



Electric Circuit Theory, Experiment 3:

Frequency Response

By: Moe Wasserman
College of Engineering
Boston University
Boston, Massachusetts

Purpose:

To display the Bode magnitude plot, or gain vs frequency, for a filter or an amplifier, and to determine the cutoff frequency, or the frequency at which the gain becomes less than the midband value by a factor of $1/\sqrt{2}$.

Equipment:

- Agilent 33120A Function Generator
- Agilent 34401A Digital Multimeter

Introduction:

In each of the following experiments, you will "write" a program to instruct the instruments on the lab bench to perform prescribed measurements on your circuits. In some cases your program will analyze the data received by the instruments, and will present the results on the computer screen in graphical and/or tabular form.

The reason why the word "write" is in quotation marks is that the programming language you will use, Agilent VEE, has a purely graphical, rather than text, interface. Conventional program statements will be replaced by objects, or icons on the computer screen, and the order of execution of the objects will be determined by "wires" that connect the icons.

Before performing any of these experiments, you should read the introductory document, entitled Using Agilent VEE, then work through the four exercises that you will find there.

The first step in programming any Agilent VEE-controlled experiment is to place on the screen an **Panel Driver** object for each of the instruments to be used. (Recall that there is no instrument panel object for the triple power supply; you must use a **Direct I/O** object.) These objects will be used to set the default configurations for the instruments; they will not be connected by wires to anything else on the screen. Instructions for setting the defaults will be given in each experiment. The settings will be made on the Main Panel of each object unless another panel is designated. Only the necessary settings will be specified; all others are immaterial.

As is often the case, a program may not perform as expected on the first try. If this occurs, two useful debugging tools are available. They can be activated with the menu commands

Debug --> Show Data Flow and
Debug --> Show Execution Flow.

To use these to best advantage, set the slowest speed for these processes with **File —> Default Preferences** on the **General** tab, in the **Debug** group, click the **Data Flow Rate** arrow to show the drop-down list. Set the rate to **1(Slowest)**.

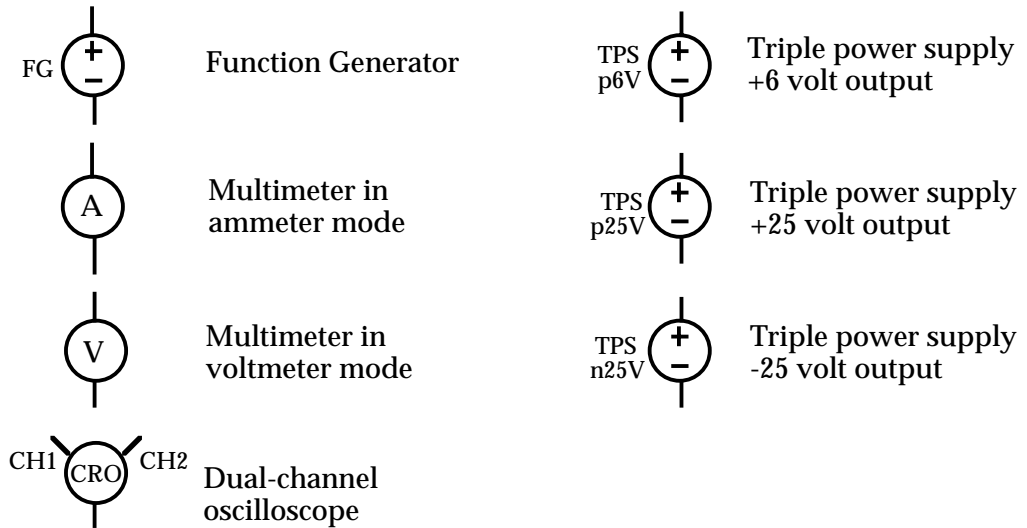
When the program is run, you will see symbols representing data and commands moving along the wires between objects, and each object will be highlighted when it is active.



Operating in this mode is also useful to assist you in understanding how Agilent VEE works. But don't use these options all the time, because they slow down execution considerably.

