Experiment # 15

Frequency Selective Networks

Principles

A frequency selective network is a passive network which responds to a selected range of frequencies. The voltage gain for frequencies in the selected range is unity or near unity while that for all other frequencies is minimal.

Passive networks comprise of resistors, capacitors and inductors. Capacitors and inductors have previously been shown to react to frequencies. They react to frequency oppositely to one another. The reactance of a capacitor decreases with increase in frequency while that of an inductor increases. This property leads to *resonance*, in a series R, L, C circuit, fed by a variable-frequency AC source. A series circuit, however, is only one of the many configurations available to the network engineers. Each configuration has a different pattern of frequency response. It is for this reason that such circuits are called *frequency selective networks*. In this experiment we shall study a series LC circuit, as a frequency selective network.

A Series LC Circuit

A series LC circuit is shown in Fig (1a). The function generator produces voltage V_S of variable frequency ω rad/ sec, and is written as $V_{S(\omega)}$. For the purpose of analysis, we replace the two elements by their respective reactances, as shown in Fig (1b).

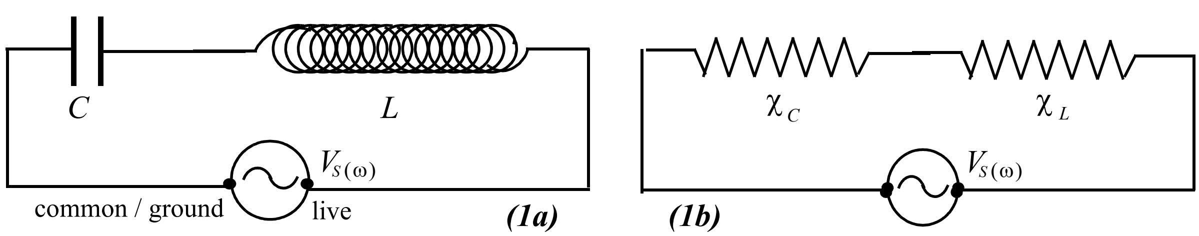


Fig (1) The Series LC Circuit

As the two reactances are connected in series, there is a great temptation to write the net reactance (χ_{eq}), as:

$$\chi_{eq} = \chi_L + \chi_C$$

One should, however, not forget that the two reactances are 180° out of phase with one another! As such we need construct a phasor diagram. A typical phasor diagram is shown in Fig (2). The voltage and current of the (unavoidable) resistance of the inductor lie along the +x-axis, though they are not shown. The inductor voltage and the inductive reactance, are plotted along the +y-axis while the capacitor voltage and the capacitive reactance are plotted along the –y-axis. The equivalent reactance of the circuit will be $\chi_L - \chi_C$ for $\omega > \omega_o$ (i.e $\omega^2 LC > 1$) or $\chi_C - \chi_L$, for $\omega < \omega_o$ (i.e $\omega^2 LC < 1$). Here ω_o is the resonant frequency at which $\chi_L = \chi_C$.

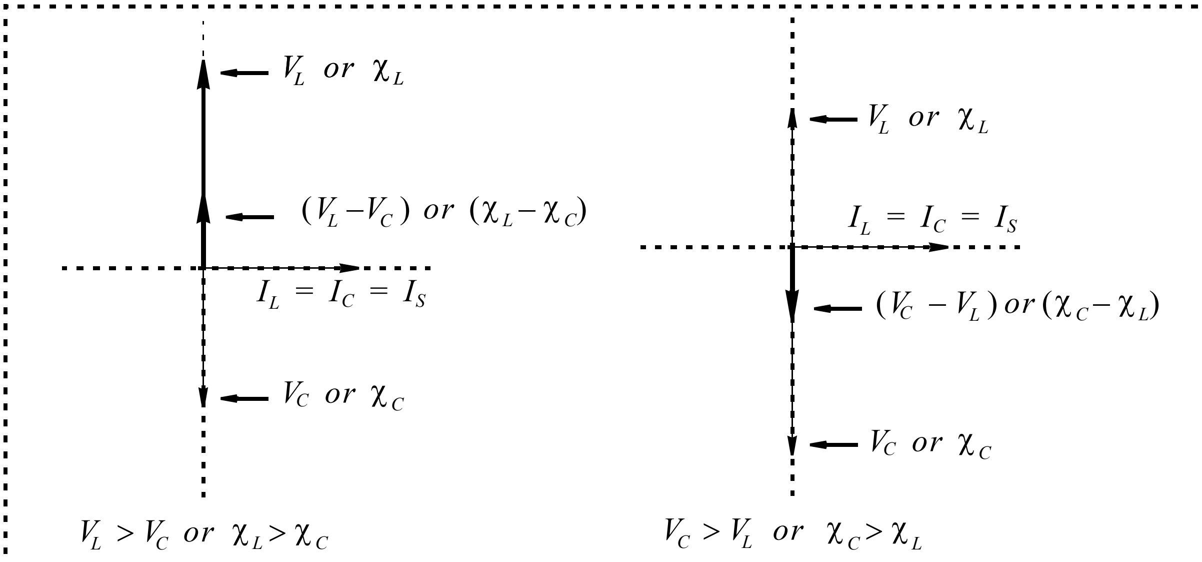


Fig (2) The phasor diagram

Voltage Gain Across the Inductor

(a) $\chi_L > \chi_C$ *or* $\omega > \omega_o$, *or* $\omega^2 LC > 1$ *(the post-resonance-peak region of* ω*)*

