The Hashemite University

Faculty of Engineering

Department of Electrical Engineering

Electrical Circuit Lab

Experiment “8 “(Complex Power & Power Factor)

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Date:12-27-2020 (Sunday)

- Objectives:

1. Calculate both theoretical and experimental complex power, apparent power, real power, reactive power and power factor.

2. Determine the parallel reactance and component values required for power factor correction.

- Theory:

Complex Power:

Complex power can always be determined from the general complex power equation:

$$\vec{S} = \vec{V}_{eff}\,\vec{I}^{\,*}_{eff} = V_{eff} I_{eff} \angle(\theta_V - \theta_I) = S\angle\theta = P + jQ \quad 9$$

Where the voltage and current phasors use RMS values. Complex power can also be determined by summing individual component powers (again, with RMS voltage and current phasors). The relevant equations for R,L, and C components are:

$$P_R = V_{R\,eff} I_{R\,eff} = \frac{V^2_{R\,eff}}{R} = I^2_{R\,eff} R \qquad Q_R = 0$$

$$P_C = 0$$

$$Q_C = V_{C\,eff} I_{C\,eff} = \frac{V^2_{C\,eff}}{X_C} = I^2_{C\,eff} X_C$$

$$P_L = 0 \qquad Q_L = V_{L\,eff} I_{L\,eff} = \frac{V^2_{L\,eff}}{X_L} = I^2_{L\,eff} X_L$$

$$\vec{S} = \vec{V}_{eff}\,\vec{I}^{\,*}_{eff} = \sum P + j\left[\sum Q_L - \sum Q_C\right]$$

P is known as the average power or real power and Q is known as the reactive power.

Apparent Power and Power Factor:

Apparent power and power factor can be obtained using the following formulas:

$$\text{Apparent power (in V.A)} = V_{eff} I_{eff} = \sqrt{P^2 + Q^2}$$

$$PF = \frac{\text{Average power}}{\text{Apparent power}} = \frac{P}{V_{eff} I_{eff}} = Cos\ (\theta_V - \theta_I)$$

Power Factor Correction:

Power factor correction is achieved by limiting the reactive power in the circuit; this leads to make the value of the apparent power closer to the value of the average power. In other words the power factor correction aims to make the power factor as possible equals to 1

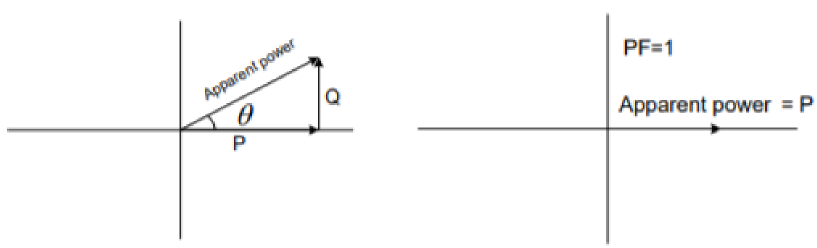


Figure 8.1: Power Factor Correction

The basic objective of the power factor correction is to decrease the power cost. Since the real power is the useful power, on the other hand the reactive power and its cost are not desired.

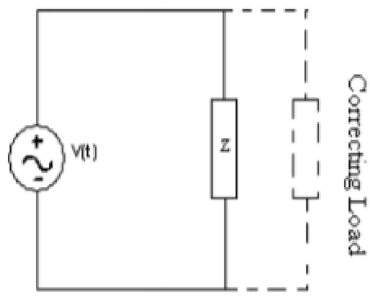


Figure 8.2: Power Factor Correction.

Z Load	***Correcting Load***	***Correcting Load Reactance***
Inductive	Capacitive	$X_C = \frac{V^2}{Q_L}$
Capacitive	Inductive	$X_L = \frac{V^2}{Q_C}$

