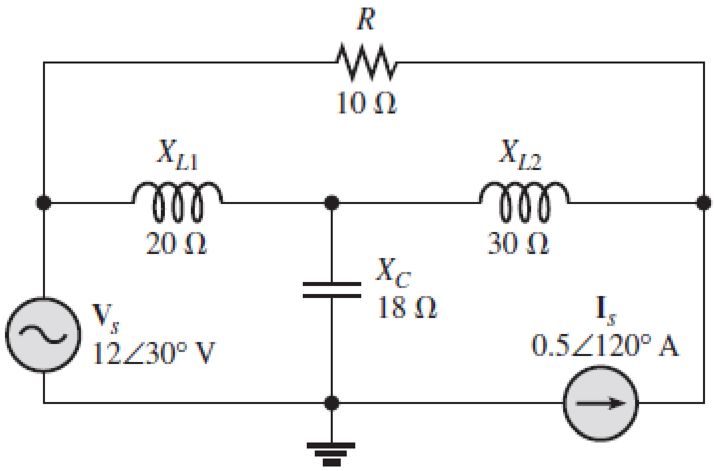
$$V_A = 9V$$

$$V_B = 5.97V$$

$$V_C = 4.97V$$

$$V_D = 4.97V$$

***6.** Use el teorema de superposición para determinar la corriente en el capacitor de la figura 19-48.



▲ FIGURA 19–48

$$\frac{V_1}{20 < 90°} + \frac{V_1}{18 < -90°} + \frac{V_1 - V_2}{30 < 90°} = 0$$

$$V_1 = 1.22V_2$$

$$\frac{V_2 - V_1}{j30} + \frac{V_1}{10} + 0.5 < 120° = 0$$

$$V_2 = 5 < 116°\,V$$

$$V_1 = 6.1 < 116°\ \mathrm{V}$$

$$I_{C1} = \frac{V_1}{X_C}$$

$$I_{C1} = 0.33 < 206°\,A$$

$$\frac{V_3 - 12 < 30°}{20 < 90°} + \frac{V_3}{18 < -90°} + \frac{V_3 - 12 < 30°}{10 + 30 < 90°} = 0$$

$$V_3 = 25.94 < -139.91°$$

$$I_{C2} = \frac{V_3}{X_C}$$

$$I_{C2} = 1.44 < -49.91°$$

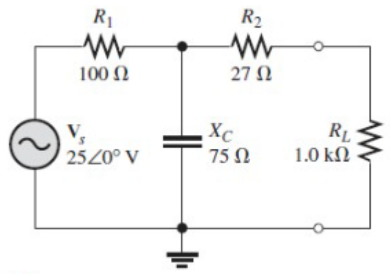
$$I_L = I_{C1} + I_{C2}$$

$$I_L = 1.39 < -63.45°\ A$$

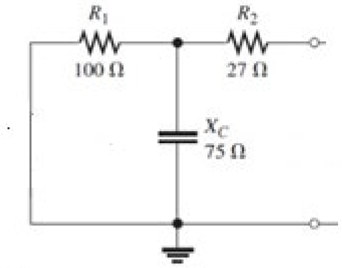
Teorema de Thevenin

7. En cada circuito de la figura 19-49, determine el circuito equivalente de Thevenin para la parte vista por RL.

Calculando Zth.



(a)



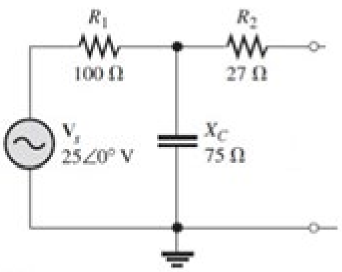
(a)

$$Z1 = \frac{1}{\frac{1}{100} - \frac{1}{j75\Omega}} = 36 - 48j$$

$$Z2 = Zeq = Z1 + R2 = 36 - 48j + 27 = 63 - 48j$$

$$Zth = 63 - 48j = 79.20 < -37.30$$

Calculando el Vth.

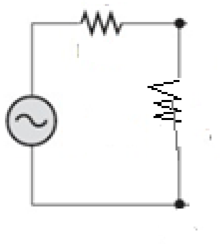


(a)

$$IT = \frac{VT}{Rt} = \frac{25 < 0}{79.20 < -37.30} = 0.2056 < 37.30$$

$$VTH = IT * Xc = 0.2056 < 37.30 * 75 < -90 = 15.425 < -52.7276(v)$$

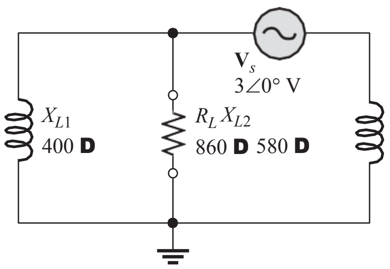
Circuito Thevenin.

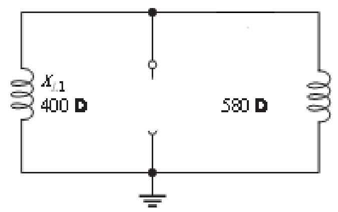


$$IT = \frac{VTH}{RT + RL} = \frac{15.425 < -52.7276(v)}{79.20 < -37.30 + 1000} = 0.014484 < -50.14061(\mathrm{A})$$

b)

Calculando Zth

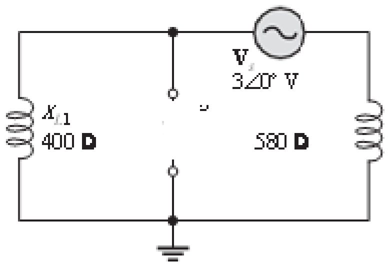




$$Z1 = \frac{1}{\frac{1}{400j} + \frac{1}{580j}}$$

$$Z1 = Zth = 237 < 90$$

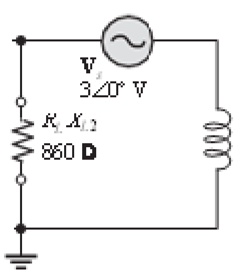
Calculando el Vth.



$$IT = \frac{VT}{Rt} = \frac{3 < 0}{237 < 90} = 0.0126506 < -90$$

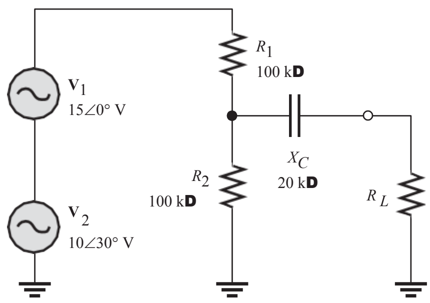
$$VTH = IT * Xl = 0.0326506 < -90 * 400j = 1.224(v)$$

Circuito Thevenin.

