# ELEN 100L (Electric Circuits II): Project 1, YourName

## Table of Contents



# Project 1: Passive Filter Design

The circuit below

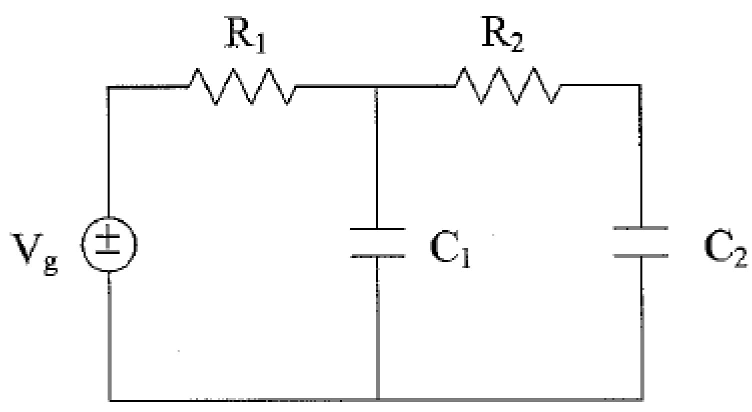



Fig. 1. A passive filter.

it driven by a sinusoidal voltage source of the form $v_g(t) = \cos \omega t$.

**Hard Copy Deliverables:**

1. Hard copy for hand calculations.
2. A MATLAB script and publish the solution using MATLAB's **publish** feature.
3. Turn in MATLAB scripts and a document of the run-time results.
4. Turn in the Excel file with the measured results.

**Soft Copy Deliverables:**

1. Turn in MATLAB files.

2. Turn in LTSpice files.

3. Turn in the Excel file with the measured results.

# Initialize MATLAB Environment

```
clear; clc; clf; cla; close all;
format long; format compact;
```

# Setup global variables

```
% These Ideal Design element values are fixed in the circuit.
VG  =  1                    ;    % Generator voltage
R1_ideal =      1250        ;    % Ohms
R2_ideal =      1333.33     ;    % Ohms
C1_ideal =      0.1*10^-6   ;    % Farads
C2_ideal =      0.1*10^-6   ;    % Farads

% These Actual Design element values are fixed in the circuit.
R1_actual =     1200        ;    % Ohms
R2_actual =     1300        ;    % Ohms
C1_actual =     0.1*10^-6   ;    % Farads
C2_actual =     0.1*10^-6   ;    % Farads

% Setup values for the poles.
w0 =     3000   ;        % Radians/Second
w1 =     20000   ;        % Radians/Second
f0 =     (3000/(2*pi))   ;        % Hertz
f1 =     (20000/(2*pi))   ;        % Hertz

% Build an array for the angular frequency and convert it to Hertz.
dw = 10;                         % Step size for analysis
w = [1:dw:w0-dw, ...
     w0, ...
     w0+dw:dw:w1-dw, ...
     w1, ...
     w1+dw:dw:1.0e6];      % Radians/Second (ensure poles are
 included)

 f =      w/(2*pi)     ;            % Hertz

% These values are used for plotting purposes.
fignum = 1;
plot_left   = 1;       plot_right = 2e5;    % x-axis range (Hertz)
plot_bottom = -90;     plot_top   = 5;      % y-axis range (dB)
```

# Problem 3

**Problem 3.** Write an m-file that solves the circuit in Fig. 1 for different frequencies. Then, plot $20 \log |H(j\omega)|$ for the element values obtained in Problem 2. Compare the obtained curve with the Bode plot of the desired transfer function, and verify that the design requirements have been met.

```
fignum = fignum+1;
```