The equivalent reactance of the circuit, χ_{eq} , is given by:

$$\chi_{eq} = \chi_L - \chi_C = \omega L - \frac{1}{\omega C} = \frac{(\omega L)(\omega C) - 1}{\omega C} = \frac{\omega^2 LC - 1}{\omega C} \qquad \text{..........(1)}$$

The series current is given by:

$$I_L = I_C = I_S = \frac{V_S}{\chi_{eq}} = \frac{V_S}{\dfrac{\omega^2 LC - 1}{\omega C}} = \left(\frac{\omega C}{\omega^2 LC - 1}\right) V_S \qquad \text{..........(2)}$$

The inductor voltage is given by:

$$V_L = \chi_L I_S = (\omega L)\left(\frac{\omega C}{\omega^2 LC - 1}\right) V_S = \left(\frac{\omega^2 LC}{\omega^2 LC - 1}\right) V_S \qquad \text{..........(3)}$$

And the circuit gain or the *transfer function* for the inductor $T_{L(\omega)}$ is given by:

$$T_{L(\omega)} = T_L = \frac{V_L}{V_S} = \left(\frac{\omega^2 LC}{\omega^2 LC - 1}\right) = \frac{1}{1 - \dfrac{1}{\omega^2 LC}} \qquad \text{..........(4)}$$

Eqn (4) shows that for large enough values of ω, $\omega^2 LC \to \infty$, and, $T_{L(\omega)} \to 1$. Thus for $\omega^2 LC \gg 1$, the circuit gain $T_{L(\omega)}$ will be unity or near unity. Again, in this region as $\chi_L > \chi_C$, then $V_L > V_C$ and we are in the +y-axis domain. The gain $T_{L(\omega)}$ must be positive.

(b) $\chi_L < \chi_C$ or $\omega < \omega_o$ or $\omega^2 LC < 1$ (*the pre-resonance-peak region of* ω*)*

The equivalent reactance χ_{eq} is now given by:

$$\chi_{eq} = \chi_C - \chi_L = \frac{1}{\omega C} - \omega L = \frac{1 - (\omega L)(\omega C)}{\omega C} = \frac{1 - \omega^2 LC}{\omega C} \qquad \text{..........(5)}$$

The series current is given by:

$$I_L = I_C = I_S = \frac{V_S}{\chi_{eq}} = \frac{V_S}{\frac{1 - \omega^2 LC}{\omega C}} = \left(\frac{\omega C}{1 - \omega^2 LC}\right) V_S \qquad \text{..........(6)}$$

The inductor voltage is given by:

$$V_L = \chi_L I_S = (\omega L)\left(\frac{\omega C}{1 - \omega^2 LC}\right) V_S = \left(\frac{\omega^2 LC}{1 - \omega^2 LC}\right) V_S \qquad \text{..........(7)}$$

And the *transfer function* for the inductor $T_{L(\omega)}$ is now given by:

$$T_{L(\omega)} = T_L = \frac{V_L}{V_S} = \left(\frac{\omega^2 LC}{1 - \omega^2 LC}\right) \qquad \text{..........(8)}$$

Eqn (8) shows that for small enough values of ω, $\omega^2 LC \rightarrow 0$ and, $T_{L(\omega)} \rightarrow 0$. Thus for $\omega^2 LC \ll 1$, the circuit gain $T_{L(\omega)}$ will be minimal. Again, as $\omega^2 LC < 1$ here, the numerical value of $T_{L(\omega)}$ as found from Eqn (8) will turn out to be positive. However, as $\chi_L < \chi_C$**,** then $V_L < V_C$ and we are in the –y-axis domain. The gain $T_{L(\omega)}$ will, therefore, in reality be negative.

The circuit when poised to collect output voltage across the inductor is said to be a *high frequency selective network.* It accepts high frequencies and rejects low frequencies.

Voltage Gain Across the Capacitor

(a) $\chi_C < \chi_L$ *or* $\omega > \omega_o$***,*** *or* $\omega^2 LC > 1$ *(the post-resonance-peak region of* ω*)*

The equivalent reactance of the circuit χ_{eq} , is given by:

$$\chi_{eq} = \chi_L - \chi_C = \omega L - \frac{1}{\omega C} = \frac{(\omega L)(\omega C) - 1}{\omega C} = \frac{\omega^2 LC - 1}{\omega C} \qquad \text{..........(9)}$$

The series current is given by:

$$I_L = I_C = I_S = \frac{V_S}{\chi_{eq}} = \frac{V_S}{\frac{\omega^2 LC - 1}{\omega C}} = \left(\frac{\omega C}{\omega^2 LC - 1}\right) V_S \qquad \text{..........(10)}$$

The capacitor voltage is given by:

$$V_C = \chi_C I_S = \left(\frac{1}{\omega C}\right)\left(\frac{\omega C}{\omega^2 LC - 1}\right) V_S = \left(\frac{1}{\omega^2 LC - 1}\right) V_S \qquad \text{..........(11)}$$

And the circuit gain or the *transfer function* for the capacitor $T_{C(\omega)}$, is given by:

$$T_{C(\omega)} = T_C = \frac{V_C}{V_S} = \left(\frac{1}{\omega^2 LC - 1}\right) \qquad \text{..........(12)}$$

Eqn (12) shows that for large enough values of ω, $\omega^2 LC \to \infty$, and $T_{C(\omega)} \to 0$. Thus for $\omega^2 \; LC \gg 1$, the circuit gain $T_{C(\omega)}$ will be minimal. Again, as $\omega^2 LC > 1$ here, Eqn (12) indicates that the magnitude of $T_{C(\omega)}$ is positive. However, from the perspective of the capacitor, the –y-axis is the natural abode (to be considered positive). The +y-axis is the unnatural region and hence the gain in this region must be deemed negative.