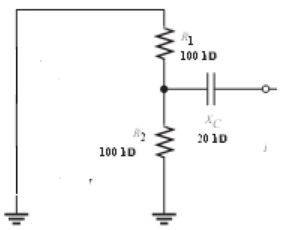


$$IT = \frac{VTH}{RT + RL} = \frac{1.224(v)}{237 < 90 + 860\Omega} = 1.38 * 10 - 3 < -15.7313(\text{A})$$

C)



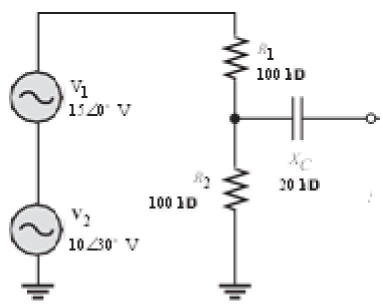
Calculando Zth



$$Z1 = \frac{1}{\frac{1}{100k\Omega} + \frac{1}{100k\Omega}} = 50k\Omega$$

$$Z2 = Zth = z1 - 20j = 50 - 20j$$

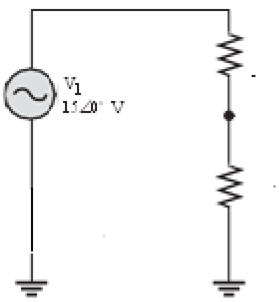
Calculando el Vth.



$$IT = \frac{VT}{Rt} = \frac{15 < 0 + 10 < 30}{200k\Omega} = 0.1209 < 11.93(ma)$$

$$VTH = IT * Xl = 0.1209 < 11.93 * -20j = 12.418 < -78.067(v)$$

Circuito Thevenin.



$$VTH = IT * Xl = 0.6209 < 11.93 * -20j = 12.418 < -78.067(v)$$

8. Aplique el teorema de Thevenin y determine la corriente a través de la carga RL en la figura 19-50.

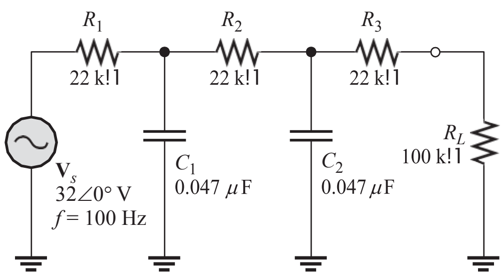


FIGURA 19–50

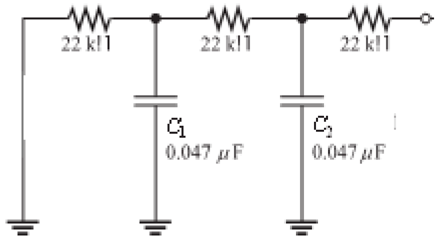
Calculando la frecuencia angular.

$$w = 2\pi f$$

$$w = 2\pi 100$$

$$w = 200\pi \text{ rad/s}$$

Calculando la Rth.



Z1=Z3=Z5=22kΩ

$$Z2 = Z4 = -\frac{1}{wc} = -\frac{1}{200\pi * 0.047\text{x}10 - 6} = -33.8627ik\Omega$$

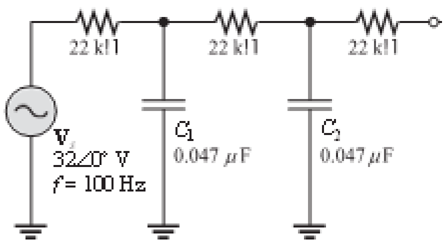
$$Za = \frac{1}{\frac{1}{22k\Omega} - \frac{1}{33.8627ik\Omega}} = 15.4702 - 10.0507i$$

$$Zb = Za + Z3 = 22 + 15.4702 - 10.0507i = 37.89351 - 10.05072i$$

$$Zc = Zb \| Z4 = \frac{1}{\frac{1}{37.89351 - 10.05072i} - \frac{1}{33.8627ik\Omega}} = 12.89351 - 18.75207i$$

$$Rth = Zc + Z5 = 34.893517 - 18.75207i$$

Calculando el Vth.



$$\begin{cases} 32 - 22(I1) + 33.8627i(I1 - I2) = 0 \\ 33.8627i(I2 - I1) - 22(I2) + 33.8627i(I2) = 0 \end{cases}$$

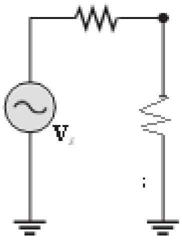
$$\begin{cases} -22 + 33.8627i(I1) - 33.8627i(I2) = -32 \\ -33.8627i(I1) - 22 + 67.7254i(I2) = 0 \end{cases}$$

$$\begin{cases} I1 = 0.805 + 0.5538i \\ I2 = 0.445 + 0.1321i \end{cases}$$

$$VTH = I2 * Z4 = 0.445k\Omega + 0.1321i * -33.8627ik\Omega$$

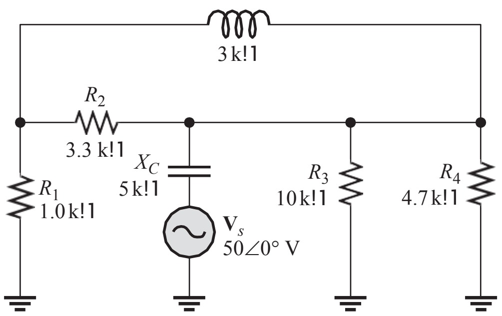
$$VTH = 4.91826v$$

Circuito Thevenin.

