Qais Abu El Haija, abuelhaq
400294443

# Deliverable 2 - ENG PHYS 2E04

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**Created Circuit:**

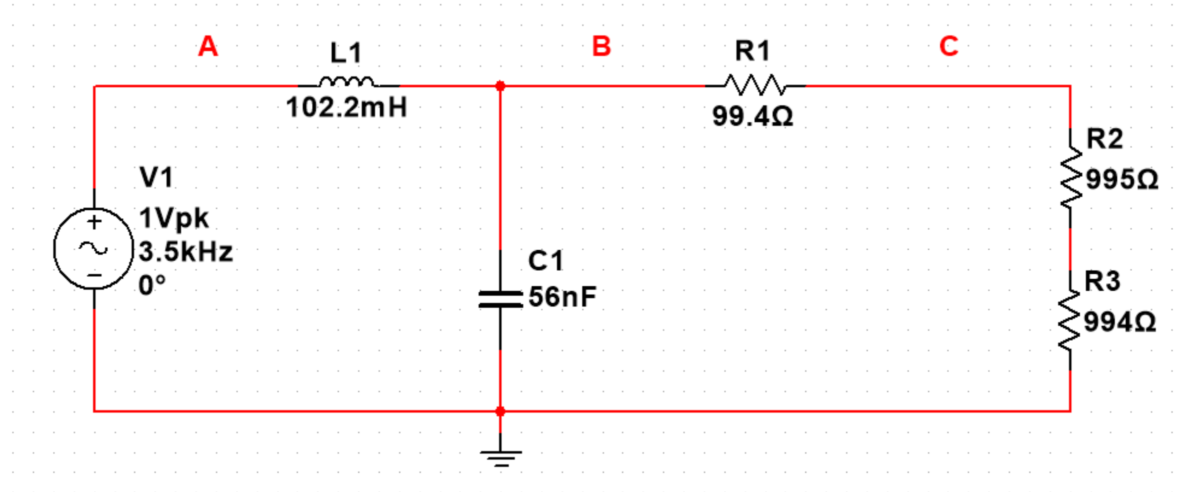


Fig 2.1

The circuit made above has an AC power source that has an amplitude of 1 V and a frequency of 3.5 kHz. The circuit also consists of 3 resistors, 1 capacitor and 1 inductor. The above circuit will be used to calculate the values of the voltage at nodes A, B and C, which will lead to finding the voltage and current through R1,C1,and L1.

The lab involves solving it in several ways. Firstly, solving it analytically, I used the voltage divider method and ohms law, and the nodal analysis method. Then, solving it digitally, where I used a single frequency sweep in Multisim to find the real and imaginary parts of each value, and then used a normal oscilloscope to compare solutions with the analytical method. Finally, solving it physically, where I used the breadboard, a Hantek 2D42, and oscilloscope from my lab kit.

The values of the resistors and capacitors was measured using the Hantek 2D42. However, the value obtained for the inductor was through averaging inductor values obtained by a VICHY LCR Meter DM4070.

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| Component | Actual Value | Measured Value |
|---|---|---|
| R1 | 100.0Ω | 99.3Ω |
| R2 | 1000.0Ω | 994.0Ω |
| R3 | 1000.0Ω | 995.0Ω |
| C1 | 100.0nF | 56.0nF |
| L1 | 100.0mH | 102.2mH |

Table 2.1

## Analytical Method

Using Maple Code, I outlined the results gotten from the formulas below. These formulas below were obtained using:

1. *Voltage divider and Ohms law*

> $restart:$

> $f := 3500 : w := 2\cdot\pi\cdot f : R1 := 99.4 : R2 := 995 : R3 := 994 : L1 := 102.2e-3 : C1 := 5.6e-8 :$

> $Reff := R1 + R2 + R3;$

$$Reff := 2088.4 \quad (1)$$

> $VA := 1$

$$VA := 1 \quad (2)$$

> $ZC := \frac{1}{I\cdot w\cdot C1};$

$$ZC := -812.0150158\,I \quad (3)$$

> $ZL := I\cdot w\cdot L1;$

$$ZL := 2247.495385\,I \quad (4)$$

> $Zpar := \left(\frac{1}{Reff} + \frac{1}{ZC}\right)^{-1};$

$$Zpar := 274.2649806 - 705.3748691\,I \quad (5)$$

> $VB := \frac{Zpar}{Zpar + ZL}\cdot VA;$

$$VB := -0.4127209337 - 0.2512513617\,I \quad (6)$$

> $VC := \frac{R2 + R3}{Reff}\cdot VB;$

$$VC := -0.3930769667 - 0.2392927401\,I \quad (7)$$

(8)

> $\mathrm{abs}(VB); \mathrm{argument}(VB); DeltaTVB := \frac{\%}{w};$

$$0.4831830045$$
$$-2.594750912$$
$$DeltaTVB := -0.0001179906953 \quad (9)$$

> $\mathrm{abs}(VC); \mathrm{argument}(VC); DeltaTVC := \frac{\%}{w};$

$$0.4601853075$$
$$-2.594750912$$
$$DeltaTVC := -0.0001179906953 \quad (10)$$

Fig 2.2

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- The voltage **VA** is the same as the source voltage and can be written in phasor form as

$$VA = 1e^{j0} = 1\text{ V}$$

- The angular frequency, ***ω*** is calculated using the formula:
  - ω = 2πf
  - ω = (2) (π) (3500) = **21991.149 rad/s** ≈ **22000 rad/s**

- The impedances, ***ZR, ZL, and ZC***, of the components are calculated. ***ZR*** is the same as the value for ***Reff***. On the other hand, the complex impedances ***ZC*** and ***ZL*** are calculated as follows:
  - ZR = Reff
  - ZL = jωL
  - ZC = $\frac{1}{j\omega C}$

- ***VB*** can be calculated by using the voltage divider formula. However, ***ZC*** and ***Reff*** need to be combined to find ***VB***. Generally, Impedances can be treated like resistors and can be combined using the parallel resistor formula giving $Z_{Parallel}$

$$Zparallel = \left(\frac{1}{Reff} + \frac{1}{Zc}\right)^{-1}$$

- ***VB*** is then calculated as follows:

$$VB = \frac{Zparallel}{ZL + Zparallel} \cdot VA$$

This gives a value in phasor form:

$$VB = 0.483e^{-j2.59}V$$

- ***VC*** is also calculated using a voltage divider:

$$VC = \frac{R2 + R3}{Reff} * VB$$

The value (phasor form) obtained is:

$$VC = 0.460e^{-j2.59}V$$

- The △t for ***VB***, ***VC*** and ***IR*** is calculated, and all give a result of

$$\triangle\mathrm{t} = 117.99\ \mu s$$

Therefore, we can find both the current and voltage through R1, C1, and L1.