(b) $\chi_C > \chi_L$ or $\omega < \omega_o$ or $\omega^2 LC < 1$ (*the pre-resonance-peak region of* ω*)*

The equivalent reactance χ_{eq} is now given by:

$$\chi_{eq} \;=\; \chi_C - \chi_L \;=\; \frac{1}{\omega C} - \omega L \;=\; \frac{1-(\omega L)(\omega C)}{\omega C} \;=\; \frac{1-\omega^2 LC}{\omega C} \qquad \text{..........(13)}$$

The series current is given by:

$$I_L \;=\; I_C \;=\; I_S \;=\; \frac{V_S}{\chi_{eq}} \;=\; \frac{V_S}{\dfrac{1-\omega^2 LC}{\omega C}} \;=\; \left(\frac{\omega C}{1-\omega^2 LC}\right) V_S \qquad \text{..........(14)}$$

The capacitor voltage is given by:

$$V_C \;=\; \chi_C I_S \;=\; \left(\frac{1}{\omega C}\right)\left(\frac{\omega C}{1-\omega^2 LC}\right) V_S \;=\; \left(\frac{1}{1-\omega^2 LC}\right) V_S \qquad \text{..........(15)}$$

And the transfer function for the capacitor $T_{C(\omega)}$ is now given by:

$$T_{C(\omega)} \;=\; T_C \;=\; \frac{V_C}{V_S} \;=\; \left(\frac{1}{1-\omega^2 LC}\right) \qquad \text{..........(16)}$$

Eqn (16) shows that for small enough values of ω, $\omega^2 LC \to 0$ and, $T_{C(\omega)} \to 1$. Thus for $\omega^2 LC \ll 1$, the circuit gain $T_{L(\omega)}$ will be unity or near unity. Again, as $\omega^2 LC < 1$ in this region, Eqn (16) indicates that the gain $T_{C(\omega)}$ will be positive. As we are already in the –y-axis mode ($\chi_C > \chi_L$), which is the natural abode of capacitors, the algebraic sign of $T_{C(\omega)}$ stays positive.

The circuit when poised to collect output voltage across the capacitor is said to be a *low frequency selective network.* It accepts low frequencies and rejects high frequencies.

Cut-Off Frequencies

The *cut-off* frequency ω_c that separates the frequencies that are *filtered in* from those that are *filtered out* has been determined to be the frequency at which voltage gain reduces to $1/\sqrt{2}$ of the maximum gain. This is the half-power point. As the maximum gain is unity, the voltage gains $T_{L(\omega)}$ and $T_{C(\omega)}$ at cut-off frequencies, will be 0.7071.

(a) The High Frequency Selective Network

It should be noted that the cut-off frequency ω_c will occur *before* the resonance sets in. This is because gain will rise from zero only in the low frequency or pre-resonance region. In the post-resonance region, the gain will stay at unity. Letting ω_o be the resonance frequency, we find that $\omega_c < \omega_o$. The correct equation to calculate the circuit gain, therefore, is Eqn. (8)

Setting $T_L \;=\; 0.7071$ in Eqn. (8), We get:

$$0.7071 = \left(\frac{\omega_c^2 LC}{1 - \omega_c^2 LC} \right)$$

$$(0.7071) - (0.7071)(\omega_c^2 LC) = \omega_c^2 LC$$

$$(\omega_c^2 LC)(1 + 0.7071) = 0.7071$$

$$\omega_c^2 LC = \frac{0.7071}{1 + 0.7071} = 0.41421$$

$$\omega_c = \sqrt{\frac{0.41421}{LC}} \qquad f_c = \frac{1}{2\pi}\sqrt{\frac{0.41421}{LC}} = \sqrt{\frac{0.010492}{LC}} \qquad \text{..........(17)}$$

(b) The Low Frequency Selective Network

It should be noted that the cut-off frequency ω_c will occur *after* the resonance sets in. This is because in the pre-resonance region, gain will stay at unity. It will decrease down to zero only in the post-resonance region. Letting ω_o be the resonance frequency, we find that $\omega_c > \omega_o$. The correct equation to calculate the circuit gain, therefore, is Eqn. (12).