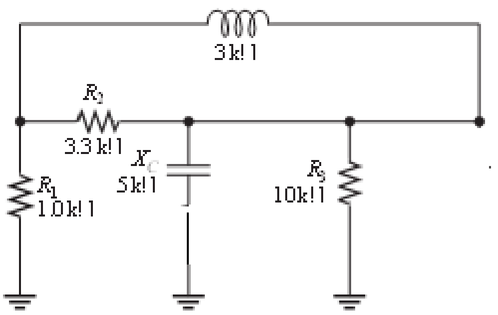


$IT = \frac{VTH}{RT+RL} = \frac{4.91826v}{34.893517-18.75207i+100k\Omega}$ = 0.03576+4.9723x10-3ima

9. Aplique el teorema de Thevenin y determine el voltaje en R4 en la figura 19-51.



Calculando Zth



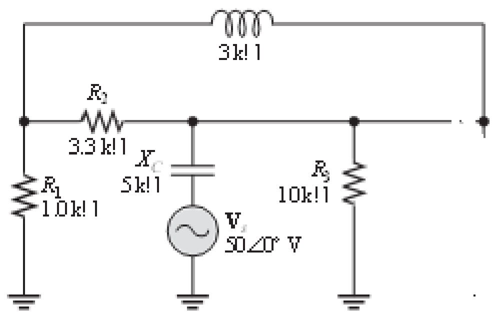
$$Za = \frac{1}{\frac{1}{3k\Omega j} + \frac{1}{3.3k\Omega}} = 2.2198 < 47.7263$$

$$Zb = Za + 1.0k\Omega = 2.9856 < 33.37$$

$$Zeq = \frac{1}{\frac{1}{2.9856 < 33.37} - \frac{1}{5k\Omega j} + \frac{1}{10k\Omega} + \frac{1}{4.7k\Omega}} = 1.687 < -1.524$$

$$Zth = 1.687 < -1.524$$

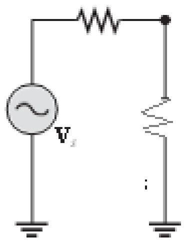
Calculando el Voltaje de Thevenin.



$$IT = \frac{VT}{RT} = \frac{50 < 0}{1.687 < -1.524} = 29.63841 < 1.524$$

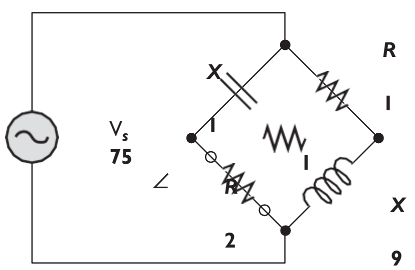
$$VTH = I2 * Z4 = 3.5994 < 1.524 * 10k\Omega = 12.349 < 1.524$$

Circuito Thevenin



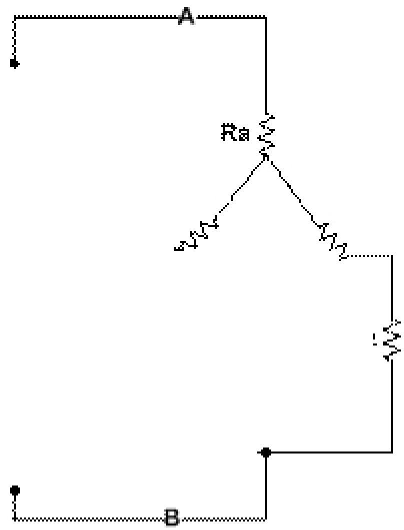
$$VTH = I2 * Z4 = 3.5994 < 1.524 * 4.7k\Omega = 16.9\angle 88.2° \text{ V}$$

10.- Simplifique el circuito externo a R3 mostrado en la figura 19-52 a su equivalente de Thevenin.



Calculando la Rth.

Transformando Delta a Estrella.



$$Ra = \frac{xc * R2}{xc + R1 + R2} = \frac{18000i}{250 + 120i} = 28.088 + 58.5175i$$

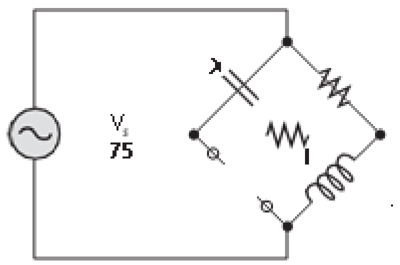
$$Rb = \frac{R1 * R2}{xc + R1 + R2} = \frac{100 * 150}{250 + 120i} = 48.764 - 23.4070i$$

$$Rc = \frac{xc * R1}{xc + R1 + R2} = \frac{120i * 100}{250 + 120i} = 18.7256 + 39.011i$$

$$Req = \frac{(28.088 + 58.5175i\ ) * (48.764 - 23.4070i)}{(28.088 + 58.5175i\ ) + (48.764 - 23.4070i)} = 40.29 + 10.168i$$

$$RTH = Rc + Req + XL = 18.7256 + 39.011i + 40.29 + 10.168i + 90i = 59.01 + 139.179i$$

Calculando el Vth.