Display the component values for the Ideal and Actual designs.

```
disp(' ');
disp('The Ideal Design component values are:');
fprintf('    R1 = %+11.4f Ohms.\n',  R1_ideal  );
fprintf('    R2 = %+11.4f Ohms.\n',  R2_ideal  );
fprintf('    C1 = %+11.4e Farads.\n', C1_ideal  );
fprintf('    C2 = %+11.4e Farads.\n', C2_ideal  );

disp(' ');
disp('The Actual Design component values are:');
fprintf('    R1 = %+11.4f Ohms.\n',  R1_actual  );
fprintf('    R2 = %+11.4f Ohms.\n',  R2_actual  );
fprintf('    C1 = %+11.4e Farads.\n', C1_actual );
fprintf('    C2 = %+11.4e Farads.\n', C2_actual );
```

```
The Ideal Design component values are:
    R1 =  +1250.0000 Ohms.
    R2 =  +1333.3300 Ohms.
    C1 = +1.0000e-07 Farads.
    C2 = +1.0000e-07 Farads.

The Actual Design component values are:
    R1 =  +1200.0000 Ohms.
    R2 =  +1300.0000 Ohms.
    C1 = +1.0000e-07 Farads.
    C2 = +1.0000e-07 Farads.
```

Compute the percent differences between the Ideal and Actual design component values.

```
diff_R1_ideal_actual = ( R1_actual - R1_ideal )/abs(R1_ideal)*100;
diff_R2_ideal_actual = ( R2_actual - R2_ideal )/abs(R2_ideal)*100;
diff_C1_ideal_actual = ( C1_actual - C1_ideal )/abs(C1_ideal)*100;
diff_C2_ideal_actual = ( C2_actual - C2_ideal )/abs(C2_ideal)*100;

disp(' ');
disp('The percent difference between Ideal and Actual design');
disp('component values:');
fprintf('    %% diff R1 = %+8.4f (%%).\n', diff_R1_ideal_actual );
fprintf('    %% diff R2 = %+8.4f (%%).\n', diff_R2_ideal_actual );
fprintf('    %% diff C1 = %+8.4f (%%).\n', diff_C1_ideal_actual );
fprintf('    %% diff C2 = %+8.4f (%%).\n', diff_C2_ideal_actual );
```

```
The percent difference between Ideal and Actual design
component values:
    % diff R1 =  -4.0000 (%).
    % diff R2 =  -2.4998 (%).
    % diff C1 =  +0.0000 (%).
    % diff C2 =  +0.0000 (%).
```

Display the poles for the target circuit design transfer function.

```
disp(' ');
disp('The poles for the circuit are:');
fprintf('    w0 = %+11.4f Radians/Second.\n',w0);
fprintf('    w1 = %+11.4f Radians/Second.\n',w1);
fprintf('    f0 = %+11.4f Hertz.\n',f0);
fprintf('    f1 = %+11.4f Hertz.\n',f1);
```

```
The poles for the circuit are:
    w0 =  +3000.0000 Radians/Second.
    w1 = +20000.0000 Radians/Second.
    f0 =   +477.4648 Hertz.
    f1 =  +3183.0989 Hertz.
```

Setup the matrices used to generate the Bode plots for the Ideal and Actual designs.

```
G1_ideal = [ ...
      (1)            (0)                           (0); ...
      (-1/R1_ideal)  (1/R1_ideal + 1/R2_ideal)     (-1/R2_ideal); ...
      (0)            (-1/R2_ideal)                 (1/R2_ideal)];

G2_ideal = [ ...
      (0)            (0)                           (0); ...
      (0)            (C1_ideal)                    (0); ...
      (0)            (0)                           (C2_ideal)];


G3_ideal = [ ...
      (0)            (0)                           (0); ...
      (0)            (0)                           (0); ...
      (0)            (0)                           (0)];


G1_actual = [ ...
      (1)            (0)                           (0); ...
      (-1/R1_actual) (1/R1_actual + 1/R2_actual) (-1/R2_actual); ...
      (0)            (-1/R2_actual)                (1/R2_actual)];


G2_actual = [ ...
      (0)            (0)                           (0); ...
      (0)            (C1_actual)                   (0); ...
      (0)            (0)                           (C2_actual)];
```

```
G3_actual = [ ...
      (0)            (0)                           (0); ...
      (0)            (0)                           (0); ...
      (0)            (0)                           (0)];


B = [VG;0;0];
```