Again, setting $T_C = 0.7071$ in Eqn. (12), we get:

$$0.7071 = \frac{1}{\omega_c^2 LC - 1}$$

Cross multiplying, we get:

$$(0.7071)(\omega_c^2 LC) - (0.7071) = 1$$

$$(0.7071)(\omega_c^2 LC) = 1 + 0.7071$$

Rearranging:

$$\omega_c^2 LC = \frac{1 + 0.7071}{0.7071} = 2.41423$$

$$\omega_c = \sqrt{\frac{2.41423}{LC}} \qquad f_c = \frac{1}{2\pi}\sqrt{\frac{2.41423}{LC}} = \sqrt{\frac{0.061153}{LC}} \qquad \text{..........(18)}$$

The ratio of the two cut-off frequencies is:

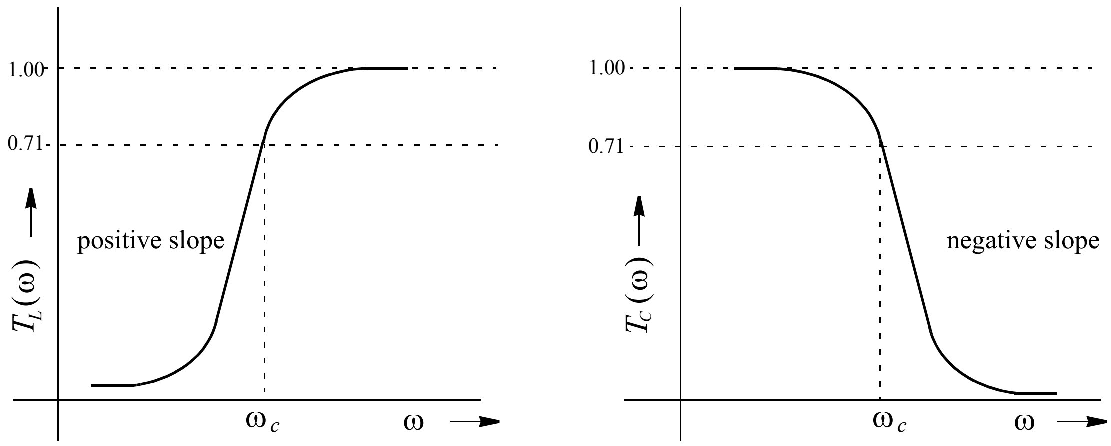
$$f_{c,\text{ high}} / f_{c,\text{ low}} = 0.41421$$

It is customary to plot a *gain versus frequency* graph to show the response of the circuit to the frequencies of interest. The graph permits us to find the cut-off frequency experimentally, which can then be compared with the calculated value. Frequency response graphs for the two cases are shown in Fig (3).

LCR Resonance

The inductor and the capacitor, together with the DC resistance of the inductor form a series R, L and C circuit and resonance occurs. The resonance frequency f_o is given by the familiar equation:

$$\omega_o = \frac{1}{\sqrt{LC}} \qquad f_o = \left(\frac{1}{2\pi}\right)\left(\frac{1}{\sqrt{LC}}\right) = \sqrt{\frac{0.0253303}{LC}} \qquad \text{..........(19)}$$



Selecting High Frequencies (b) Selecting Low Frequencies

Fig (3) High and Low Frequency Responses of a Series LC Circuit

Because of rather small resistance, a sharp peak of large gain is formed. This peak gets superimposed on the basic frequency response curves of Figs (3). Being prominent, the actual response curve gets *dwarfed*. This is shown in Fig (4), below.