Always begin an experiment setup by clicking the **reset** button on each instrument panel object. If you don't, the instrument may not be in the proper operating mode when you run the experiment.

The following symbols will be used in the circuit schematics:



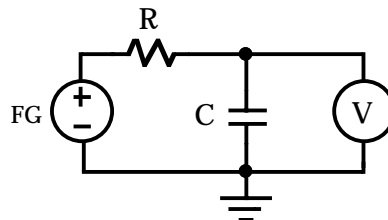
Instructions will be given in considerable detail for setting up and running the program for the first experiment only. It is assumed that you will then be familiar with the basic operations of Agilent VEE.

Method:

Using a simple series RC network, the capacitor voltage will be measured at different frequencies. The voltage transfer function $|V_c/V_{in}|$ will be plotted as a function of frequency on a logarithmic scale. Provision will be made to stop the frequency scan when the transfer function reaches the value $1/\sqrt{2}$.

Hardware Setup:

Build the circuit shown below, with $R = 10\text{ k}\Omega$ and $C = 100\text{ pF}$.



Software Setup:

Place the usual Panel Drivers and Component Drivers for the function generator and multimeter on the screen. The default configurations are:



Function Generator: Function = sinusoid; Amplitude = 1; Units = V peak-peak;
Offset = 0; Load = infinity
Multimeter: Function = AC Volts; Auto Range = on.

The function generator driver needs **frequency** input and output pins and an **amplitude** output pin, and the multimeter driver needs a **readings** output pin. Connect a wire from the sequence output pin of the function generator to the sequence input pin of the multimeter, and connect the output of a For Log Range object to the function generator input. This object will provide the sequence of frequencies of the 1-volt signal that will be applied to the circuit. The sequence will be a logarithmic progression covering several decades. At least 15 points per decade are recommended to obtain a smooth plot.

The frequency output of the function generator goes to a **Formula** object that contains the expression **log10(a)**. This output is connected to the x-axis input of an **X vs Y Plot** object, where the Bode plot will be displayed. Include the **Markers** and Delta options when you create your plot object.

The voltage gain will be calculated for each point by combining the multimeter output with the amplitude output of the function generator in another **Formula** object, to which you will add a second input pin (automatically labeled **b**). With the multimeter output connected to the **a** input, and the function generator output connected to the **b** input, the formula is **20*log10(a/b)**. This expresses the gain in dB. The output goes to the y-axis input of the XY plot.

Now you will add provisions for stopping the experiment when the cutoff frequency, or the characteristic frequency, where the voltage gain is reduced from the midband value by -3 dB, is reached. To do this, add an **If/Then** object (**Flow --> If/Then**). Open it and enter the expression

a<-3. Connect its input pin to the output of the gain-calculation object. Connect a **Break** object to the **Then** output, and nothing to the **Else** output. When the program runs, the If/Then object will see each gain value, producing no output at the Then terminal until the statement **a<-3** is true. It will then send a pulse to the **Then** terminal, which activates the Break command, stopping the program. Note that this **If/Then** object acts exactly as an If-Then loop in a conventional program.

To read the cutoff frequency, connect an Alphanumeric display to the frequency output of the function generator. Each value will be displayed in turn until the program stops. Connect another alphanumeric display to the output of the gain calculation object to read the gain at this frequency.

As always, you should give meaningful names to your objects and their terminals before you continue.

Fig. 3-1 shows a setup for this experiment. Sketch yours in your notebook. The objects named **Gain Array (dB)** and **Gain Array** are optional **logging alphanumeric** objects. At the end of execution they will contain listings of the gain at each frequency.

Procedure:

Run the program with the XY plot visible. You should see the curve being drawn. If not, click **Auto Scale**. You might have to do this more than once if the plot goes off scale. Also observe the two alphanumeric displays at the bottom of the screen. They will display the gain and the cutoff frequency at each point. When execution ceases, the gain will be slightly less than -3. If the gain is considerably less than that, you should rerun the program with more points per decade of frequency to increase the resolution of the measurement.

Compare the observed cutoff frequency with the value calculated for your circuit. Comment on any discrepancies. Do you expect close agreement between the two values?