  - ***Voltage: (Using Voltage Divider):***

- $VR_1 = VB - VC$
- $VL_1 = VA - VB$
- $VC_1 = VB - 0 = VB$

  - ***Current: (Using Ohms Law):***

- $IR_1 = \frac{VB}{Reff}$
- $IL_1 = \frac{VL_1}{ZL1}$
- $IC_1 = \frac{VC_1}{ZC1}$

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***Maple Output and code:***

> $VR1 := VB - VC; \mathrm{abs}(VR1); \mathrm{argument}(VR1); \mathrm{polar}(VR1);$

$$VR1 := -0.0196439670 - 0.0119586216\,I$$
$$0.02299769706$$
$$-2.594750910$$
$$\mathrm{polar}(0.02299769706, -2.594750910) \quad \textbf{(10)}$$

> $VL1 := VA - VB; \mathrm{abs}(VL1); \mathrm{argument}(VL1); \mathrm{polar}(VL1);$

$$VL1 := 1.412720934 + 0.2512513617\,I$$
$$1.434889433$$
$$0.1760089093$$
$$\mathrm{polar}(1.434889433, 0.1760089093) \quad \textbf{(11)}$$

> $VC1 := VB - 0; \mathrm{abs}(VC1); \mathrm{argument}(VC1); \mathrm{polar}(VC1);$

$$VC1 := -0.4127209337 - 0.2512513617\,I$$
$$0.4831830045$$
$$-2.594750912$$
$$\mathrm{polar}(0.4831830045, -2.594750912) \quad \textbf{(12)}$$

> $IR1 := \frac{VB}{Reff}; \mathrm{abs}(IR1); \mathrm{argument}(IR1); \mathrm{polar}(IR1);$

$$IR1 := -0.0001976254231 - 0.0001203080644\,I$$
$$0.0002313651621$$
$$-2.594750912$$
$$\mathrm{polar}(0.0002313651621, -2.594750912) \quad \textbf{(13)}$$

> $IL1 := \frac{VL1}{ZL}; \mathrm{abs}(IL1); \mathrm{argument}(IL1); \mathrm{polar}(IL1);$

$$IL1 := 0.0001117917142 - 0.0006285756774\,I$$
$$0.0006384393233$$
$$-1.394787417$$
$$\mathrm{polar}(0.0006384393233, -1.394787417) \quad \textbf{(14)}$$

> $IC1 := \frac{VC1}{ZC}; \mathrm{abs}(IC1); \mathrm{argument}(IC1); \mathrm{polar}(IC1);$

$$IC1 := 0.0003094171374 - 0.0005082676129\,I$$
$$0.0005950419575$$
$$-1.023954585$$
$$\mathrm{polar}(0.0005950419575, -1.023954585) \quad \textbf{(15)}$$

>

Figure 2.3

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2. *Nodal Analysis:*

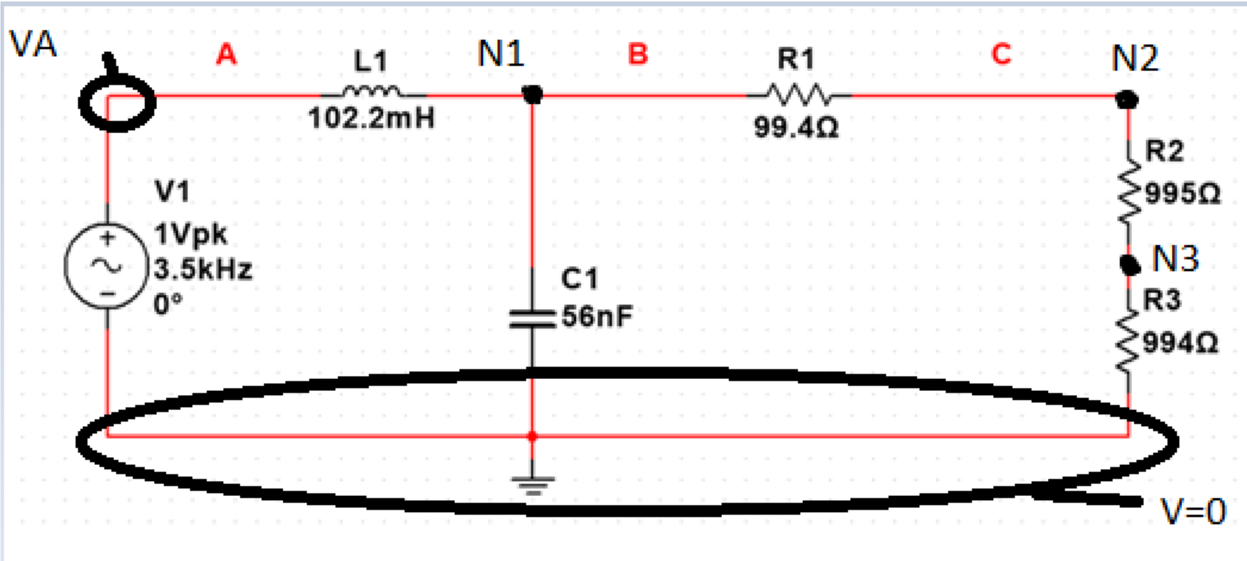


Figure 2.4

N1 = Voltage 1
N2 = Voltage 2
N3 = Voltage at R3

- V1:

$$\frac{V_A - V_1}{Z_L} + \frac{V_2 - V_1}{R_1} + \frac{0 - V_1}{Z_C} = 0$$

- V2:

$$\frac{V_1 - V_2}{R_1} + \frac{V_{R3} - V_2}{R_2} = 0$$

- VR3:

$$\frac{V_2 - V_{R3}}{R_2} = \frac{V_{R3}}{R_3}$$

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Maple Code and Output:

```
> RESTART:
  f:=3500: T:=1/f; w:=2*3.14159*f; C1:= 5.6e-8: L1:=102.2e-3:
  R1:=99.4: R2:=995: R3:=994:
  ZC:=1/(w*I*C1); ZL:=I*w*L1;
  VA:=1:
  solve([(VA-V1)/ZL+(V2-V1)/R1+(0-V1)/ZC=0,
  (V1-V2)/R1+(VR3-V2)/R2=0, (V2-VR3)/R2=VR3/R3])
```

$$T := \frac{1}{3500}$$

$$w := 21991.13000$$

$$ZC := -812.0157016\, I$$

$$ZL := 2247.493486\, I$$

$$\{V1 = -0.4127216218 - 0.2512522349\, I, V2 = -0.3930776218 - 0.2392935717\, I, VR3 = -0.1964399980 - 0.1195866316\, I\} \quad (1)$$

Figure 2.5

Finding the Voltage and current along R1, L1, and C1:

```
> w:=2*3.14159*f:V1 := -0.4127216218 - 0.2512522349*I:
  V2 := -0.3930776218 - 0.2392935717*I: VR3 := -0.1964399980 - 0.1195866316*I:
  VR1:=V1-V2;
  magnitudeVR1:=abs(VR1); phaseVR1:=argument(VR1);DeltaTVR1:=%/w; vR1:=Re (VR1);
  VC1:=V1-0;
  magnitudeVC1:=abs(VC1); phaseVC1:=argument(VC1);DeltaTVC1:=%/w;
  VL1:=VA-V1;
  magnitudeVL1:=abs(VL1); phaseVL1:=argument(VL1);DeltaTVL1:=%/w;
```

$$VR1 := -0.0196440000 - 0.01195866321\, I$$

$$magnitudeVR1 := 0.02299774688$$

$$phaseVR1 := -2.594750111$$

$$DeltaTVR1 := -0.0001179907586$$

$$vR1 := -0.0196440000$$

$$VC1 := -0.4127216218 - 0.2512522349\, I$$

$$magnitudeVC1 := 0.4831840463$$

$$phaseVC1 := -2.594750109$$

$$DeltaTVC1 := -0.0001179907585$$

$$VL1 := 1.412721622 + 0.2512522349\, I$$

$$magnitudeVL1 := 1.434890263$$

$$phaseVL1 := 0.1760094245$$

$$DeltaTVL1 := 8.003655315 \times 10^{-6} \quad (2)$$

Figure 2.6

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```
> VR1 := -0.0196440000 - 0.0119586632*I: VC1 := -0.4127216218 - 0.2512522349*I:
  VL1 := 1.412721622 + 0.2512522349*I: f:=3500: w:=2*3.14159*f:

  IR1:=(VR1)/R1;
  magnitudeIR1:=abs(IR1); phaseIR1:=argument(IR1);DeltaTIR1:=%/w;
  IL1:=VL1/(ZL);
  magnitudeIL1:=abs(IL1); phaseIL1:=argument(IL1);DeltaTIL1:=%/w;
  IC1:=(VC1)/ZC;
  magnitudeIC1:=abs(IC1); phaseIC1:=argument(IC1);DeltaTIC1:=%/w;
```

$$IR1 := -0.0001976257545 - 0.0001203084829\,I$$
$$magnitudeIR1 := 0.0002313656627$$
$$phaseIR1 := -2.594750111$$
$$DeltaTIR1 := -0.0001179907586$$
$$IL1 := 0.0001117921972 - 0.0006285765146\,I$$
$$magnitudeIL1 := 0.0006384402322$$
$$phaseIL1 := -1.394786902$$
$$DeltaTIL1 := -0.00006342497643$$
$$IC1 := 0.0003094179514 - 0.0005082680310\,I$$
$$magnitudeIC1 := 0.0005950427379$$
$$phaseIC1 := -1.023953782$$
$$DeltaTIC1 := -0.00004656212673$$

Figure 2.7

***Values using both analytical methods, (Voltage Divider & Ohms Law, and Nodal Analysis), where relatively identical (Reason: Pi was used differently in each of the methods).***

**Summary of Analytical results:**

| Value | Rectangular | Polar (phase reported in radians) |
|---|---|---|
| VA | 1 V | 1, 0 V |
| VB | (-0.4127209337 - 0.2512513617*I) V | 0.4831830045, -2.594750111 V |
| VC | (-0.3930769667 - 0.2392927401*I) V | 0.46018530750, -2.594750111 V |
| VR1 | (-0.0196440000 - 0.0119586632*I) V | 0.02299774688, -2.594750111 V |
| VC1 | (-0.4127216218 - 0.2512522349*I) V | 0.4831840463, -2.594750109 V |
| VL1 | (1.412721622 + 0.2512522349*I) V | 1.434890263, 0.1760094245 V |
| IR1 | (-0.0001976257545 - 0.0001203084829*I) A | 0.0002313656627, -2.594750111 A |
| IC1 | (0.0003094179514 - 0.0005082680310*I) A | 0.0005950427379, -1.023953782 A |
| IL1 | (0.0001117921972 - 0.0006285765146*I) A | 0.0006384402322, -1.394786902 A |

Table 2.2

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## Multisim Method

(a) Using the ***Single Frequency sweep*** simulation in Multisim to find the real and imaginary parts of each value.

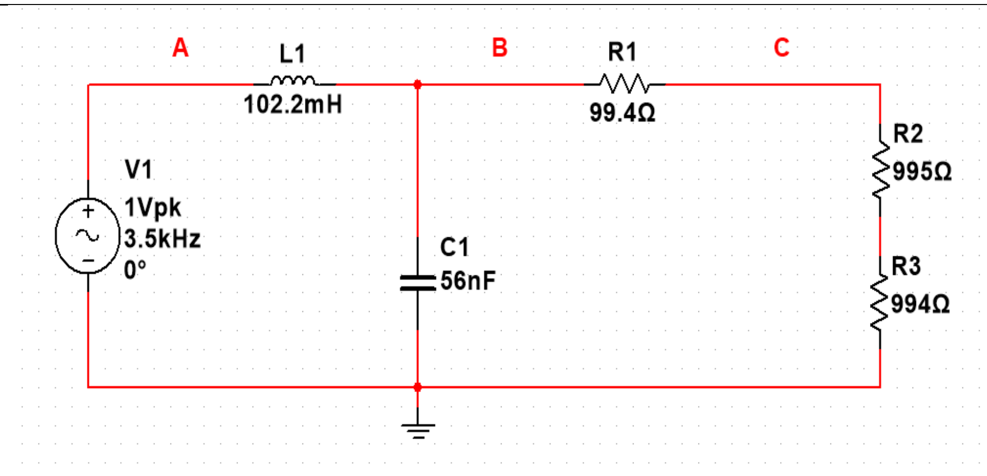
<table>
<tr><td>Circuit</td><td>
</td></tr>
<tr><td>Single frequency</td><td>
Design1<br>
Single Frequency AC Analysis @ 3500 Hz
<table>
<tr><th></th><th>Variable</th><th>Real</th><th>Imaginary</th></tr>
<tr><td>1</td><td>V(a)</td><td>1.00000</td><td>0.00000e+00</td></tr>
<tr><td>2</td><td>V(b)</td><td>-412.72093 m</td><td>-251.25136 m</td></tr>
<tr><td>3</td><td>V(c)</td><td>-393.07697 m</td><td>-239.29274 m</td></tr>
<tr><td>4</td><td>I(C1)</td><td>-309.41714 u</td><td>508.26761 u</td></tr>
<tr><td>5</td><td>I(R1)</td><td>-197.62542 u</td><td>-120.30806 u</td></tr>
<tr><td>6</td><td>I(L1)</td><td>111.79171 u</td><td>-628.57568 u</td></tr>
</table>
</td></tr>
</table>

Table 2.3

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Inputing Values of ***VA*** and ***VB*** obtained by the single frequency simulation to find the voltage and current of ***R1***, ***C1***, and ***L1***:

```
> f:=35000: w:=2*3.14159*f:
  VA:=1: VB:=-0.41272093-0.25125136*I: VC:=-0.39307697
  -0.23929274*I:
  VR1:=VB-VC;
  magnitudeVR1:=abs(VR1); phaseVR1:=argument(VR1);
  DeltaTVR1:=%/w; vR1:=Re (VR1);
  VC1:=VB-0;
  magnitudeVC1:=abs(VC1); phaseVC1:=argument(VC1);
  DeltaTVC1:=%/w;
  VL1:=VA-VB;
  magnitudeVL1:=abs(VL1); phaseVL1:=argument(VL1);
  DeltaTVL1:=%/w;
```

$$VR1 := -0.01964396 - 0.01195862\,\mathrm{I}$$
$$magnitudeVR1 := 0.02299769025$$
$$phaseVR1 := -2.594750812$$
$$DeltaTVR1 := -0.00001179907905$$
$$vR1 := -0.01964396$$
$$VC1 := -0.41272093 - 0.25125136\,\mathrm{I}$$
$$magnitudeVC1 := 0.4831830005$$
$$phaseVC1 := -2.594750911$$
$$DeltaTVC1 := -0.00001179907950$$
$$VL1 := 1.41272093 + 0.25125136\,\mathrm{I}$$
$$magnitudeVL1 := 1.434889428$$
$$phaseVL1 := 0.1760089086$$
$$DeltaTVL1 := 8.003631855 \times 10^{-7} \qquad (1)$$

```
> f:=35000: w:=2*3.14159*f:
  VA:=1: VB:=-0.41272093-0.25125136*I: VC:=-0.39307697
  -0.23929274*I:f := 3500:
  w := 2*Pi*f:
  R1 := 99.4:
  R2 := 995:
  R3 := 994:
  L1 := 0.1022:
  C1 := 0.56*10^(-7):Reff := R1 + R2 + R3:ZC := 1/(w*C1*
  I):ZL := w*L1*I:

  IR1:=VB/Reff;
  magnitudeIR1:=abs(IR1); phaseIR1:=argument(IR1);
  DeltaTIR1:=%/w;
  IL1:=(VA-VB)/ZL;
  magnitudeIL1:=abs(IL1); phaseIL1:=argument(IL1);
  DeltaTIL1:=%/w;
  IC1:=(VB-0)/ZC;
  magnitudeIC1:=abs(IC1); phaseIC1:=argument(IC1);
  DeltaTIC1:=%/w;
```

$$IR1 := -0.0001976254214 - 0.0001203080636\,\mathrm{I}$$
$$magnitudeIR1 := 0.0002313651602$$
$$phaseIR1 := -2.594750911$$
$$DeltaTIR1 := -0.0001179906953$$
$$IL1 := 0.0001117917134 - 0.0006285756756\,\mathrm{I}$$
$$magnitudeIL1 := 0.0006384393214$$
$$phaseIL1 := -1.394787418$$
$$DeltaTIL1 := -0.00006342494631$$
$$IC1 := 0.0003094171353 - 0.0005082676083\,\mathrm{I}$$
$$magnitudeIC1 := 0.0005950419525$$
$$phaseIC1 := -1.023954584$$
$$DeltaTIC1 := -0.00004656212387 \qquad (1)$$

Figure 2.8

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(b) Using the normal oscilloscope:

❖ ***VA & VB***:

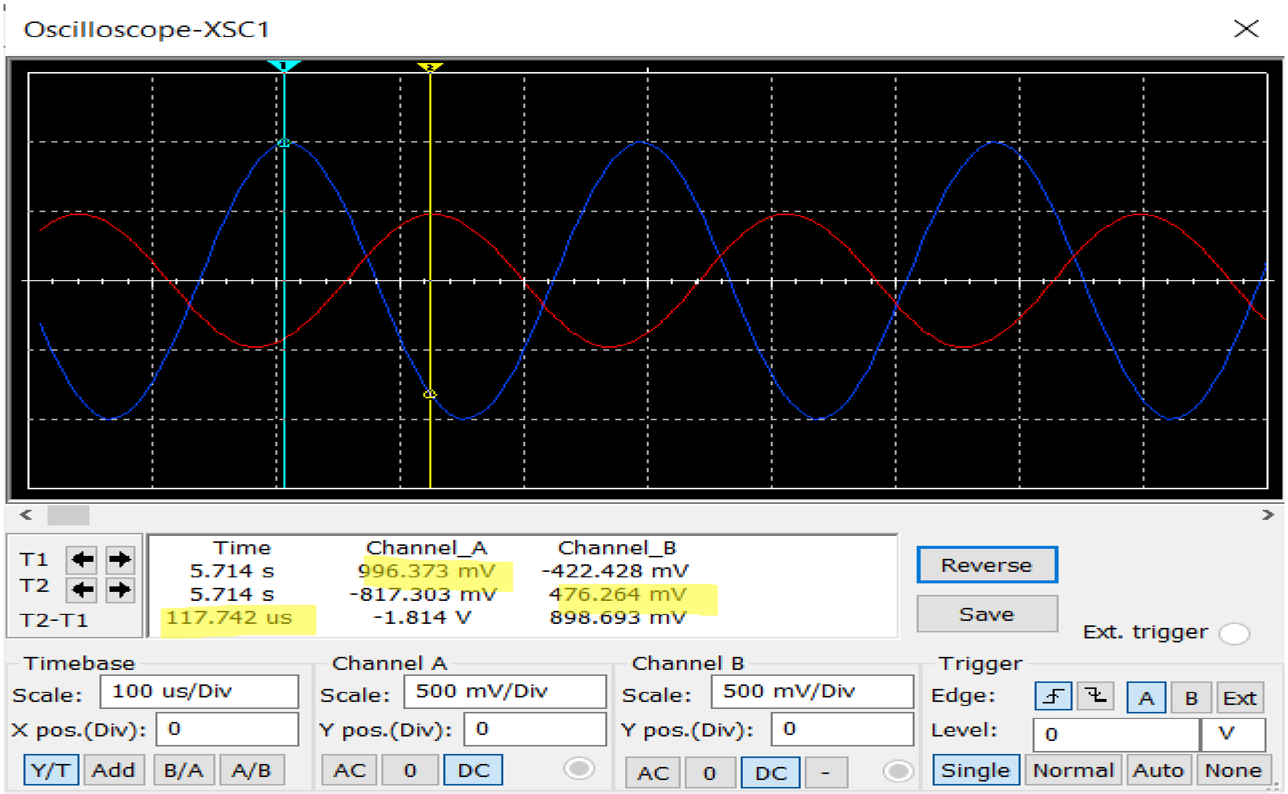
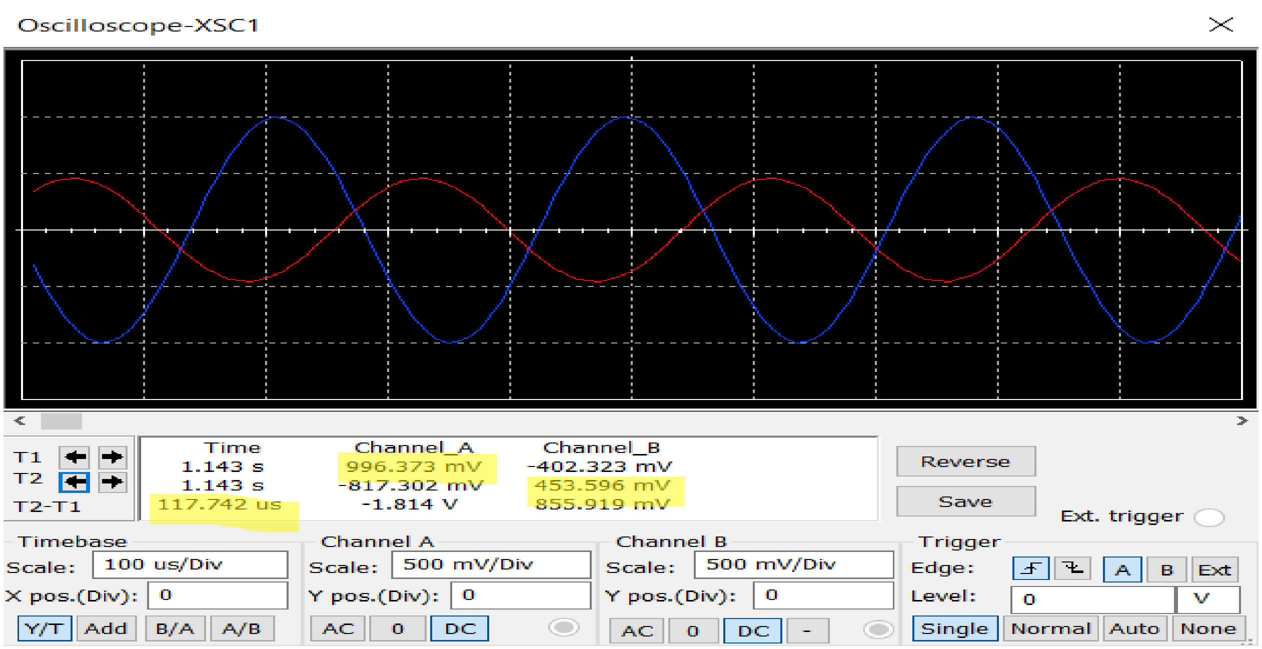



Figure 2.9

❖ ***VA & VC:***



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The Oscilloscope read values of ***VA, VB, VC,*** and ***deltaT . VA*** is ***996.373mV***, ***VB*** is ***476.364mV*** and ***VC*** is ***453.596 mV***. The value of ***deltaT*** is ***117.742*** $\mu s$.

These values are very close compared to the values obtained using the analytical method as can be seen in the table below comparing them.

| Value | Analytical | Multisim |
|---|---|---|
| VA | 1.000V | 0.996V |
| VB | 0.483V | 0.476V |
| VC | 0.460V | 0.454V |
| △t | 117.991 $\mu s$ | 117.742 $\mu s$ |

Table 2.4

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**<u>Experimental Method</u>**