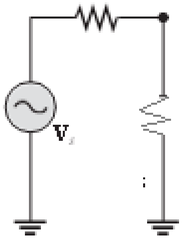
$$IT = \frac{V}{RTH} = \frac{75}{59.01 + 139.179i} = 0.19366 - 0.4567i$$

$$VTH = 0.19366 - 0.4567i * 90i = 41.10 + 17.429i$$

Circuito Thevenin.

$$I(RL) = \frac{VTH}{RT + RL} = \frac{41.10 + 17.429i}{59.01 + 139.179i + 220} = 0.1429 - 8.8193x10 - 3i(A)$$

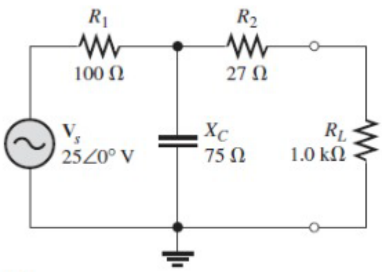
$$V(RL) = IRL * RL = 0.1429 - 8.8193x10 - 3i * 220 = 31.43 - 1.94025i(V)$$



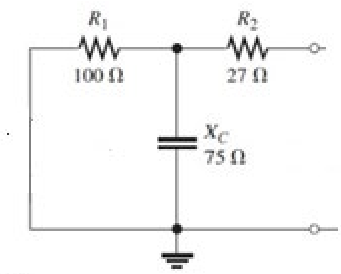
Teorema de Norton.

11. Para cada circuito de la figura 19-49, determine el equivalente de Norton visto por RL.

Calculando Zth.



(a)



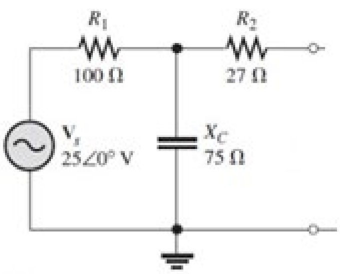
(a)

$$Z1 = \frac{1}{\frac{1}{100} - \frac{1}{j75\Omega}} = 36 - 48j$$

$$Z2 = Zeq = Z1 + R2 = 36 - 48j + 27 = 63 - 48j$$

$$Zth = 63 - 48j = 79.20 < -37.3039$$

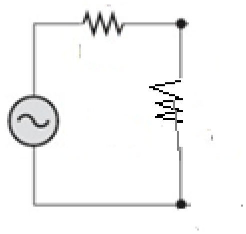
Corriente de Norton.



(a)

$$IT = \frac{VT}{Rt} = \frac{25 < 0}{79.2022 < -37.3039\Omega} = 189 < -15.8(ma)$$

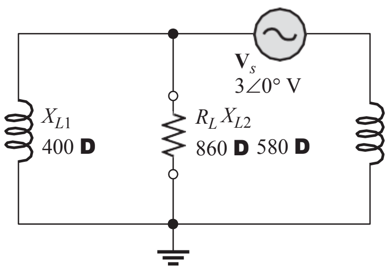
Circuito Norton.

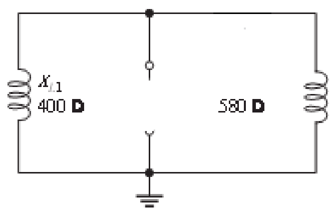


$$IT = \frac{VT}{Rt} = \frac{25<0}{79.2022<-37.3039\Omega} = 189 < -15.8(ma)$$

b)

Calculando Zth

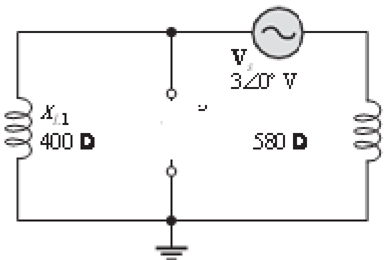




$$Z1 = \frac{1}{\frac{1}{400j} + \frac{1}{580j}} = 236.73 < 90$$

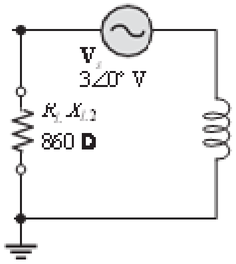
$$Z1 = Zth = 236.73 < 90$$

Corriente Thevenin.



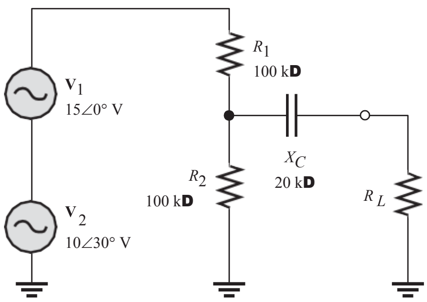
$$IT = \frac{VT}{Rt} = \frac{3 < 0}{236.7346 < 90} = 0.0126 < -90(A)$$

Circuito Norton.

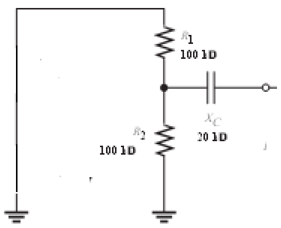


$$ITh = \frac{VTH}{RT + RL} = \frac{5}{236.73 + 860\Omega} = 5.15 < -90(\mathrm{ma})$$

C)



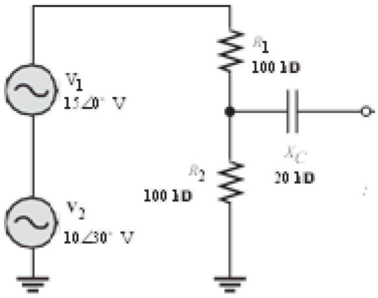
Calculando Zth



$$Z1 = \frac{1}{\frac{1}{100k\Omega} + \frac{1}{100k\Omega}} = 50k\Omega$$

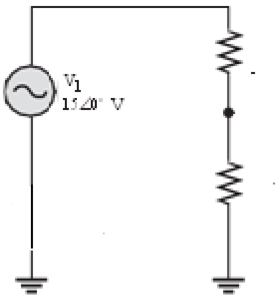
$Z2 = Zth = z1 - 20j = 50 - 20j$

Calculando el Vth.