Table 8.1

If load Z is Inductive

load, the correcting load must be capacitive load in order to generate a reactive power that cancels the one caused by inductive load Z and its capacitance must equal to a value satisfies this formula:

$$XC = \square^2/\square\square$$

Where QL is the reactive power of load Z. On the other hand, if load Z is capacitive load, the correcting load must be inductive load and its inductance must equal to a value that satisfies this formula:

$$XL = \square^2/\square\square$$

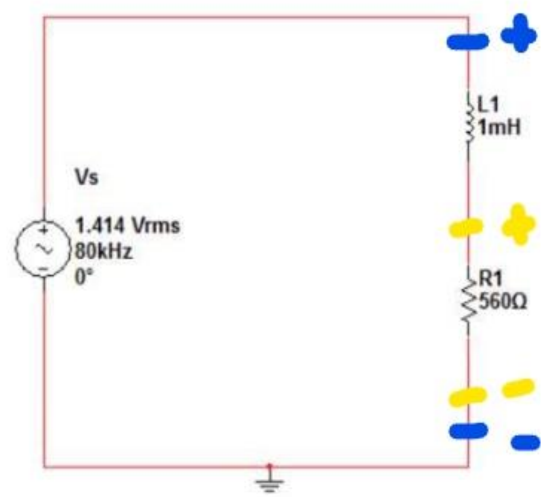
Where QC is the reactive power of load Z. After adding the correcting load, the power factor at which the source operates will almost equal to unity

- Equipment:

FG, CRO, DMM, and various components.

- Procedure:

- **Part A**



1) we built the circuit in the breadboard as shown in the figure
2) we turn on the AC source and the digital oscilloscope
3) we change the frequency to 80 k Hz and the amplitude 1.44 vrms and the the type of wave is (sin wave) then connect the source to the breadboard
4) we connect channel 1 as we see in the figure (blue color) to show the current Is
5) we connect channel 2 as we see in the figure (yellow color) to show the voltage Vs
6) after the two waves shown in the screen we try to move the position corser to make the signals as much as close then we noticed that the voltage lead the current
7) to find ▯ t we press on cursor button then we chose type of then time

*now we have two cursors (cursor 1 ,cursor 2) we controlled the cursors by multipurpose roll .

*we press on the cursor 1 button and put it on the peak of voltage wave and press on the cursor 2 button and put it on the peak of current wave then take the value of ▯ t

experiment's calculations:

1. **fill the table below?**

Quantity	Value
$V_{R1\ P\text{-}P}$	2.976 V
$V_{R1\ P}$	1.488 V
$V_{R1\ eff}$	1.052 V
$I_{R1\ eff}$	1.878mA
θ source	41.91^0
PF=Cos θ	0.7741 lag

Vs=1.414 Vrms → **Vp**= 1.414*$\sqrt{2}$= 2v → **Vs**= 2 $\sin(160\pi 10^3 t + 0)$

F= 80 KHz → ω = 2π*F= $160\pi * 10^3$

To calculate

- **Is** = $\frac{VS}{Zeq}$ = $\frac{2<0^0}{752.5<41.91^0}$ = $2.657*10^{-3}$ $<-41.91^0$ A

→ $I_{R1\ eff}$ = $I_{S\ eff}$ = $\frac{IS}{\sqrt{2}}$ = $\frac{2.657*10^{-3}}{\sqrt{2}}$ = $1.878 * 10^{-3}$ A