The circuit was set up tentatively using the at Home-Kit, a breadboard, and using the Hantek as the fundamental source AC voltage. Also, jumper links were used as the wires as displayed beneath:

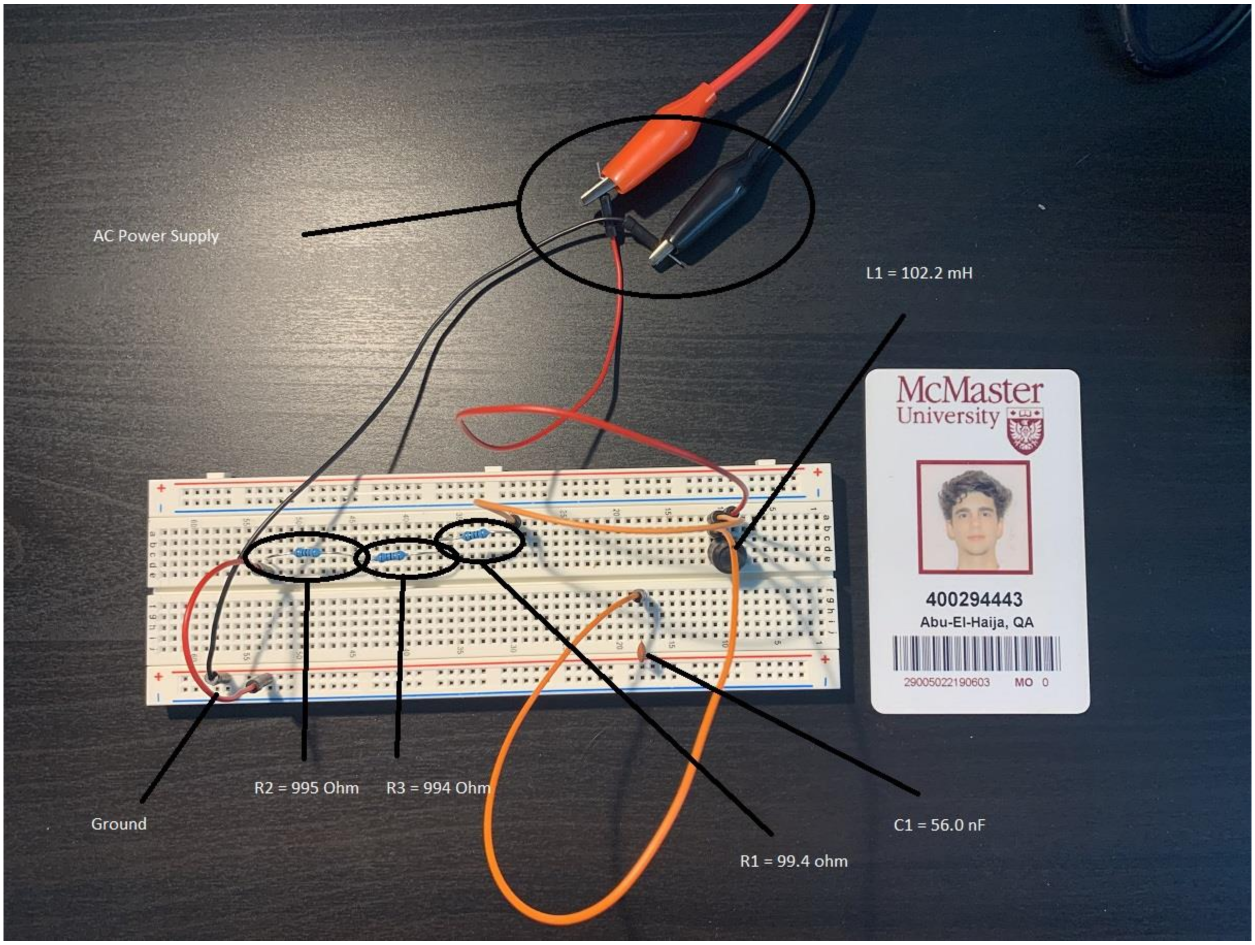


Figure 2.11

***AC Supply properties:***

***Frequency = 3.5 kHz***
***Amplitude = 1V***

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- The Hantek was used to supply the power to the circuit. As mentioned above, it was set as follows:

Figure 2.12

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- The picture below shows the voltage measured at Node A, ***VA***. According to the Hantek, ***VA*** has a max of ***<u>1.14V</u>*** and a minimum of ***<u>-900mV</u>***. The frequency is ***<u>3.52KHz</u>***.

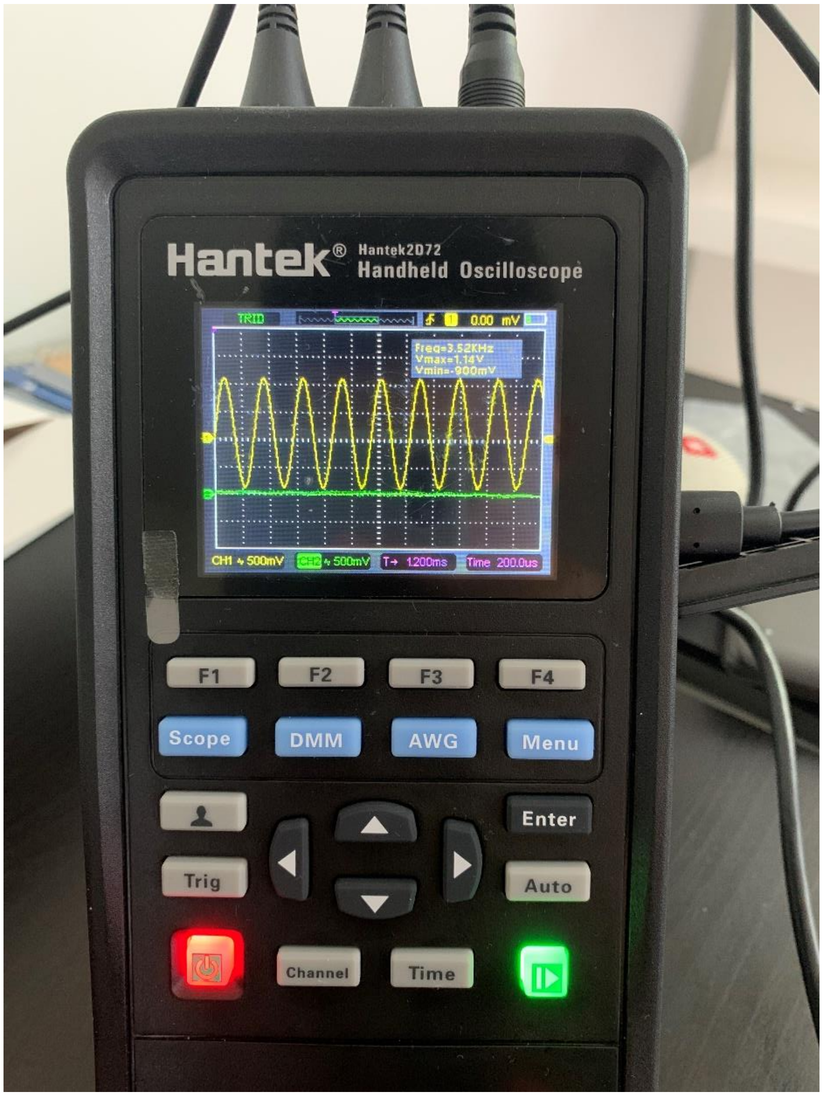


Figure 2.13

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- The picture below shows the voltage measured at Node B, ***VB***. According to the Hantek, ***VB*** has a max of ***<u>480mV</u>*** and a minimum of ***<u>-460mV</u>***. The frequency is ***<u>3.50KHz</u>***.

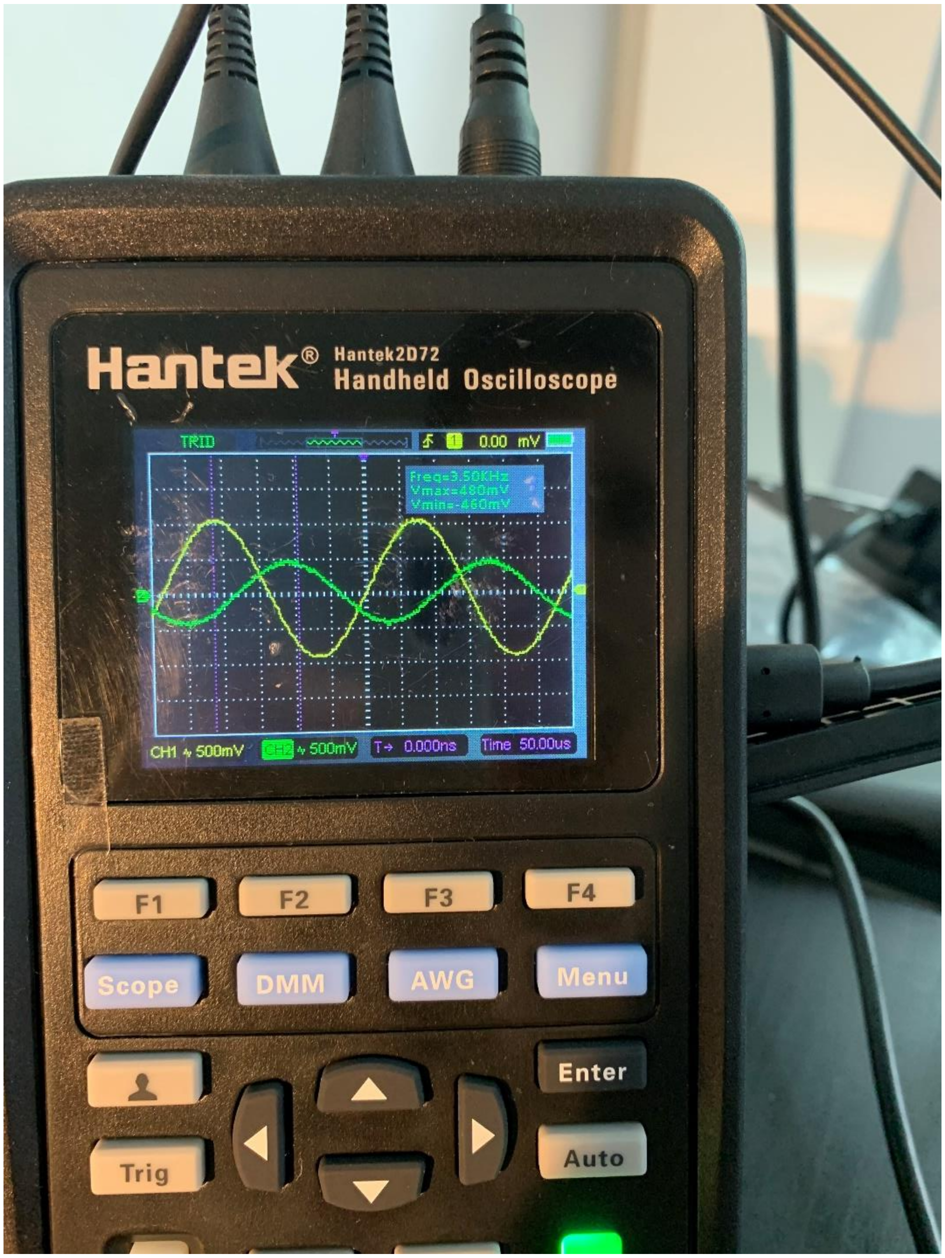


Figure 2.14

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- The picture below shows the voltage measured at Node C, ***VC***. According to the Hantek, ***VC*** has a max of ***456mV*** and a minimum of ***-472mV***. The frequency is ***3.48KHz***.

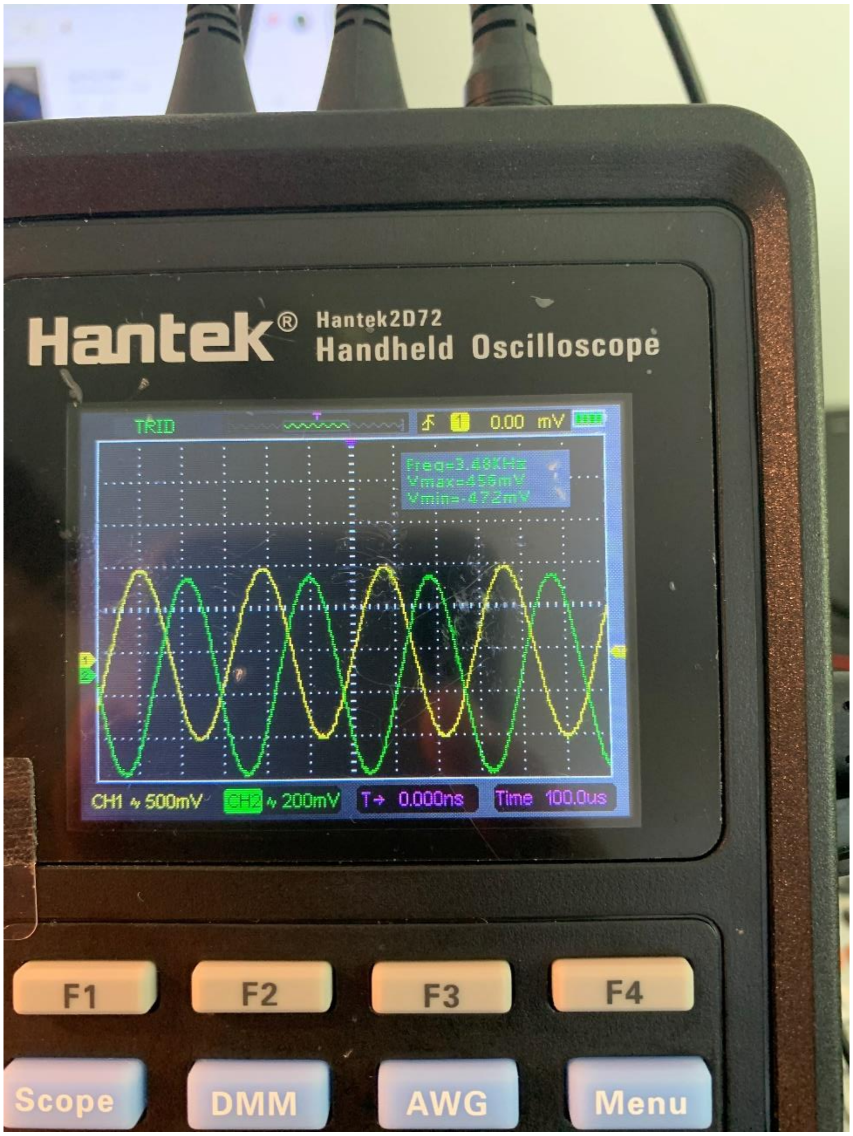


Figure 2.15

- The $\Delta t$ was measured between the two waves, through all nodes, using the ***cursor function*** and a value of ***<u>118 µs</u>*** was obtained.


Figure 2.16

***EXTRA: (Just used for result analysis)***

- The current through the resistor ***R1*** was measured and a value of ***<u>0.218mA</u>*** was obtained.