Locate the poles in the frequency vector for plotting purposes.

```
% Find the pole values.
pole_1 = 0;
for iter = 1:length(f)              % Locate the first pole
    if (f(iter) == f0)
        pole_1 = iter;
        break;
    end
end

pole_2 = 0;
for iter = pole_1+1:length(f)      % Locate the second pole
    if (f(iter) == f1)
        pole_2 = iter;
        break;
    end
end
```

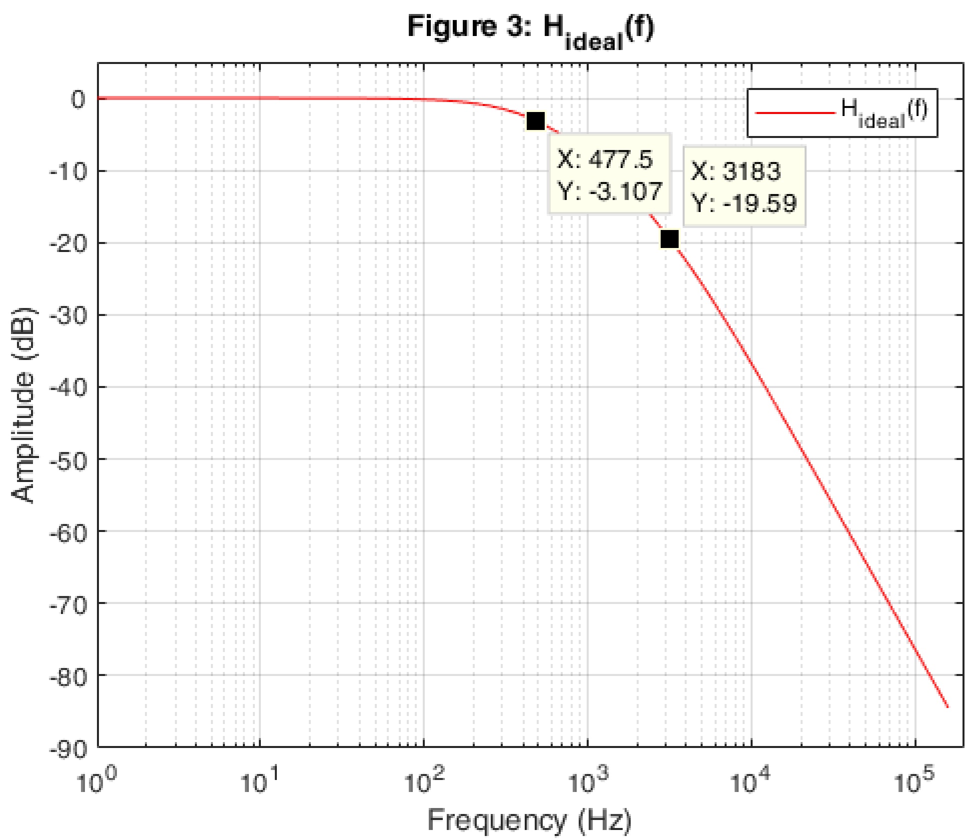
Calculate the frequency response for the Ideal and Actual designs.

```
Hw_ideal   = proj1E100_freqresp( G1_ideal,G2_ideal,G3_ideal,B,w,VG);
Hw_actual  =
 proj1E100_freqresp( G1_actual,G2_actual,G3_actual,B,w,VG);

% Capture the values at the poles.
Hw_ideal_f0  = Hw_ideal(pole_1);
Hw_ideal_f1  = Hw_ideal(pole_2);

Hw_actual_f0 = Hw_actual(pole_1);
Hw_actual_f1 = Hw_actual(pole_2);
```

Generate the plot for $H_{ideal}(f)$ and indicate where the two poles occur.