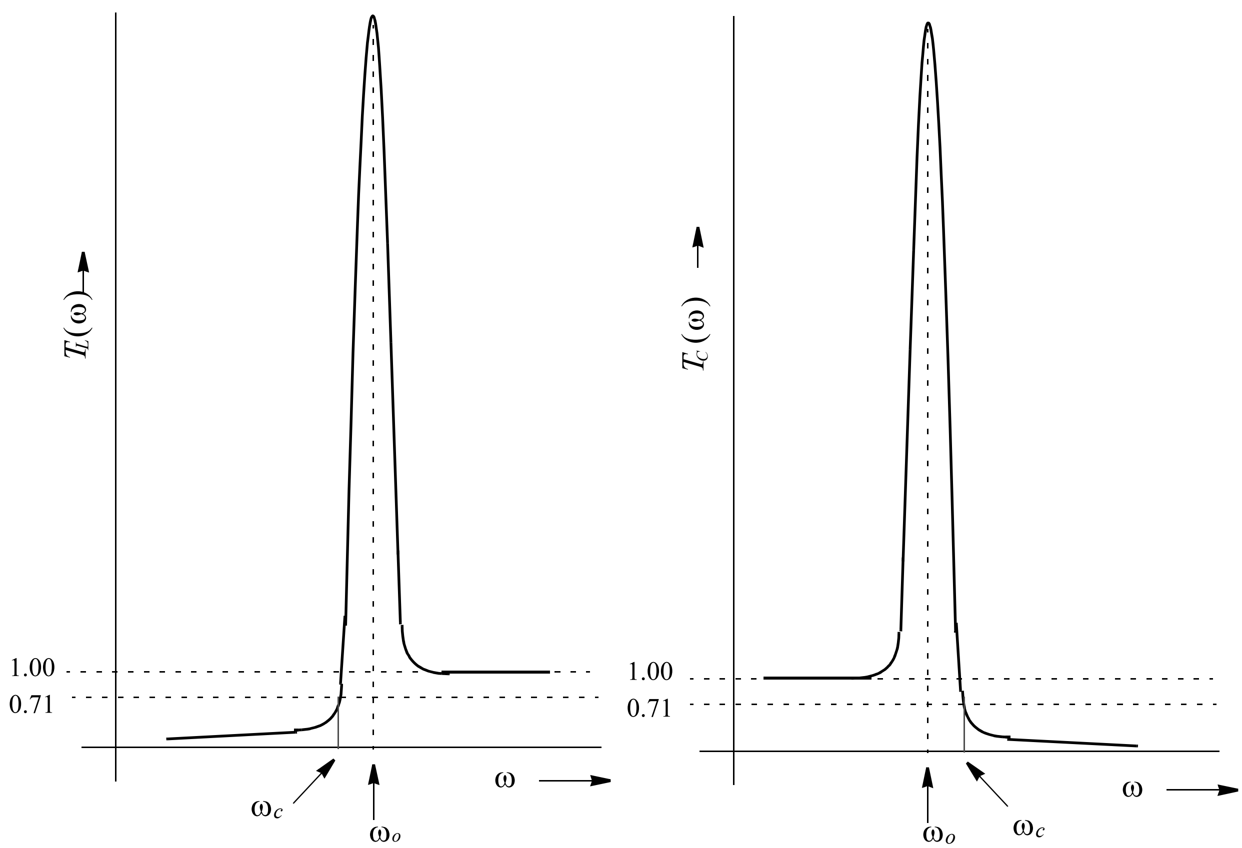


Fig (4) The High and the Low Frequency Response Curves with the Resonance Curve Superimposed

Objectives of the Experiment

(a) To study (i) a high frequency selective network, and (ii) a low frequency selective network by plotting their frequency response curves and finding their respective cut-off frequencies.

(b) To compare the experimental cut-off frequencies with the calculated ones and to show that the ratio of the two cut-off frequencies is:

$$\frac{f_{c,\,\text{high}}}{f_{c,\,\text{low}}} = 0.41421$$

Setting Up

The circuit for this experiment is a straightforward series combination of an inductor and a capacitor, together with a function generator as the AC source. The transfer functions for the outputs taken across the inductor and the capacitor (one at a time) are given by the following expressions:

$$T_{L(\omega)} = \frac{V_{L(\omega)}}{V_{S(\omega)}} \qquad T_{c(\omega)} = \frac{V_{c(\omega)}}{V_{S(\omega)}}$$

The values of these transfer functions can be determined experimentally using a two-channel oscilloscope. A large range of frequencies is recommended for V_S . The frequency scale for plotting the graph should be selected as $\log\omega$. Even though it is not necessary that V_S be the same for each frequency, it will be helpful if it is maintained at a constant level, using the *amplitude control* knob of the function generator. It is, therefore, suggested that the source voltage V_S be checked for being constant for each frequency, with the help of an oscilloscope.

Reshaping the Equations to Conform to the Equation of a Straight Line

(a) High Frequency Selective Network:

As the cut-off frequency ω_c occurs *before* the resonance frequency ω_o, we shall use the equation for the pre-resonance frequencies, i.e. Eqn (8):

$$T_{L(\omega)} = T_L = \left(\frac{\omega^2 LC}{1-\omega^2 LC}\right) \qquad \text{............ Eqn (8)}$$

Taking reciprocal on both sides, we get:

$$\frac{1}{T_{L(\omega)}} = \frac{1}{T_L} = \frac{1-\omega^2 LC}{\omega^2 LC} = \left(\frac{1}{LC}\right)\left(\frac{1}{\omega^2}\right) - 1$$

$$\frac{1}{T_L} = -1 + \left(\frac{1}{LC}\right)\left(\frac{1}{\omega^2}\right) \qquad \text{..........}\textit{(20)}$$

Eqn (20) shows that if we plot $1/T_L$ against $1/\omega^2$, we should get a straight line with a slope of magnitude $1/(LC)$ and a negative y-axis intercept of magnitude unity, i.e. "–1". It should be noted that in order to get a positive slope, values of gain T_L for the *pre-resonance* frequencies, will have to be assigned a negative sign before plotting the graph.

(b) Low Frequency Selective Network:

As the cut-off frequency ω_c occurs *after* the resonance frequency ω_o, we shall use the equation for the post-resonance frequencies, i.e. Eqn (12).

$$T_{C(\omega)} = T_C = \frac{V_C}{V_S} = \left(\frac{1}{\omega^2 LC - 1}\right) \qquad \text{........ Eqn (12)}$$

Taking reciprocal on both sides, we get:

$$\frac{1}{T_{c(\omega)}} = \frac{1}{T_c} = \frac{\omega^2 LC - 1}{1} = \omega^2 LC - 1$$

$$\frac{1}{T_c} = -1 + (LC)(\omega^2) \qquad \text{..........(21)}$$

Eqn (21) shows that if we plot $1/T_c$ against ω^2, we should get a straight line with a slope of magnitude LC and a negative y-axis intercept of magnitude unity, i.e. "–1". It should be noted that in order to get a positive slope, values of gain T_c for the *post-resonance* frequencies, will have to be assigned a negative sign before plotting the graph.

Procedure

(1) The inductor to be used in this experiment will have a value in the low *millihenries*. Likewise the capacitor will have a nominal value of few nanofarads. Use the digital function generator as the source of AC electricity of variable frequency. We shall use both channels of the oscilloscope for this experiment. Channel 2 will be used for monitoring V_L or V_C while Channel #1 will be used for monitoring V_S .

(2) For each frequency selected on the digital function generator, check the level of the input voltage V_S and adjust it to the preselected value, using the amplitude control knob and channel 1 of the oscilloscope. As we shall be measuring the *heights* only, it will be helpful to have a large number of waves on the screen. This can be achieved by turning the *time base* control clockwise. Getting a continuous band of frequencies may not be a bad idea.