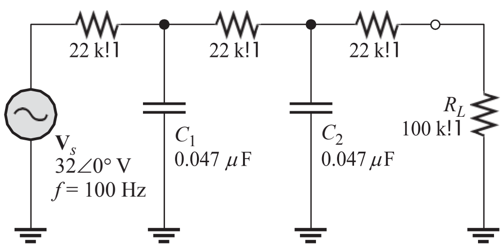
$$IT = \frac{VT}{Rt} = \frac{15 < 0 + 10 < 30}{200k\Omega} = 0.1209 < 11.93(ma)$$

Circuito Norton.



$$IT = \frac{VTH}{RT + RL} = \frac{2.418 < -78.067(v)}{50 - 20j + Rl} = 224\angle 33.7° \text{ mA}$$

12. Aplique el teorema de Norton y determine la corriente a través del resistor de carga RL en la figura 19-50.



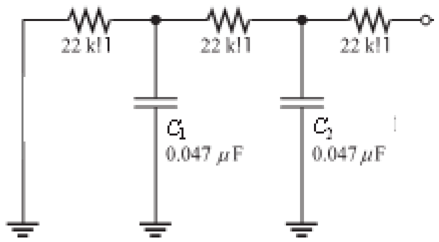
Calculando la frecuencia angular.

$w = 2\pi f$

$w = 2\pi 100$

$w = 200\pi \text{ rad/s}$

Calculando la RN.



Z1=Z3=Z5=22kΩ

$$Z2 = Z4 = -\frac{1}{wc} = -\frac{1}{200\pi * 0.047\text{x}10-6} = -33.8627ik\Omega$$

$$Za = \frac{1}{\frac{1}{22k\Omega} - \frac{1}{33.8627ik\Omega}} = 15.4702 - 10.0507i$$

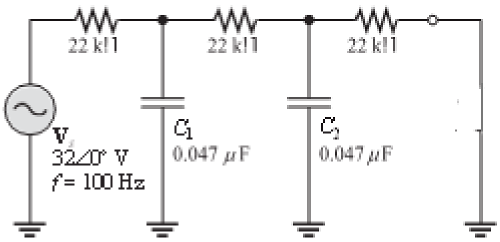
$$Zb = Za + Z3 = 22 + 15.4702 - 10.0507i = 37.89351 - 10.05072i$$

$$Zc = Zb \| Z4 = \frac{1}{\frac{1}{37.89351 - 10.05072i} - \frac{1}{33.8627ik\Omega}} = 12.89351 - 18.75207i$$

$$RN = Zc + Z5 = 34.893517 - 18.75207i$$

Calculando corriente Norton.

Cortocircuito la carga



$$\begin{cases} -22 + 33.8627i(I1) - 33.8627i(I2) = -32 \\ -33.8627i(I1) - 22 + 67.7254i(I2) - 33.8627i(I3) = 0 \\ -33.8627i(I2) - 22 - 33.8627i(I3) = 0 \end{cases}$$

$$\begin{cases} I1 = 0.685674 + 6.010i \\ I2 = 0.2952 + 0.101498i \\ I3 = -0.016 - 0.2062i \end{cases}$$

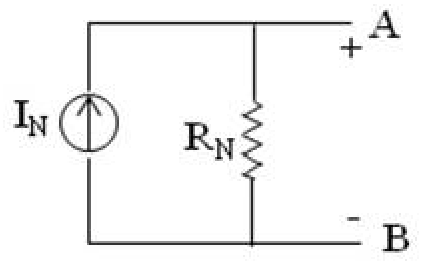
IN=$-0.016 - 0.2062i$

Circuito de Norton.

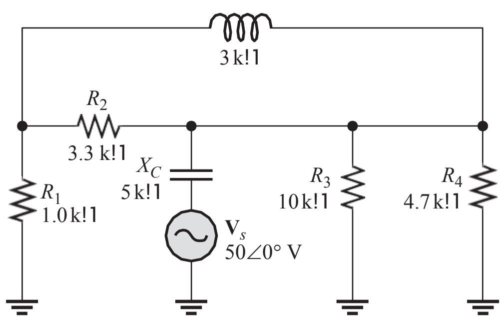
$$RT = \frac{34.893517 - 18.75207i * 100K\Omega}{34.893517 - 18.75207i + 100K\Omega} = 2.1496 - 13.6025i$$

$Vt100k\Omega = IN * RT = -0.016 - 0.2062i * 2.1496 - 13.6025i = -0.016 - 14.045i$

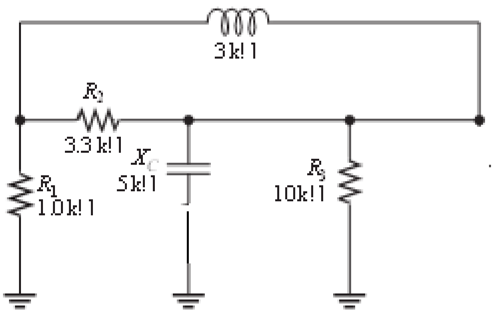
$I100k\Omega = \frac{V}{R} = \frac{-0.016 - 14.045i}{100} = -1.6 * 10 - 4 - 0.1404i$



13. Aplique el teorema de Norton para determinar el voltaje en R4 en la figura 19-51.



Calculando Zth



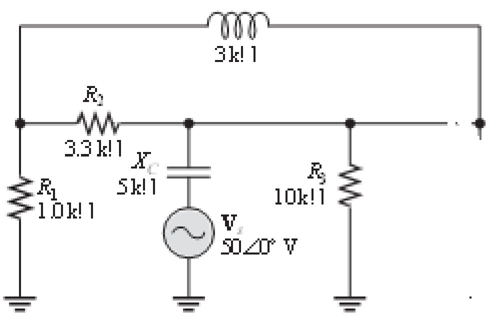
$$Za = \frac{1}{\frac{1}{3k\Omega j} + \frac{1}{3.3k\Omega}} = 2.2198 < 47.7263$$

$$Zb = Za + 1.0k\Omega = 2.9856 < 33.37$$

$$Zeq = \frac{1}{\frac{1}{2.9856 < 33.37} - \frac{1}{5k\Omega j} + \frac{1}{10k\Omega} + \frac{1}{4.7k\Omega}} = 13.9887 < -1.524$$

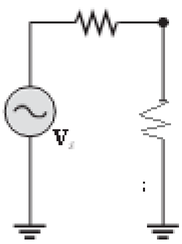
$$Zth = 13.9887 < -1.524$$

Corriente de norton.



