**I. Function 1 (a single output function): A Cut-off Frequency Function**

A filter circuit is one that allows some frequencies to pass through the circuit with little or no change in amplitude and others to be “attenuated” (i.e., significantly diminished in magnitude). Figure 1 shows the diagram of a very simple first-order filter using a resistor and an inductor. The left side of the filter is the input side. The input voltage has an amplitude of Vi. The output is on the right side of the filter. The output voltage has an amplitude of Vo. The attenuation of the filter is measured by the magnitude ratio, the ratio of these two voltages (Vo/Vi). The magnitude ratio varies with the frequency of the input signal. This lab analyzes the performance of this simple filter circuit to teach and give practice in programming user-defined functions in MATLAB.



**Figure 1:** The circuit diagram for a first order low-pass filter. The left side is the input and the right the output. The change in voltage will be a function of the angular frequency, ω.

Notice this circuit is a simple variation on the RL loop that was analyzed in the class on phasors. The input (Vi) is the source voltage and the output voltage (Vo) is the voltage drop across the inductor.

For the circuit in Figure 1, the Cut-off frequency is the frequency where half of the input voltage is dropped across the resistor and half across the inductor. At this point the magnitude of the impedance of the resistor (R), is equal to the magnitude of the impedance of the inductor (ωL). Setting these two equal and solving for the frequency results in equation (1).

$ω\_{c}= \frac{R}{L} or f\_{c}= \frac{R}{2πL} $ (1)

where: R = resistance of resistor (Ohms)

 L= inductance of inductor (Henrys)

 ωc = angular cutoff frequency (radians/sec.)

 fc = cyclic cutoff frequency (Hertz)

1. Function Setup
Figure 2 shows the Goal and I/O sections of a Program Development Worksheet. The next step in developing the function background is to do a careful step-by-step hand calculation to identify the steps needed and to have a calculation result to check your function with. For a resistance of 1000 Ohms and an inductance of 2 mH, calculate the cutoff frequency (f) in Hz by hand. Then list the steps required to complete this calculation.

**Check calculation with your neighbor and the instructor/TA.**

See next page for how to develop the function in MATLAB

**Figure 2:** Goal and I/O sections of the Program Development Worksheet. This information is used to setup the function definition line and to guide the key I/O variables in the function.

Set Up/ Planning Type of Program:  Script 🗹 Function

1. Problem Statement:

Write a user-defined function that returns the cyclic frequency in Hz, given the resistance in Ohms and the inductance in mH.

1. Inputs: (full name, variable to be used, units)

|  |  |  |  |
| --- | --- | --- | --- |
| Variable Name | Description | Units or Values | Input Source\* |
| R | Resistance in filter circuit | Ohms | Command line |
| L | Inductance in filter circuit | mH | Command line |

\* Possible sources: command line, file, interactive input

1. Output: (full name, variable to be used, units)

|  |  |  |  |
| --- | --- | --- | --- |
| Variable Name | Description | Units or Values | Output type\* |
| fc | Cutoff frequency for the filter  | Hz | Command line |

\* Possible types: command line, file, display

1. Code: Develop a code that matches this setup. To do this you will need to:
* Starting a Function File: There are two ways to start a function in MATLAB:

1) open a new script and type a function definition line on the first line of the file. Start with the word “function” and complete the line using the information from the setup above.

2) click on the plus sign labeled “New” on the Home Tab. This will reveal a drop down menu. Select Function for this menu. Notice the first line; this is the function definition line. It begins with word “function” which tells MATLAB this is a function not a script. The rest of this line needs to be edited to match your needs for this function. Use the information in Figure 2, replace the text “output\_args” with the output variable name and the text labeled “input\_args” with the input variable names separated by a comma. Replace “Untitled” with a name for this function (**be sure there are no spaces in the name**).

The first line in your .m-file should end up something like:
 function fc = cutoff(R, L)

Save the function to the same name as in this line (i.e., cutoff.m for the case above).

* Initial Comments: Add initial comments that form a help file for the code. Describe the purpose of the function. Put a copy of the function definition line on a separate comment line. Then define the meaning and units for the I/O variables.
* Preparation of main code and comments: Use the steps from the setup above to organize your coding of this problem. Include comments to identify the steps in your code. Do not include any additional input (no hard-coded or interactive inputs) or output (no display commands, put a semicolon at the end of all executable lines).
1. Validate:

Run the code on the test case above. To do this: (1) make sure the .m file is visible in the Current Folder window, (2) “Call” the function from the command window using a format similar to the line below:
 >> freq = cutoff (1000, 2)
Replace “cutoff” with the file name used. The result should match your test calculation (does it)?