- **Zeq** =Req+JωI = 560+j502.65 → 752.5<41.91^0 Ω

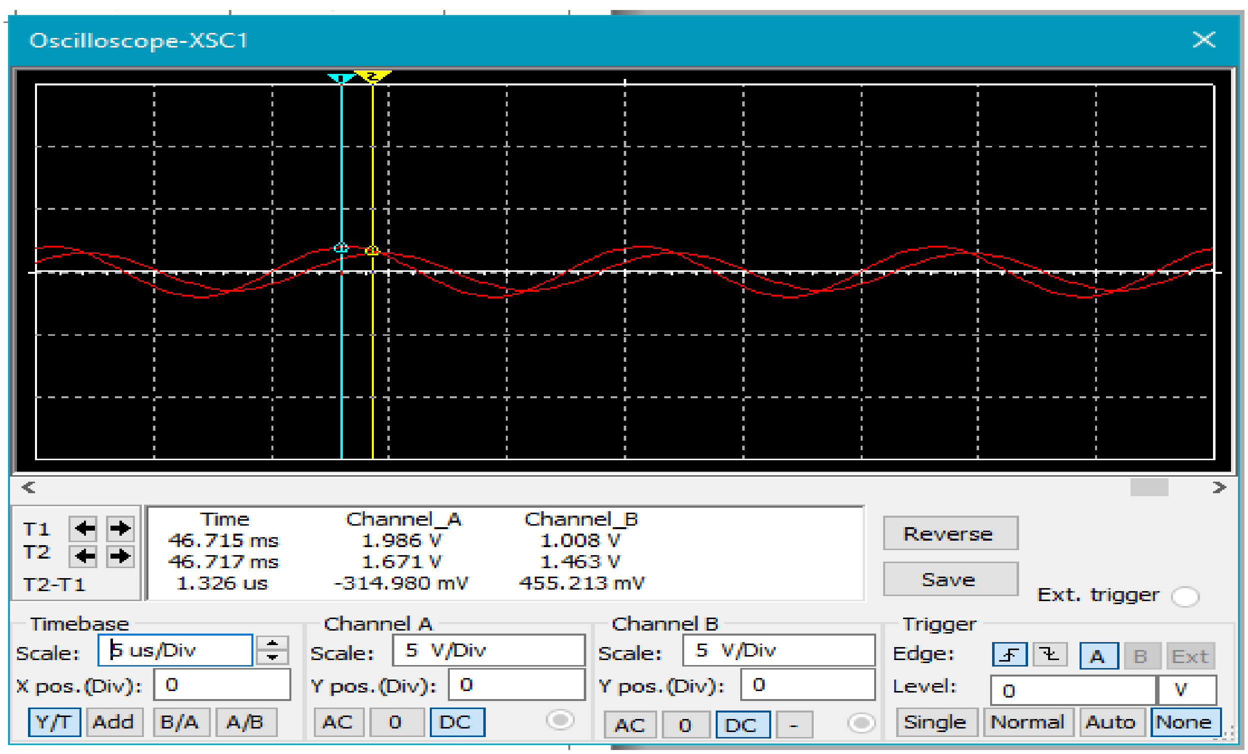
  → ϴ source $=tan^{-1}(\frac{502.65}{560})$ = 41.91^0

  → PF=Cos ϴ = Cos(41.91)= 0.7741 lag

- $V_{R1\ P}$ = R1*IS = $560*2.657*10^{-3}$ =1.488 V → $V_{R1\ p\text{-}p}$ =2*$V_{R1\ P}$ = 2.976 V