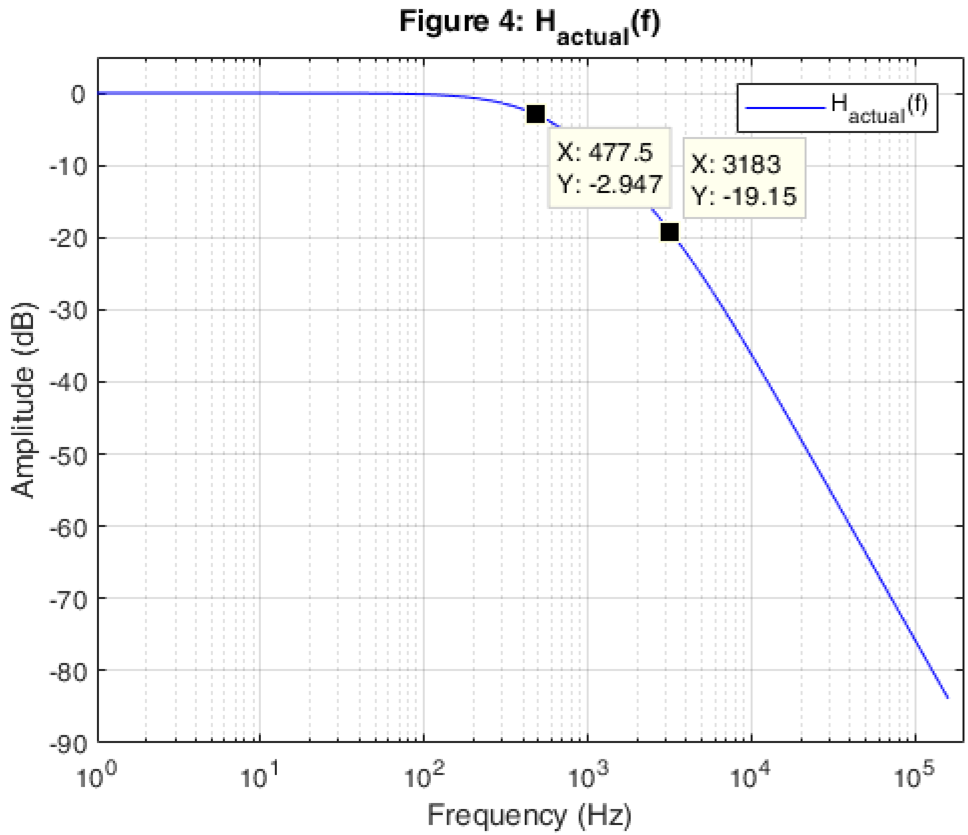
```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name',['H(f) Ideal Design']);   % Name the figure

Hw_ideal_Plot = ...
      semilogx( f, Hw_ideal ,'-r');          % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
```

```
        ': H_i_d_e_a_l(f)']);
legend('H_i_d_e_a_l(f)', 'Location', 'NorthEast');

% Add cursors to the plot.
makedatatip(Hw_ideal_Plot, [pole_1; pole_2]);
```



