## Multisim Demo 7.4: Making an Impedance Purely Real

The goal of this simulation is to find what the value of $Z_{l}$ should be in the circuit in Fig. 7.4.1 in order to cause the voltage and current across $Z_{i n}$ to be in phase at 2 kHz .

We know from reading the book late at night 24 hours before an exam that if the voltage and the current are in phase, it means that the impedance is purely real. So using this information, we realize that we need to basically add a single component, $Z_{l}$, to the circuit to cancel all imaginary impedance contributed by the defined components on the left side of the circuit.

Let's use the Network Analyzer as well as our intelligence to solve this problem. Build the circuit in Fig. 7.4.1 minus the unknown impedance $Z_{l}$, and attach the Network Analyzer across its terminals. Once completed, the circuit should resemble Fig. 7.4.2.


Figure 7.4.1 Add a component in series to make the impedance real.


Figure 7.4.2 Circuit with Network Analyzer implemented in Multisim.

Set up the Network Analyzer so that it will sweep from 1 Hz to 10 kHz . You may want to change the resolution of the instrument via the RF Param. Set button. (The author used 50 points per decade). Once you're ready, press F5. Switch the Network Analyzer screen to the RF Characterizer Mode and view the impedance. Place your cursor as close to 2 kHz as possible, as shown in Fig. 7.4.3 below.


Figure 7.4.3 Measuring the Impedance
As we can see, at the frequency of interest, the impedance of the system is $120.279+\mathrm{j} 252.308$ $\Omega$. (remember you need to subtract $50 \Omega$...see Demo 7.1 if this is confusing).

Because $Z_{l}$ is in series with the impedance just measured, the two values $Z_{l}$ and $120.279+$ j252.308 will add together. This gives a clear way in which we can cancel out the imaginary component: set $Z_{l}$ such that it's imaginary impedance is the negative of the impedance we just measured. This means that at $2 \mathrm{kHz}, Z_{l}$ should have an impedance of $-\mathrm{j} 252.308 \Omega$, which is capacitive. So let's figure out what capacitance this would correspond to:

$$
\begin{gathered}
\frac{1}{j \omega \cdot C}=-j Z_{1} \quad \frac{1}{j 2 \pi \cdot 1.995 \times 10^{3} \cdot C}=-j 252.308 \\
C=316.19 \times 10^{-12} \mathrm{~F}
\end{gathered}
$$

Note that the frequency 1.995 kHz was used above because that's the frequency from which the data point was taken.

So now we need to simply incorporate that capacitor back into the original circuit. As shown in Fig. 7.4.4 below.


Analyze the entire circuit with the Network Analyzer over the same frequency range as before. You should get an almost entirely real impedance at about 2 kHz as shown in Fig. 7.4.5 below.


Figure 7.4.5 Network Analyzer showing an almost completely real impedance at 2 kHz .
Now let's simulate the circuit we just completed in an AC Analysis. Add an AC_VOLTAGE source with an AC Analysis magnitude of 5 V across the terminals our newly designed $Z_{i n}$.

The Network Analyzer does not require a ground when it measures values but when we go and do the AC analysis now, we will need to add a ground. Remember that!

Run the AC Analysis from 1 Hz to 10 KHz and set the resolution to 50 points per decade. In order to plot the voltage across $Z_{i n}$ and the current into $Z_{i n}$ we need to simulate with the variables $\mathrm{V}(5)$ and $-\mathrm{I}(\mathrm{v} 2)$. Running this simulation, and then using the cursors, reveals that at 2 kHz , both the current and voltage are indeed in phase with each other. We have accomplished our mission.


Figure 7.4.5 AC Analysis revealing that the both voltage and current are in phase at 2 kHz .

