Lab #4
Attenuator Analysis

Name __________________________
Partner(s) _________________________ Grade _____/10

Introduction
Attenuators are circuits that are commonly used in radio frequency (RF) applications to both reduce the level of the signal and to match the resistance of the source ($R_S$) to that of the load ($R_L$). One of the reasons that you want to match the source and load resistance is to eliminate standing waves on the transmission lines, thereby reducing distortion. Another reason is to transfer maximum power to the load. Shown below is a circuit called a π-attenuator whose name is derived from its visual architecture.

![Circuit Diagram]

Lab Objectives
- Develop proficiency with two new pieces of laboratory equipment:
  - The function generator;
  - The oscilloscope.
- Understand resistance matching.

Equipment
- Breadboard;
- Decade resistance box;
- Assorted resistors;
- Multi-meters;
- Waveform Function Generator (new);
- Oscilloscope (new).
References
- Pre-lab #4 assignment;
- Circuits text book;
- Descriptions of instruments hand-out;
- Resistor color-code chart.

Procedure
The first step in this lab exercise is to model the function generator as a non-ideal voltage source and compute its Thévenin equivalent circuit as shown at the right. The resistance $R_S$ is called the output impedance of the function generator. This part of the lab requires finding the optimum values for $V_S$ and $R_S$ by connecting a decade resistance box between the + and – terminals at the output of the Source and measuring the output voltage ($V_O$) as a function of load resistance.

1) Place the oscilloscope probe directly across the output of the function generator and adjust $V_S$ to 6 volts peak-to-peak at a frequency of 1000Hz. Note that $R_S$ shown in the circuit at the right is internal to the function generator and not part of your external circuit.

2) Using an $R_S$ value of 50$\Omega$, use the voltage-divider law to calculate the expected value of $V_O$ from the circuit above and place your calculated values in the table below.

<table>
<thead>
<tr>
<th>$R_L$</th>
<th>1000</th>
<th>500</th>
<th>200</th>
<th>100</th>
<th>80</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_O$(calc) (V)</td>
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<tr>
<td>$V_O$(meas) (V)</td>
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</table>

3) Connect the decade resistance box across $V_O$ to provide a load resistance and fill in the measured values in the table above for the indicated values of $R_L$. Measure peak-to-peak voltage using the oscilloscope.

4) Download the Excel Solver Spreadsheet from the Lab4 section of the course web page. The spreadsheet has adjacent columns with $R_L$, $V_{O\text{meas}}$, $V_{O\text{calc}}$, and the square of the difference between $V_{O\text{meas}}$ and $V_{O\text{calc}}$. Replace the $V_{O\text{meas}}$ data with your own data but leave the other columns alone. Add the Solver function in Excel using the following steps:

- Choose File ⇒ Options ⇒ Add-ins
- Select the Go… button near the bottom of the screen.
- Check the Solver add-in box.
- Find the Solver tab on the far right in the Data menu.

5) Using Solver, find the values of $V_S$ and $R_S$ that minimize the sum-squared error in ($V_{O\text{meas}} - V_{O\text{calc}}$) while it fits the data to the following equation:

$$V_O = V_S \frac{R_L}{R_L + R_S}$$
\[ \begin{align*} V_S &= \underline{\text{__________}} \text{ V} \quad R_S &= \underline{\text{__________}} \text{ } \Omega \\
\end{align*} \]

6) Using the \( V_s \) and \( R_s \) values optimized by Solver in step 5, recalculate \( V_o \) using the equation in step 5 for the \( R_L \) values in step 2 and enter the results into the table below. Then calculate % difference.

<table>
<thead>
<tr>
<th>( R_L )</th>
<th>1000</th>
<th>500</th>
<th>200</th>
<th>100</th>
<th>80</th>
<th>60</th>
<th>50</th>
<th>40</th>
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<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_o(\text{calc}) ) step 2</td>
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<tr>
<td>( V_o(\text{calc}) ) step 6</td>
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<tr>
<td>% difference</td>
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7) Assemble the \( \pi \)-attenuator circuit shown above on your breadboard. These values are chosen to create a 20 decibel (factor of 10) attenuation between the input and output voltages. Calculate (or copy from your pre-lab) and measure, using a Fluke meter, the input resistance to the attenuator stage (the resistance seen to the right of \( R_s \)) for loads of \( R_L = 0 \) \( \Omega \), \( R_L = 50 \) \( \Omega \) and \( R_L = \infty \) \( \Omega \). You may draw your circuits on the right and below to aid your computations.

For \( R_L = 0 \) \( \Omega \)

\[ \begin{align*} R_{in, \text{calculated}} &= \underline{\text{__________}} \text{ } \Omega \\
R_{in, \text{measured}} &= \underline{\text{__________}} \text{ } \Omega \\
\end{align*} \]

For \( R_L = 50 \) \( \Omega \)

\[ \begin{align*} R_{in, \text{calculated}} &= \underline{\text{__________}} \text{ } \Omega \\
R_{in, \text{measured}} &= \underline{\text{__________}} \text{ } \Omega \\
\end{align*} \]

For \( R_L = \infty \) \( \Omega \)

\[ \begin{align*} R_{in, \text{calculated}} &= \underline{\text{__________}} \text{ } \Omega \\
R_{in, \text{measured}} &= \underline{\text{__________}} \text{ } \Omega \\
\end{align*} \]
8) Set the function generator output to $6.00v_{pp}$ and assemble the source, attenuator, and load (the decade resistance box) to measure $V_o$ like you did in step 2.

<table>
<thead>
<tr>
<th>$R_L$ (Ω)</th>
<th>1000</th>
<th>500</th>
<th>200</th>
<th>100</th>
<th>80</th>
<th>60</th>
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</thead>
<tbody>
<tr>
<td>$V_o$ (V)</td>
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9) Please write your observations and conclusions concerning this lab exercise.