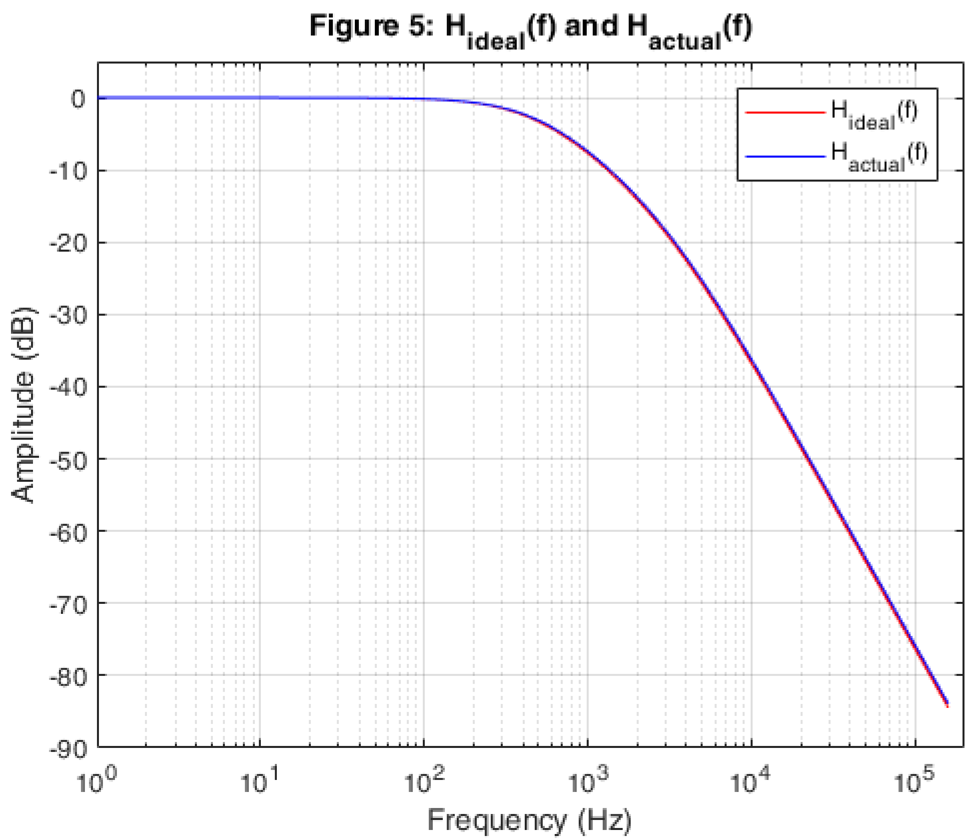

Generate the plot for $H_{actual}(f)$ and indicate where the two poles occur.

```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name',['H(f) Actual Design']);  % Name the figure

Hw_actual_Plot = ...
      semilogx(f , Hw_actual ,'-b');         % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
        ': H_a_c_t_u_a_l(f)']);
legend('H_a_c_t_u_a_l(f)', 'Location', 'NorthEast');

% Add cursors to the plot.
makedatatip(Hw_actual_Plot, [pole_1; pole_2]);
```




Generate the plot for comparing $H_{ideal}(f)$ and $H_{actual}(f)$.

```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name', ...
    ['H(f) Ideal and Actual Design']);       % Name the figure

Hw_ideal_actual_Plot = ...
    semilogx( f , Hw_ideal ,'-r', ...
              f , Hw_actual ,'-b');          % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
       ': H_i_d_e_a_l(f) and H_a_c_t_u_a_l(f)']);
legend('H_i_d_e_a_l(f)', 'H_a_c_t_u_a_l(f)', 'Location', 'NorthEast');
```




Calculate the percent difference between $H_{ideal}(f)$ and $H_{actual}(f)$ at the two poles.

```
diff_0_ideal_actual = (abs(Hw_actual_f0) - abs(Hw_ideal_f0))/
abs(Hw_ideal_f0)*100;
diff_1_ideal_actual = (abs(Hw_actual_f1) - abs(Hw_ideal_f1))/
abs(Hw_ideal_f1)*100;

disp(' ');
disp('The difference between Ideal and Actual designs at the poles:');
fprintf('    Ideal  Design H(%+10.4f) = %+8.4f (dB).\n', f0,
 Hw_ideal_f0);
fprintf('    Actual Design H(%+10.4f) = %+8.4f (dB).\n', f0,
 Hw_actual_f0);
fprintf('        %% diff = %+8.4f (%%).\n', diff_0_ideal_actual);
fprintf('    Ideal  Design H(%+10.4f) = %+8.4f (dB).\n', f1,
 Hw_ideal_f1 );
fprintf('    Actual Design H(%+10.4f) = %+8.4f (dB).\n', f1,
 Hw_actual_f1 );
fprintf('        %% diff = %+8.4f (%%).\n', diff_1_ideal_actual);
```

```
The difference between Ideal and Actual designs at the poles:
    Ideal  Design H( +477.4648) =  -3.1069 (dB).
    Actual Design H( +477.4648) =  -2.9469 (dB).
        % diff =  -5.1510 (%).
    Ideal  Design H(+3183.0989) = -19.5851 (dB).
```