(a) High Frequency Selective Network

(3) Set up the circuit as shown in Fig (5). Let $C = 0.001\ \mu F$.

(4) Set the vertical amplifier of Channel 1 on *0.2 volts/div.* Make sure that the variable-volt/div-control knob is in the off position. For each frequency, set input voltage V_S to 5 divisions, peak to peak (vertically) on the oscilloscope screen. The peak-to-peak input voltage will then be 1 volt. Such a small input voltage is necessary to keep the resonance voltage within the limits of oscilloscope display

Most digital function generators will produce such a low voltage. If a particular generator does not produce low enough voltage, consult the instructor for a workable solution.

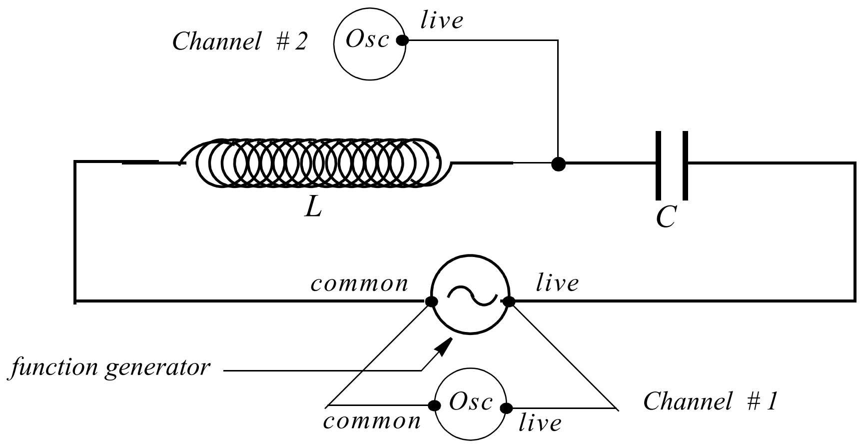


Fig (5) Circuit Diagrams for the Study of the High Frequency Selective Network

(5) The output voltage V_L will be measured on Channel 2 of the oscilloscope. To measure V_L, read the number of divisions on the screen, vertically, to one decimal place and then multiply this number by the *volt/div* setting of the vertical amplifier for Channel 2. This setting may be at *0.2 volts/div* for the first few trials. It will have to be changed to other values for later trials. If the height of waves exceeds the 8 divisions of the grid (or even 7 divisions), rotate the *volts/div* control counterclockwise to bring it to a higher *volts/div* setting. If, on the other hand, the height of waves is small (less than (say) 3 divisions), rotate the said knob clockwise for a lower *volts/div* setting.

(6) Start selecting frequencies from higher to lower values. Begin with a frequency of 100,000 Hz. (If the function generator does not give you 100,000 Hz, start with 99,500 Hz.) The output voltage V_L (channel 2) will be the same as the input voltage at this time, i.e. 5 divisions at *0.2 volts/div* setting. Record this height. Next select frequencies 90,000 Hz, 80,000 Hz etc., and record corresponding peak-to-peak amplitudes. You will notice little or no change in V_L. We say that V_L is barely moving at this stage.

When the peak-to-peak amplitude of V_L begins to rise significantly, then instead of selecting frequencies, select the peak-to-peak amplitudes of V_L by letting it grow by half a division at a time. Read and record the actual frequency, as it appears on the digital display of the function generator. For this rate of growth of V_L, we say that V_L is *walking*. When V_L begins to *run*, we shall let its peak-to-peak amplitude increase by one division at a time. For each designated increase of peak-to-peak amplitude, record the corresponding frequency. When the amplitude has grown to fill the screen (total 8 divisions) switch to the next *volts/div* setting by turning the knob counterclockwise. Let the amplitude on the new scale also, grow by 1 division.

Follow this procedure until you reach the resonance peak. Carefully record this frequency as the *resonance frequency* f_o. As you continue beyond f_o, the amplitude of V_L will begin to decrease. Let it decrease in steps of one division at a time and keep recording the corresponding frequencies. When the amplitude has decreased to 3 divisions, switch to the next lower *volts/div* setting by turning the knob clockwise. Follow exactly the opposite procedure of what you did before, until you have gone down to 0.1 *volts/div* setting.

There should be about 45 to 50 trials. The approximate time is about 45 minutes.

(7) Now proceed to determine precisely, the cut-off frequency f_c. Scan the frequencies until the amplitude of the output waves (channel 2) is 71.71% of the amplitude of the input waves. Since the amplitude of the input waves was set to 5 divisions on *0.2 volts/div,* (we hope you have been checking it throughout the experiment), the amplitude of the output voltage should be 3.54 divisions on *0.2 volts/div* setting on channel 2, or better still, 7.07 divisions on *0.1 volts/div* setting. Read and record the frequency as displayed at this time, on the digital function generator. This is the cut-off frequency f_c .

If V_S was not (or could not) be set to 1-volt, peak-to-peak, ask the instructor for help.

(8) This part of the experiment ends.