$$IT = \frac{VT}{RT} = \frac{50 < 0}{13.9887 < -1.524} = 3.5847 < 1.524$$

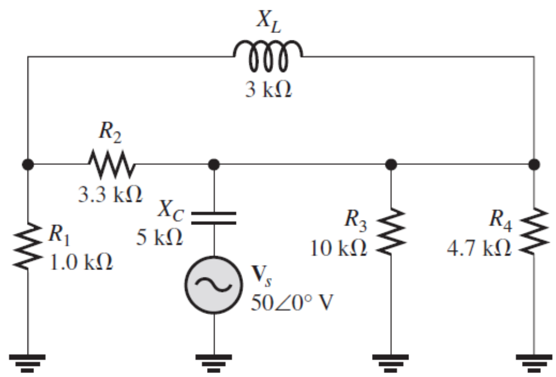
Circuito Norton



$$VTH = I2 * Z4 = 3.5847 < 1.524 * 4.7k\Omega = 16.8\angle 88.2° \text{ V}$$

Teorema de Norton

13. Aplique el teorema de Norton para determinar el voltaje en R4 en la figura 19-51.



$$Z1 = R3||Xc = \frac{R3 * Xc}{R3 + Xc} = \frac{(10 < 0°)(5k < 90°)}{(10 < 0°) + (5k < 90°)}$$

$$Z1 = \ \ 4{,}47k < -63{,}43°$$

$$Z2 = R2||Xl = \frac{R2 * Xl}{R2 + Xl} = \frac{(3{,}3k < 0°)(3k < 90°)}{(3{,}3k < 0°) + (3k < 90°)}$$

$$Z2 = \ \ 2{,}61k < 37{,}47°$$

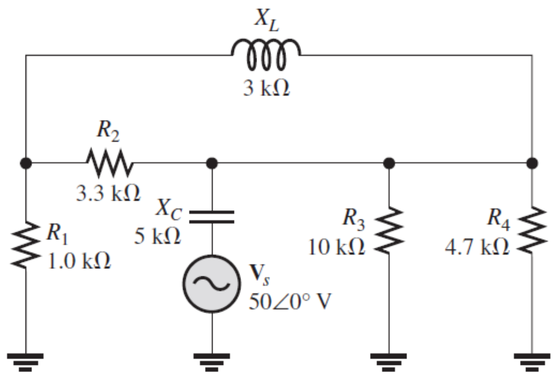
$$Z = \ \ R1 + Z1 + Z2 = 1{,}0k + 4{,}47k < -63{,}43° \ + \ 2{,}61k < 37{,}47°$$

$$Z = 5{,}61\ k << -25{,}42°$$

$$Is = \frac{Vs}{Z} = \frac{50 < 0°}{5{,}61 < -25{,}42°} = 8{,}91 < 25{,}42°$$

Encontrar In

Metodo de mallas



Malla 1

$$1,0k + 3,3k(I1 - I3) - 5kj(I11 - I2) = 0$$

Malla 2

$$-50 < 0° - 5kj(I2 - I1) + 10k(I2 - In) = 0$$

Malla 3

$$3kj + 3,3k(I3 - I2) = 0$$

Malla n

$$10k(In - I2) + 4,7k\ (In) = 0$$

Sistema de ecuaciones

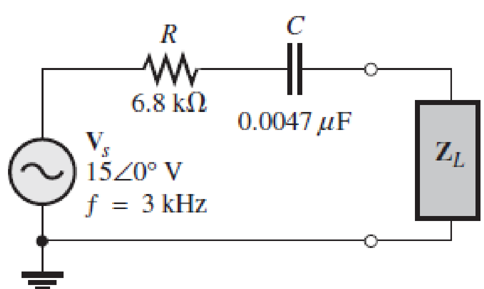
$$\begin{cases} 1{,}0k + 3{,}3k(I1 - I3) - 5jk(I1 - I2) + 50 < 0 = 0 \\ -50 < 0 - 5jk(I2 - I1) + 10k(I2 - In) = 0 \\ 3kj + 3{,}3k(I3 - I1) = 0 \\ 10k(In - I2) + 4{,}7k(In) = 0 \end{cases}$$

$$In = 9{,}34x10^{-5} - 3{,}56j = 3{,}57x10^{-3} < -88{,}5°$$

$$V_{R4} = In * R4 = 3{,}57x10^{-3} < -88{,}5° * 47 < 0° = 16{,}8 < -88{,}5°$$

Ejercicios de Teorema de máxima transferencia de potencia

14. En cada circuito de la figura, se tiene que transferir potencia máxima a la carga RL. Determine el valor apropiado para la impedancia de carga en todos los casos.



Impedancia equivalente de Thevenin:

$$x_{c1} = \frac{1}{2\pi f C1} = \frac{1}{2\pi * 3k * 0{,}00047\mu F} = 11{,}28k\Omega$$

- $x_{c1} = 11{,}28 < -90° k\Omega$

- $R_1 = 6{,}8 < 0°\ k\Omega$

Circuito en serie

$$Zth = X_{c1} + R1 = 11{,}28 < -90°\ k\Omega + 6{,}8 < 0°\ k\Omega$$

$$Zth = (6{,}8 - 11{,}28i)k\Omega = \ 13{,}171 < -58{,}91^\circ \ k\Omega$$

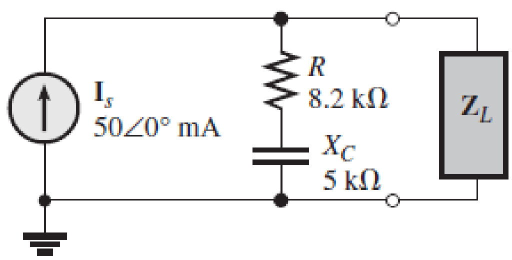
Máxima transferencia de potencia

Complejo Conjugado: *R* - *jXC* es *R* +*jXL*

$$ZL = Zth^*$$

$$Zth = (6{,}8 - 11{,}28i)k\Omega$$

$$ZL = (6{,}8 + 11{,}28i)k\Omega$$



Impedancia equivalente de Norton:

- $x_{c1} = 5 < -90^\circ k\Omega$
- $R_1 = 8{,}2 < 0^\circ \ k\Omega$

Circuito en serie

$$Zn = X_{c1} + R1 = 5 < -90^\circ \ k\Omega + 8{,}2 < 0^\circ \ k\Omega$$

$$Zn = (8{,}2 - 5i)k\Omega$$

Máxima transferencia de potencia

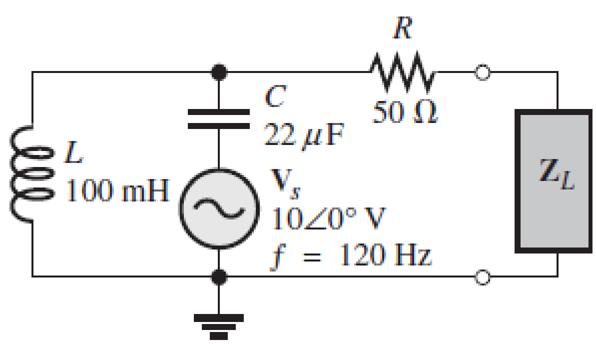
Complejo Conjugado: *R* - *jXC* es *R* +*jXL*

$$ZL = Zth^*$$

$$ZL = Zn^*$$

$$Zn = Zn = (8{,}2 - 5i)k\Omega$$

$$ZL = (8{,}2 + 5i)k\Omega$$



Impedancia equivalente de Thevenin:

$$x_{c1} = \frac{1}{2\pi f C1} = \frac{1}{2\pi * 120 * 22\mu} = 60{,}28\Omega$$

$$x_{c1} = 60{,}28 < -90°\Omega$$

$$X_{L1} = 2\pi * f * L1 = 2\pi * 120 * 100m\Omega$$

$$X_{L1} = 62{,}8\Omega = 62{,}8 < 90°$$

$$R_1 = 50\Omega = 50 < 0°\Omega$$

R1 está en serie con el paralelo $X_{L1} \parallel x_{c1}$

$$X_{L1}||x_{c1} = \frac{62{,}8 < 90° * 60{,}28 < -90°}{62{,}8 < 90° + 60{,}28 < -90°}$$

$$X_{L1}||x_{c1} = 1502{,}21 < -90°$$

$$X_{L1}||x_{c1} + \ R_1 = \ \ 50 < 0° + 1502{,}21 < -90°$$

$$X_{L1}||x_{c1} + \ R_1 = \ \ \text{Zth} \ \ = (\ 100 - 1502{,}21\ \text{i})\ \Omega$$

Máxima transferencia de potencia

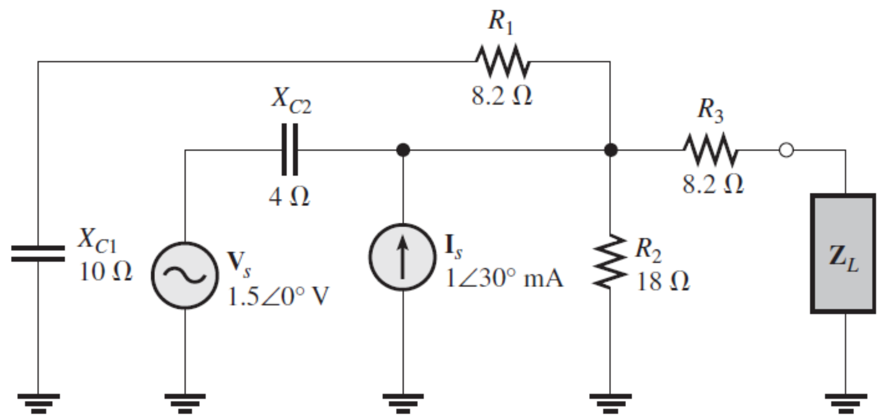
Complejo Conjugado: *R* - *jXC* es *R* +*jXL*

$$ZL = Zth^*$$

$$Zth = (100 - 1502{,}21i)\Omega$$

$$ZL = (100 + 1502{,}21i)\Omega$$

15. Determine ZL para transferir potencia máxima en la figura 19-54.



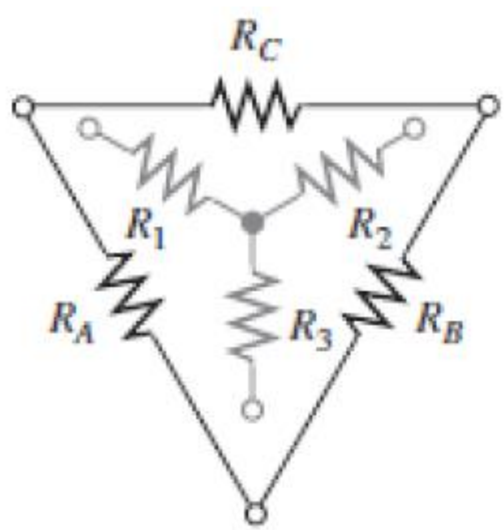
$$Z1 = Xc1 + R1 = 10 - 8j$$

$$Xc2 = -4j$$

$$R2 = 18\ \Omega$$

$$R3 = 8{,}2\ \Omega$$

Conversión Y-Delta



$$R_A = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

$$R_B = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

$$R_C = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3}$$

$$ZA = \frac{-4j * 8{,}2 - 4j * 18 + 8{,}2 * 18}{8{,}2} = 18 - 12{,}78j$$

$$ZB = \frac{-4j * 8{,}2 - 4j * 18 + 8{,}2 * 18}{-4j} = -26{,}2 - 36{,}9j$$

$$ZC = \frac{-4j * 8{,}2 - 4j * 18 + 8{,}2 * 18}{818} = 8{,}2 - 5{,}82j$$

$$Z2 = ZA||Z1 = \frac{(10-8j)(18-12{,}78j)}{(10-8j)-(18-12{,}78j)} = 6{,}43 - 4{,}93j$$