This program works for a low-pass filter when the frequencies are increasing. It will also work for a high-pass filter when the frequency is decreasing. If you use it for a high-pass, be sure to



make the starting frequency value larger than the ending value, and enter a negative number in the points/decade box of the For Log Range object.

Make a simple change to your program so that the plot covers the entire frequency range that you entered in your **For Range** boxes, without stopping at the -3 dB point. Use the markers on the plot to calculate the rolloff rate beyond the cutoff frequency. Compare the result with the expected value.

An interesting design problem is to change the software so that a bandpass or band-reject filter can be measured, with both the low-frequency and high-frequency cutoff points identified and displayed.

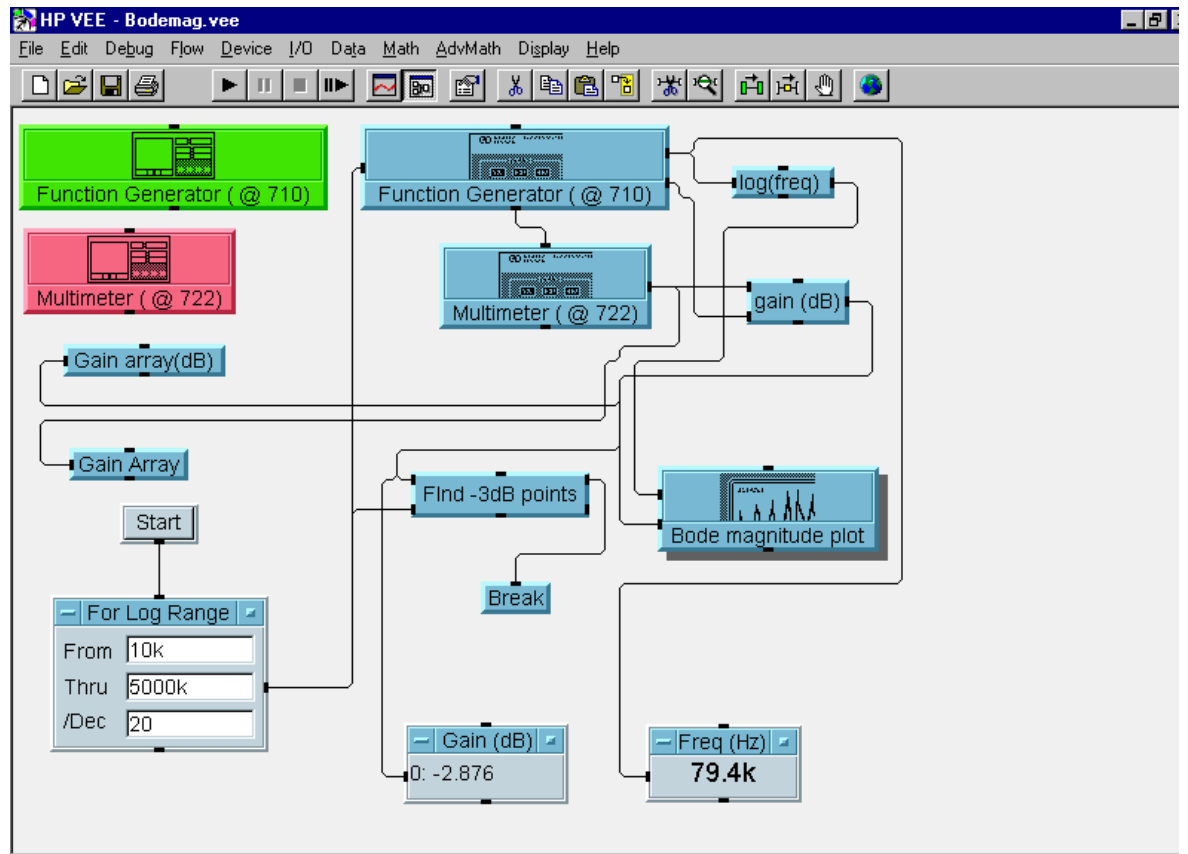


Fig. 3-1 Agilent VEE Layout for the Bode Plot Experiment