(B) Low Frequency Selective Network

(9) Set up the circuit of Fig (6), as shown below

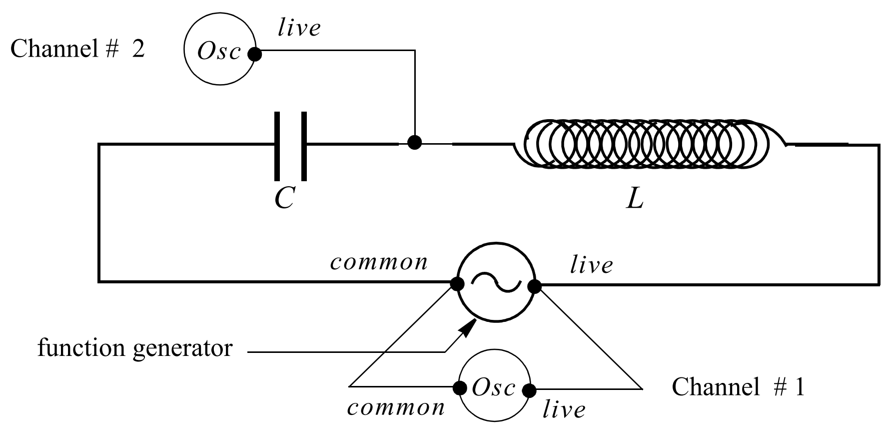


Fig (6) Circuit Diagrams for the Study of the Low Frequency Selective Network

(10) Repeat Step (6) and (7) but start from low frequencies, say 100 Hz. Channel 2 will now read V_C .

(11) When all trials are completed and the resonance and cut-off frequencies have been found, switch off the circuit and disconnect. Arrange all material and equipment neatly on the table.

Plotting Graphs

Plotting the Resonance Curve

(1) For each trial (both parts), find V_L and V_C by multiplying together *number of divisions* and *volt/div* values. As V_S was set to 1 volt, V_L and V_C themselves will be the gain T_L and T_C . If V_S was not one volt, divide V_L and V_C by V_S to get T_L and T_C .

(2) Find *log* of all frequencies using the computer.

(3) Plot T_L or T_C on y-axis and $\log f$ on x-axis. Ask the computer to *interpolate*. The computer will draw a smooth line through all the points thereby giving you a pattern as shown in Fig. (4), including a beautiful sharp resonance peak.

If you are plotting a straight line graph, then skip steps (4) 0below.

(4) To find the two cut-off frequencies, use the following extrapolation method, **using your data (and not the graph)**:

Let the gain just below 0.7071 be T_1 and let the corresponding frequency be f_1.

Let the gain just above 0.7071 be T_2 and let the corresponding frequency be f_2.

Then the cut-off frequency is given by:

$$f_{cut-off} = f_c = \left(\frac{0.7071 - T_1}{T_2 - T_1}\right)(f_2 - f_1) + f_1 \qquad \text{..........(22)}$$

(5) Calculate the *expected* value of f_o using Eqn (19)

(6) Find the average of the two values of f_o (one each from the high and low frequency data). This is the *experimental* value of f_o. Compare it with the *expected* value found in step (5) above. Find percent error.

Plotting Straight Line Graphs

High Frequency Selective Network,

As the gain T_L in the pre-resonance region is negative ($V_L < V_C$), we need to assign a ***negative*** sign to the corresponding values of $1/T_L$. Proceed as follows:

(1) Reenter the data on a fresh data sheet. Entries in the column for "*# of divisions*" will be assigned a negative sign, starting from the value of "*# of divisions*" that corresponds to the frequency ($f = 100\,Hz$) all the way up to the value of "*# of divisions*" that corresponds to the frequency at which resonance occurs. This is the pre-resonance region.

All remaining values of "*# of divisions*" will stay positive. These belong to high ω data, where the circuit behaves as high-frequency selective network.

(2) Enter the rest of data normally and calculate T_L, $1/T_L$, ω, ω^2, and $1/\omega^2$.

(3) Plot $1/T_L$ on y-axis and $1/\omega^2$ on x-axis. If the linear fit does not turn out to be suitable, a second order polynomial fit should be obtained to eliminate leakage effects of the capacitor and other errors (such as stray capacitances). One may even try a higher order polynomial fit, for the same raesons.The best fit is one that yields both, the intercept and the r^2, values, closest to unity. Ask the computer to print the equation in scientific mode with 4 significant decimal places.

Low Frequency Selective Network

As the gain T_C in the post-resonance region is negative ($V_C < V_L$), we need to assign a ***negative*** sign to the corresponding $1/(T_C)$. Proceed as follows:

(4) Reenter the data on a fresh data sheet. Entries in the column: "*# of divisions*" will be assigned a negative sign, starting from the "*# of divisions*" that corresponds to the frequency ($f = 100,000\,Hz$) all the way down to the "*# of divisions*" that corresponds to *the* frequency at which resonance occurs. This is the post-resonance region.

All remaining values of "*# of divisions*" will stay positive. These belong to low ω data, where the circuit behaves as a low frequency selective network

(5) Enter the rest of data normally and calculate T_C, $1/(T_C)$, ω, and ω^2

(6) Plot $1/T_C$ on y-axis and ω^2 on x-axis and follow other instructions given in step (3).

Obtaining Results from the Two Graphs

(1) Compare the y-axis intercepts of each graph with its expected value: unity and find percent error. Unity here represents the limiting gain for each network. Please note that limiting gains are found by setting $\omega = \infty$ for the high frequency circuit and $\omega = 0$ for the low frequency circuit (Eqns 4 & 16 respectively).

(2) The slope is $1/(LC)$ for the high frequency graph and LC for the low frequency graph. Use the slopes to find two values of LC (expected to be the same for both circuits). The unit is *sec*^{2}. Compare the individual values of LC (two of them) and then their average value with the calculated value and find percent errors.