$$Zth = Z2 + ZB + ZC = 6{,}43 - 4{,}93j - 26{,}2 - 36{,}9j8{,}2 - 5{,}82j$$

$$Zth = 9{,}18 - 2{,}90j$$

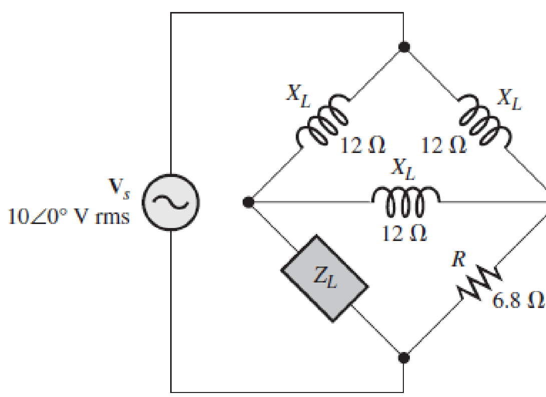
$$Zth^* = 9{,}18 + 2{,}90j$$

$$Zl = Zth^*$$

$$Zl = 9{,}18 + 2{,}90j$$

16. Determine la impedancia de carga requerida para transferir potencia máxima a ZL en la figura

Determine la potencia real máxima.



$$X_{l1} = 12\Omega = 12 < 90°\ \Omega$$

$$X_{l2} = 12\Omega = 12 < 90°\ \Omega$$

$$X_{l3} = 12\Omega = 12 < 90°\ \Omega$$

$$R_1 = 6{,}8\ \Omega = 6{,}8 < 0°\ \Omega$$

En Serie:

$$X_{l1} + X_{l2} = \;\; 12 < 90° + 12 < 90° = 24 < 90°$$

$$XA = X_{l1} + X_{l2} \,||x_{l3} = \frac{24 < 90° * 12 < 90°}{24 < 90° + 12 < 90°} = \;\; 8 < 90°$$

En serie

$$Zth = XA + R1 = 8 < 90° + 6{,}8 < 0° = \; 13{,}6 + 8i \; \Omega$$

Máxima transferencia de potencia

Complejo Conjugado: *R* - *jXC* es *R* +*jXL*

$$ZL = Zth^{*}$$

$$Zth = 13{,}6 + 8i \; \Omega$$

$$ZL = 13{,}6 - 8i \; \Omega$$

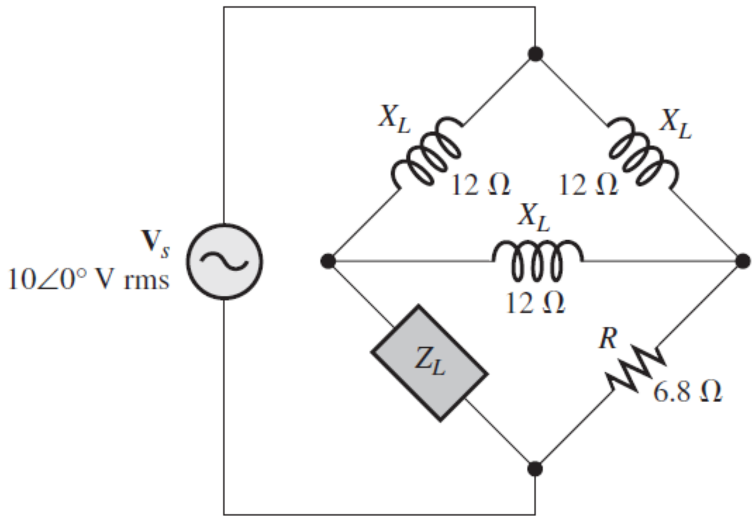
Potencia Máxima:

$$Z_{tot} = \sqrt{(Rs + Rl)^2 + (Xl - Xc)^2} = \sqrt{(13{,}6 + 13{,}6)^2 + (8 + 8)^2} = 25{,}01$$

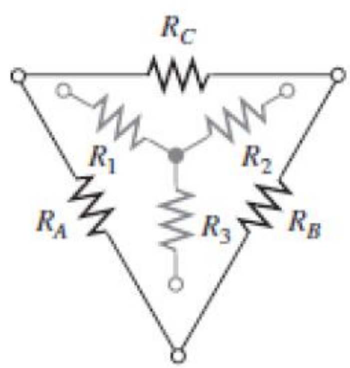
$$I = \frac{Vs}{Z_{tot}} = \frac{10}{25{,}01} = 0{,}399$$

$$Pl = 0{,}399^2 * 13{,}6 = 2{,}174 \; w$$

17. Se tiene que conectar una carga en el lugar de R2 en la figura 19-52 para lograr transferencia de potencia máxima. Determine el tipo de carga y exprésela en forma rectangular.



Conversión Delta-Y



$$R_1 = \frac{R_A R_C}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_B R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A R_B}{R_A + R_B + R_C}$$

$$Z1 = \frac{R3 * R2}{R2 + R3 + XL} = \frac{220 * 150}{150 + 220 + 90j} = 84{,}20 - 20{,}4j$$

$$Z2 = \frac{R2 * XL}{R2 + R3 + XL} = \frac{150 * 90j}{150 + 220 + 90j} = 8{,}37 + 34{,}4j$$

$$Z3 = \frac{R3 * XL}{R2 + R3 + XL} = \frac{220 * 90j}{150 + 220 + 90j} = 12{,}28 + 50{,}52j$$

$$Z4 = Z1 + Xc = 84{,}20 - 20{,}4j - 120j = 84{,}2 - 140{,}4j$$

$$Z5 = Z2 + R1 = 8{,}37 + 34{,}4j + 100 = 108{,}37 + 34{,}4j$$

$$Z6 = Z4 \,||Z5 = \frac{(84{,}2 - 140{,}4j)(108{,}37 + 34{,}4j)}{(84{,}2 - 140{,}4j) + (108{,}37 + 34{,}4j)} = 82{,}63 - 18{,}48j$$

$$ZL = Z6 + Z3 = 95{,}2 + 42{,}7j$$