  → $V_{R1\ eff} = \frac{VR1\ P}{\sqrt{2}} = \frac{1.488}{\sqrt{2}}$ = 1.052 V

2. Plot Vs and VR1 on the same screen then find ϴ



→ **ϴ=** Δt*F*360 $=1.326*10^{-6}*80*10^3*360=38.18^0$

3. Find P_R, Q_R, Complex $power_{source}$, P_L ,Q_L ,PF ,Z , Req, and X_L ?

→ **P_R** = $\frac{(VrmsR1)^2}{R1}$ = $\frac{1.052^2}{560}$ = $1.976*10^{-3}$W

→ **Q_R** = Vrms*Irms*sin(0)= 0 → **P_L** = Vrms*Irms*cos(90)= 0

→ **Q_L** = $Irms^2 * XL$ = $(1.878 * 10^{-3})^2 * 502.65$ =$1.772*10^{-3}$ VAR

→ **Complex $power_{source}$** = P+JQ = $1.976*10^{-3} + j1.772 * 10^{-3}$ VA

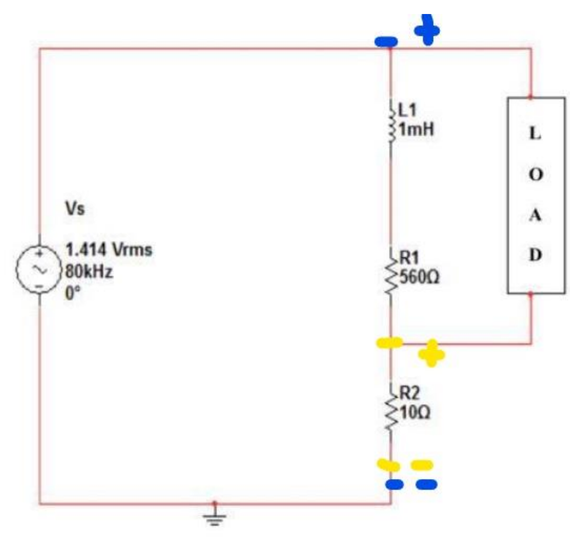
→ **PF**= Cos(41.91)= 0.7741 lag

→ **Zeq** =$\sqrt{R^2 + XL^2}$ =$\sqrt{560^2 + 502.65^2}$ =752.5 Ω

→**Req** = 560 Ω → **XL** = ωl= 502.65

- Part B

1) we built the circuit in the breadboard as shown in the figure
2) return the same steps in part A **BUT :**
3) we connect channel 1 as we see in the figure (blue color) to show the voltage Vs
4) we connect channel 2 as we see in the figure (yellow color) to show the current Is



5) we notice that ⍰ t will up to zero (in phase)

experiment's calculations:

1.Calculate the reactance load that makes PF near unity ?

→ **Q_L** = $Irms^2 * XL$ = $(1.878 * 10^{-3})^2 * 502.65$ =$1.772*10^{-3}$ VAR

- *QL=QC → At unity PF*

→ XC = $Vrms^2/Ql = \frac{1.414^2}{1.772*10^{-3}}$ =1128.327

→C =$\frac{1}{2\pi f*XC}$ =$\frac{1}{160\pi*10^3*1128.327}$ = 1.7631 Nf

2.The load will be (capacitive load)**and it has the value of** (1.7631 nF)

3.Construct the circuit with the load then finding the quantities in the table?

Quantity	Value
$V_{R2\ P\text{-}P}$	0.039 V
$V_{R2\ P}$	0.0195 V
$V_{R2\ eff}$	0.0137 V
$I_{R2\ eff}$	1.384mA
θ_{source}	0.0824
PF=Cos θ	0.999

Vs=1.414 Vrms → **Vp**= 1.414*$\sqrt{2}$= 2v → **Vs**= 2 sin($160\pi 10^3 t + 0$)

F= 80 KHz → **ω** = 2π*F= $160\pi * 10^3$

To calculate

- **Zeq** =((R1+JωI)//(1/JωC))+R2 = ((560+J502.65)//-J1128.37)+10

→Zeq = 1021.17+j1.469 → 1021.17<0.0824

→ $\frac{1}{JWC}$ = -J1128.37 → JωI= J502.65

→ PF=Cos θ = Cos(0.0824)= 0.999

- **Is** = $\frac{VS}{Zeq}$ = $\frac{2<0^0}{1021.17<0.0824^0}$ = $1.958*10^{-3}$ <-0.0824^0 A

→ $I_{R2\ eff}$ = $I_{S\ eff}$ = $\frac{IS}{\sqrt{2}}$ = $\frac{1.958*10^{-3}}{\sqrt{2}}$ = $1.384 * 10^{-3}$ A

- $V_{R2\ P}$ = R2*IS = 10*1.958*10^{-3} =0.0195 V → $V_{R2\ p\text{-}p}$ =2*$V_{R2\ P}$ = 0.039 V

→ $V_{R2\ eff}$ = $\frac{VR2\ P}{\sqrt{2}}$ = $\frac{0.0195}{\sqrt{2}}$ = 0.0137 V

4.Find P_R, Q_R, S_{source} , P_L ,Q_L ,PF ,Z , Req, and X_L ?