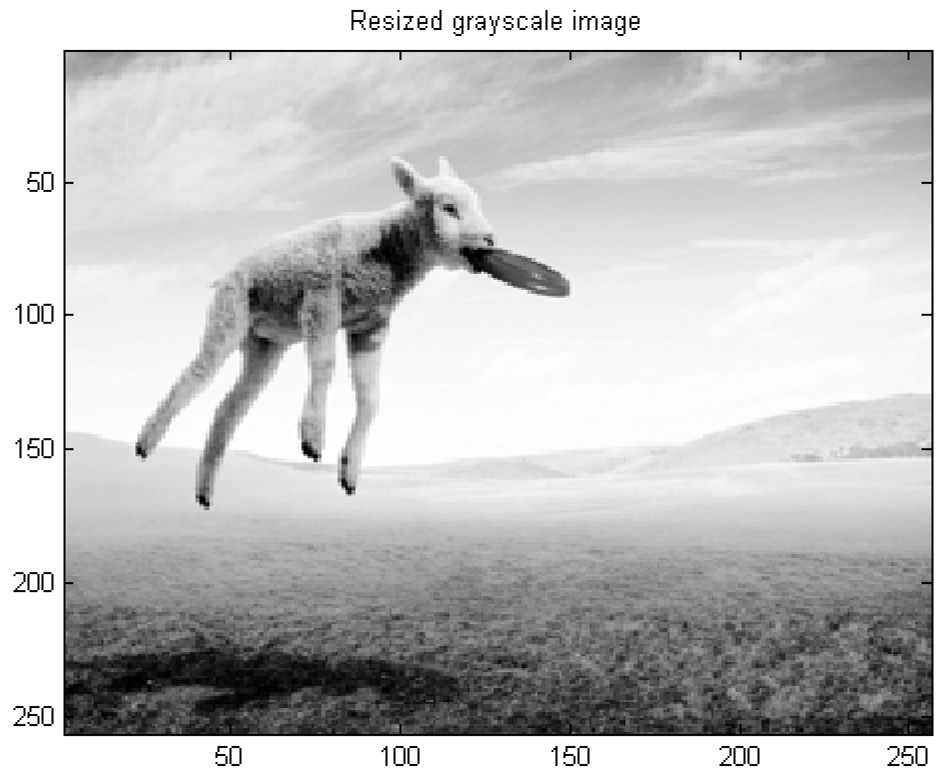
```
Actual Design H(+3183.0989) = -19.1496 (dB).
    % diff =  -2.2234 (%).
```

# Problem 4

**Problem 4.** Perform an AC analysis of your circuit in SPICE, and compare with the results obtained using Matlab.

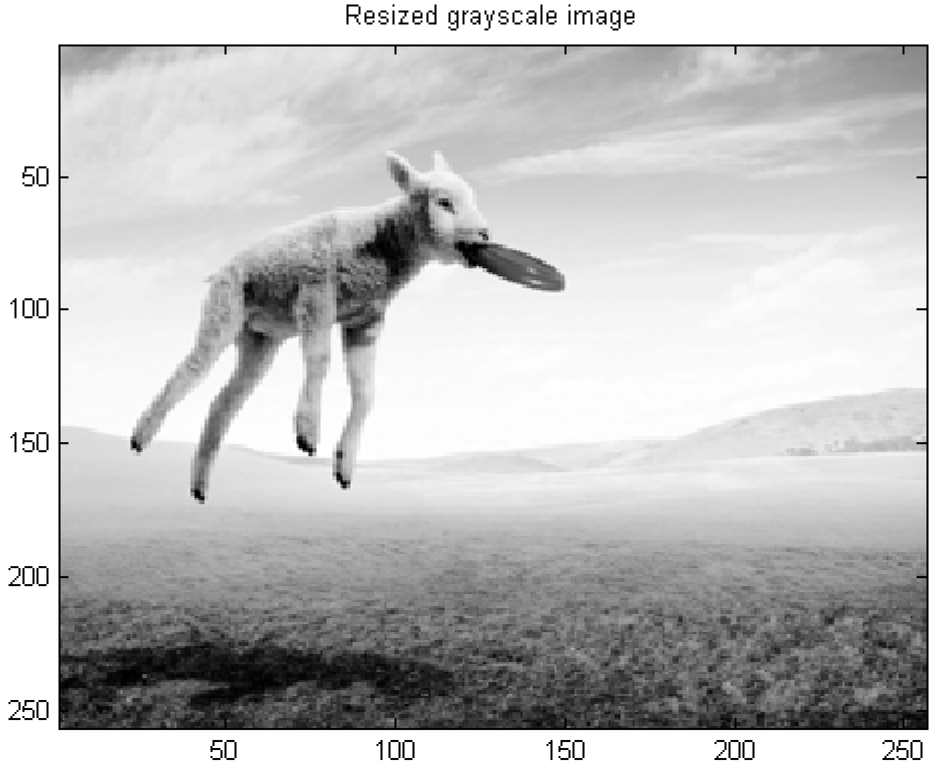
```
fignum = fignum+1;
```

The LTSpice model for the circuit is shown below.




```
fignum = fignum+1;
```

The LTSpice model for the simulation result is shown below.




```
fignum = fignum+1;
```