**Prepare Solution for turn in (next week):** Copy of this function and its execution to a word document showing match to test calculation and show to your instructor.

**II. Function 2 (a two output function): Cartesian to Polar Function**

The next function to develop is one to take a complex number in Cartesian form and return the value of its polar magnitude and its angle in degrees. Steps 1-3 of the Program Development Worksheet are shown in Figure 3. Notice 1.) that all inputs and outputs are to be at the command line only, 2) this is a function version of what you developed as a script for homework.

Set Up/ Planning Type of Program:  Script 🗹 Function

1. Problem Statement:

A function that takes the Cartesian form of a complex number as the input and returns the magnitude and angle in degrees of the polar form

1. Inputs: (full name, variable to be used, units)

|  |  |  |  |
| --- | --- | --- | --- |
| Variable Name | Description | Units or Values | Input Source\* |
| C | complex number to convert | Any | Command line |

\* Possible sources: command line, file, interactive input

1. Output: (full name, variable to be used, units)

|  |  |  |  |
| --- | --- | --- | --- |
| Variable Name | Description | Units or Values | Output type\* |
| M | Magnitude of Polar form | Same as input | Command line |
| Theta | Angle of Polar form | Degrees | Command line |

\* Possible types: command line, file, display

**Figure 3:** Goal and I/O sections of the Program Development Worksheet. This information is used to setup the function definition line and to guide the key I/O variables in the function.

**Calculation and Steps:** The next step (step 4) is to do a hand calculation and list the steps required for the program. Show this step below.

Functions with 2 outputs

Take particular notice of the forms required to

1. Define a function with two outputs
2. Call a function with two outputs

**Code & Comments:** This function has a new issue in that it has two outputs. This will require a modification the function definition line. The multiple outputs are put in square brackets and are separated by a space and/or a comma. For example your function definition line for this case could be:

 function [M, Theta] = Cart2Polar(C)

Prepare the code and comments similar to the cutoff frequency function.

**Validate:**  Run the code on the test case above. To do this: (1) make sure the .m file is visible in the Current Folder window, (2) “Call” the function from the command window using a format similar to the line below:
 >> [Magnitude, Shift] = Cart2Polar (3 + 5j)
Replace “Cart2Polar” with the file name used and the input with the hand calculation above. The result should match your test calculation (does it)? **Notice** to get the two output values you need to provide two target variables, one for each of them to be stored in. Otherwise you only get the first output.

**Prepare Solution for turn in:** Copy of your hand calculation, your step list, this function and its execution to a word document.

**III. Trifolium Function: Calculate area & arc length**

The plane geometric shape shown in Figure 2 is an example of a trifolium aligned along the x-axis. This figure is plotted in polar coordinates with a scale factor of 2. The area of the trifolium is given by equation 2 and the arc (i.e., perimeter) length is approximated by equation 3.

  (2)

  (3)

where: a = a scale factor

* 1. **Setup:** Complete the first page of the program development worksheet (including goal, I/O tables, and hand calculation with steps) for a function that will calculate and return the area (Equation 2) and arc length (Equation 3) of a trifolium for given the scale factor a. This function should be able to handle vector input (i.e., the user can input a vector of scale factors and the function will return a vector of areas and a vector of arc lengths). Note: the vector calculations will require the use of a dot operator (e.g., .\*, ./ or .^). Ask if you need help with these operators.

**Figure 2:** A MATLAB polar graph of a Trifolium figure with a scale factor of 2. Notice the scale factor is the maximum radial distance. This graph shows angles in degrees.

* 1. **Code and validate:** Develop a function matching this setup and document with page 2 of the Program Development Worksheet. Validate this function for both scalar input against a hand calculation and vector input showing that the program runs with vectors and the output is logical. Copy these steps into page 2 of the Program Development Worksheet.

Turn in the complete program development worksheet for this problem (due next Lab).

**Assignment Deliverables Summary** (see rubric online) **Due:** Next Lab

1. Cutoff Frequency Function: A copy of
1) the function matching the setup in Figure 2 with complete comments and
2) its execution of the function for R = 1000 Ω, and L = 2 mH, with comparison to hand calculation.
2. Cartesian to Polar Function: A copy of
1) hand calculation for a test case and program step list,
2) the function based on Figure 3 with complete comments and
3) its execution on the same test case.
3. Trifolium Function: Complete Program Development Worksheet (available on the website) for a function to return the area and arc length (perimeter) of a Trifolium shape given its scale factor. Must include setup with calculation and steps, program with comments and validation. This function must handle vector inputs.
4. Bring ear buds or headphones that can be plugged into the lab computers to the next lab (do make sure their cord is enough to reach the computers under the desks).