(3) Find the cut-off frequency for each network from their respective equations (printed out by the computer) by setting $y = \sqrt{2}$, and solving the equations for x where $x = 1/\omega_c^2$. for the high frequency graph and simply ω_c^2 for the low frequency graph. Use the two values of x to find $f_{c,\text{high}}$ and $f_{c,\text{low}}$ respectively. Compare with their expected values and find percent errors

(4) find the ratio of $f_{c,\text{high}}$ to $f_{c,\text{low}}$ and compare with the expected value of 0.41421 . Find percent error.

(5) Find the resonance frequency for each case from the respective equations (printed out by the computer) by setting $y = 0$ and solving the equations for x where $x = 1/\omega_o^2$ for the high frequency graph and simply ω_o^2 for the low frequency graph. Find ω_o and hence f_o. Compare the individual values of f_o (two of them) and then their average value with the calculated value (Eqn. 19) and find percent errors.

(6) Compile the *Results,*

Conclusions and Discussions

Write your conclusions from the experiment and discuss them.

What Did You Learn in this Experiment?.

A hearty and thoughtful account of what you learned in this experiment by way of the principle and the techniques of experimentation, should be given

Data & Data Tables

Name...................................   **Date**.............................

Instructor.............................   **Lab Section**...................

Partner..........................   **Table #**..........................

The Capacitor; nominal value 0.001 μF Actual value: μF

The Inductor; nominal value mH Actual value: mH

The Source Voltage V_S : 1.00 volt (peak-to-peak) Actual value Volts

(a) High Frequency Selective Network

Table 1: Voltage Gain for the High Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_L	$T_L = \frac{V_L}{V_S} = V_L$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
1.	100,000					
2.	90,000					
3.	80,000					
4.	70,000					
5.						
6.						
7.	--					
8.	--					
9.	--					
10.	--					
11.	--					
12.	--					
13.	--					
14.	--					
15.	--					
16.	--					
17.	--					

Table 1: Voltage Gain for the High Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_L	$T_L = \frac{V_L}{V_S} = V_L$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
18.	--					
19.	--					
20.	--					
21.	--					
22.	--					
23.	--					
24.	--					
25.	--					
26.	--					
27.	--					
28.	--					
29	--					
30	--					
31	--					
32	--					
33	--					
34	--					
35	--					
36	--					
37	--					
38	--					
39	--					
40	--					
41	--					
42	--					
43	--					
44	--					

Table 1: Voltage Gain for the High Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_L	$T_L = \frac{V_L}{V_S} = V_L$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
45	--					
46	--					
47	--					
48	--					
49	--					
50	--					

(b) Low Frequency Selective Network

Table 2: Voltage Gain for the Low Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_C	$T_C = \frac{V_C}{V_S} = V_C$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
1.	100					
2.	300					
3.	500					
4.	700					
5.	900					
6.	1,000					
7.	--					
8.	--					
9.	--					
10.	--					
11.	--					
12.	--					
13.	--					

Table 2: Voltage Gain for the Low Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_C	$T_C = \frac{V_C}{V_S} = V_C$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
14.	--					
15.	--					
16.	--					
17.	--					
18.	--					
19.	--					
20.	--					
21.	--					
22.	--					
23.	--					
24.	--					
25.	--					
26.	--					
27.	--					
28.	--					
29	--					
30.	--					
31	--					
32	--					
33	--					
34	--					
35	--					
36	--					
37	--					
38	--					
39	--					
40	--					

Table 2: Voltage Gain for the Low Frequency Selective Network

Trial #	Nominal values of frequency (Hz)	Actual values of frequency (Hz)	Amplitude (peak - to - peak)		V_C	$T_C = \frac{V_C}{V_S} = V_C$ if $V_S = 1$
			# of divisions along y-axis	volts/div setting		
41	--					
42	--					
43	--					
44	--					
45	--					
46	--					
47	--					
48	--					
49	--					
50	--					

Value of f_o, as read on the digital read-out of function generator
(step 6 of procedure) Hz

value of f_o, as read on the digital read-out of function generator
(step 6 for step 10) Hz

Value of $f_{c,\text{ high}}$, as read on the digital read-out of function generator
(step 7 of procedure) Hz

value of $f_{c,\text{ low}}$, as read on the digital read-out of function generator
(step 7 for step 10) Hz

Additional information or data (if any):

Table of Results **Name:** **Date:**

Adventures in a Frequency Selective Network

A *Cut-off Frequencies f_c*

Cut-Off Frequencies f_c

	Network	Expected Value (Hz)	Experimental Value (Hz)	% difference
1	High Frequency			
2	Low Frequency			
3	Ratio		0.41421	

B *Resonance Frequencies f_o*

Resonance Frequencies f_o

	Network	Expected Value (Hz)	Experimental Value (Hz)	% difference
1	High Frequency			
2	Low Frequency			
3	Average Resonance Frequency			

C Authenticity Test #1 The LC Value

Value of LC

	Network	Expected Value (s^2)	Experimental Value (s^2)	% difference
1	High Frequency			
2	Low Frequency			
3	Average Value			

D Authenticity Test #2 Circuit Gain at Limiting Frequencies

Circuit Gain at Limiting Frequencies

	Network	Expected Value	Experimental Value	% difference
1	High Frequency	1.00		
2	Low Frequency	1.00		