Calculate the percent difference between $H_{actual}(f)$ and $H_{LTSpice}(f)$ actual designs at the two poles.

```
Hw_ltspice_f0 =   -2.94  ;      % dB
Hw_ltspice_f1 =   -19.14  ;      % dB
f0_ltspice =      3000/(2*pi)       ;          % Hertz
f1_ltspice =      20000/(2*pi)      ;          % Hertz

diff_0_actual_ltspice =  (abs(f0_ltspice) - abs(Hw_actual_f0))/
abs(Hw_actual_f0)*100;
diff_1_actual_ltspice =  (abs(f1_ltspice) - abs(Hw_actual_f1))/
abs(Hw_actual_f1)*100;

disp(' ');
disp('The percent difference between MATLAB and LTSpice Actual');
disp('designs at the poles:');
fprintf('    Actual  MATLAB H(%+10.4f) = %+8.4f (dB).\n', ....
         f0, Hw_actual_f0);
fprintf('    Actual LTSpice H(%+10.4f) = %+8.4f (dB).\n', ...
         f0_ltspice, Hw_ltspice_f0);
fprintf('        %% diff = %+8.4f (%%).\n', diff_0_actual_ltspice);
fprintf('    Actual  MATLAB H(%+10.4f) = %+8.4f (dB).\n', ...
         f1, Hw_actual_f1);
fprintf('    Actual LTSpice H(%+10.4f) = %+8.4f (dB).\n', ...
         f1_ltspice, Hw_ltspice_f1);
```

```
fprintf('        %% diff = %+8.4f (%%).\n', diff_1_actual_ltspice);
```

```
The percent difference between MATLAB and LTSpice Actual
designs at the poles:
    Actual  MATLAB H( +477.4648) =  -2.9469 (dB).
    Actual LTSpice H( +477.4648) =  -2.9400 (dB).
        % diff = +16102.3129 (%).
    Actual  MATLAB H(+3183.0989) = -19.1496 (dB).
    Actual LTSpice H(+3183.0989) = -19.1400 (dB).
        % diff = +16522.2317 (%).
```

# Problem 5

**Problem 5.** Write an m-file that generates plots of $20 \log |H(j\omega)|$ for random variations in the element values (assuming 20% tolerances). Plot the curves that you obtained on a *single* graph.

```
fignum = fignum+1;
```