Figure 2.17

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**Results comparisons:**

| Value | Analytical | Multisim | Experimental |
|---|---|---|---|
| VA | 1.000V | 1.000V | 1.000 ± 0.1V |
| VB | 0.483V | 0.476V | 0.480 ± 0.02V |
| VC | 0.460V | 0.454V | 0.456 ± 0.02V |
| I in R1 | 0.231mA | 0.231mA | 0.218 ± 0.003mA |
| △t B and A | 117.991 µs | 117.742 µs | 118.000 µs |
| △t C and A | 117.991 µs | 117.742 µs | 118.000 µs |

Table 2.5

***Analysis:***

The values obtained from the Analytical and Multisim methods are very similar, where the bound of error is rounded to approximately 1%. The voltage and current going through R1, C1, and L1 were obtained most feasibly and expediently, as their values in the analytical part and Multism were almost identical. Looking at the experimental values, there was a significant difference in some readings relative to the analytical and Multisim methods. The errors for the voltage measurements and DeltaT measurements are below 1% indicating they are accurate. There is a difference of 0.03V in the values for VB and a difference of 0.04V in the values for VC. As for the DeltaT, a value of 118microseconds is obtained by the Hantek. When comparing it to the values obtained by other methods, it shows that the phase of the voltages is identical. I chose R1 randomly to test it for the current passing through it using the Hantek and a significant difference in readings was detected when comparing them to the analytical and Multism methods. R1 was almost 0.013mA off relative to the other methods used. This leads the error to be as high as 6%. Reasons could be due to a significant loss of energy as there is also resistance in the wires. It is known for such components as inductors in an AC circuit to create an opposite emf to resist change in current. Some of the currents can also be lost in the inductor as it would create a varying magnetic field which would cause some energy to be lost by electromagnetic induction.

Overall, readings were relatively similar, and uncertainty values were comparatively small throughout the whole lab.

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**Reflection**

Steady-state AC Network analysis is important since it talks about a new representation of voltage and current. AC voltage is a voltage that shifts extremity with time. This idea permits us to manage two sorts of parts, (inductors and capacitors). It also talks about Phasors, which change the voltage and current from the time-space into a complex field making it simpler to ascertain.  There are many utilizations for AC voltage. Some of which are, the utilization as the principal technique for moving power in the electrical framework. It is also likewise appropriated in electric engines where the changing of electric energy into mechanical energy occurs. A component that was reintroduced during this lab was the capacitor, which is used to store electricity. They tend to store energy and discharge later, therefore, making them useful in time delaying circuits such as RC circuits. They are also used in smoothing circuits, which are circuits that change from AC to DC. Another component was the Inductor, which is used in transformers to either increase or decrease the voltage based on the number of turns in the coil.They are commonly used in tuning circuits and induction motors.