→ P_R =$(Irms)^2 * Req$ = $(1.384 * 10^{-3})^2 * 1021.17 = 1.956*10^{-3}$W

→ Q_R = Vrms*Irms*sin(0)= 0 → P_L = Vrms*Irms*cos(90)= 0

→ Q_L = $Irms^2 * XL$ = $(1.384 * 10^{-3})^2 * 502.65$ =9.628*10^{-4} VAR

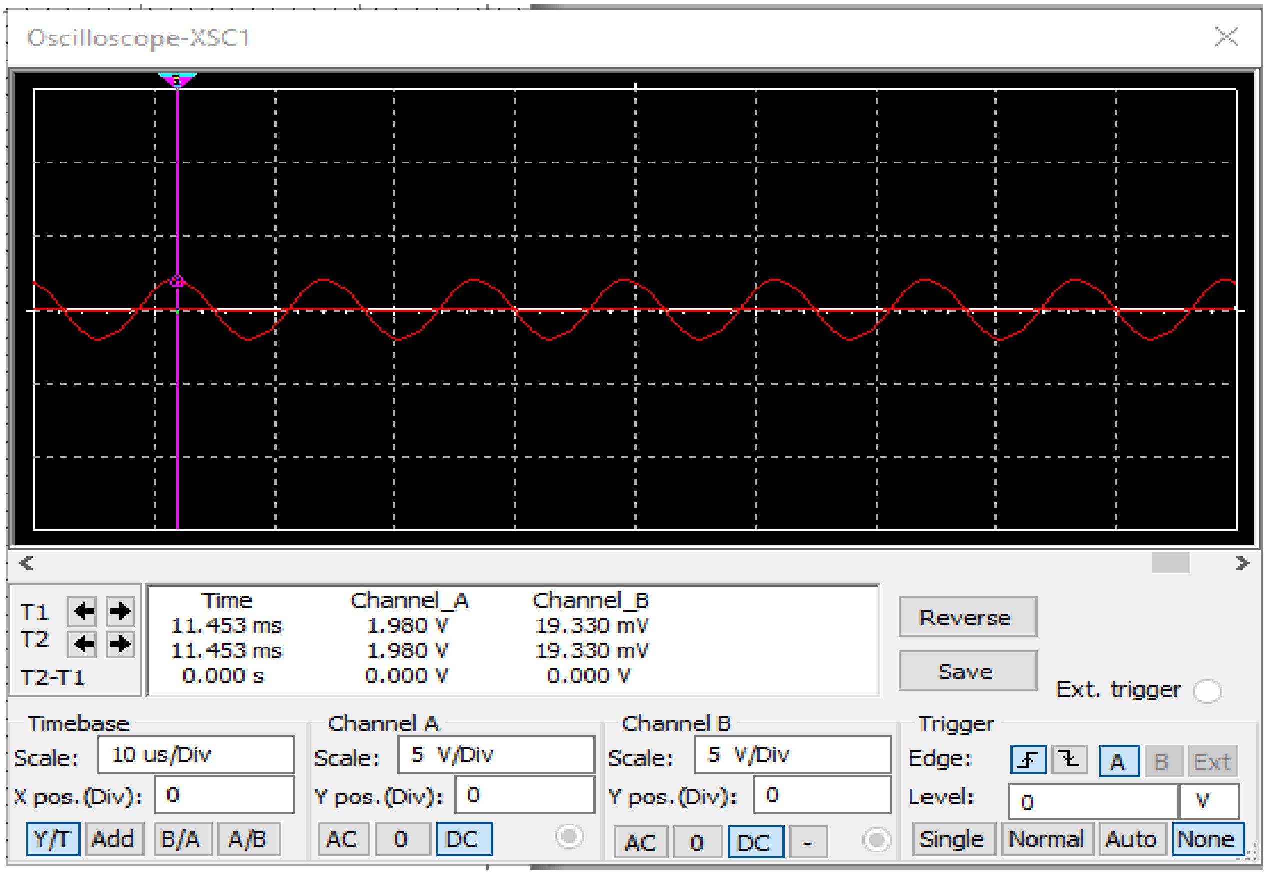
→ **Complex power source** = P+jQ = $1.956 * 10^{-3}$+J$9.628 * 10^{-4}$ VA

→ **PF**= Cos(0.0824)= 0.999

→ **Zeq** =$\sqrt{R^2 + Xeq^2}$ =$\sqrt{1021.17^2 + 1.469\ \ ^2}$ =1021.17 Ω

→**Req** = 1021.17Ω →**XL** = ωl= 502.65

5.Plot Vs and V_{R1} on the same screen then find ϴ



→= ϴ= Δt*F*360 =$0 * 80 * 10^3 * 360$ =0^0

- <u>Conclusion:</u>

1) If the digital oscilloscope does not show the rms value we can find it by pressing on the measure button then choose rms or any choice we need to show like (min, max, frequency) .
2) We use the decade capacitance box to fix the value of the capacitor that we need to connect to the circuit.