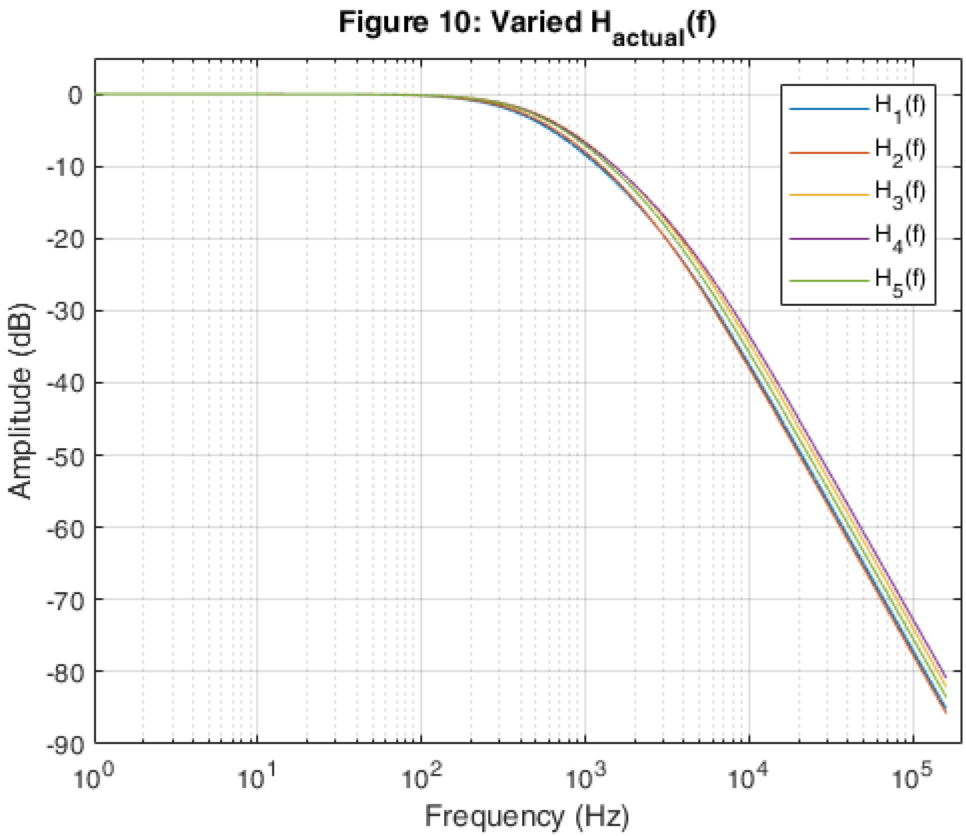
Vary the Actual design component values and calculate the frequency response for each variation.

```
% Declare the number of component value iterations.
value_sets =  5 ;

% Build the actual component vector
Q_actual = [R1_actual, R2_actual, C1_actual, C2_actual];

% Generate the frequency response values for the specified number of
% iterations.
[Hw_actual_varied, Q_actual_varied] = ...
             proj1E100_freqresp_varied( Q_actual,B,w,VG,value_sets);

% Capture the values at the poles.
Hw_actual_varied_f0 = zeros(1,value_sets);
Hw_actual_varied_f1 = zeros(1,value_sets);
for iter = 1:value_sets
    Hw_actual_varied_f0(iter)  = Hw_actual_varied(iter, pole_1);
    Hw_actual_varied_f1(iter)  = Hw_actual_varied(iter, pole_2);
end;
```

Generate the plot for variations in the Actual design component values and display all $H_{varied}(f)$ curves on a single plot.

```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name', ...
    ['H(f) Actual Design Varied']);          % Name the figure

Hw_actual_varied_Plot = ...
    semilogx( f , Hw_actual_varied );            % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
```

```
ylabel('Amplitude (dB)');                       % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);                  % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
       ': Varied H_a_c_t_u_a_l(f)']);
legend('H_1(f)', 'H_2(f)', 'H_3(f)', 'H_4(f)', 'H_5(f)', ...
       'Location', 'NorthEast');
```




Calculate the percent difference between $H_{varied}(f)$ and $H_{actual}(f)$ at the two poles of each variation.

```
diff_0_actual_varied = ...
    (Hw_actual_varied_f0 - Hw_actual_f0)/abs(Hw_actual_f0)*100;
diff_1_actual_varied = ...
    (Hw_actual_varied_f1 - Hw_actual_f1)/abs(Hw_actual_f1)*100;

disp(' ');
disp('The difference between Varied and Actual designs at the
 poles:');
for iter = 1:value_sets
    diff_R1_actual_varied = ...
        (Q_actual_varied(iter,1) - R1_actual)/abs(R1_actual)*100;
    diff_R2_actual_varied = ...
        (Q_actual_varied(iter,2) - R2_actual)/abs(R2_actual)*100;
    diff_C1_actual_varied = ...
        (Q_actual_varied(iter,3) - C1_actual)/abs(C1_actual)*100;
    diff_C2_actual_varied = ...
```

```
        (Q_actual_varied(iter,4) - C2_actual)/abs(C2_actual)*100;

    fprintf('    Variation Component Set %-2.u: \n', iter);
    fprintf('        R1 = %+11.4f Ohms,     %% diff = %+8.4f (%%).
\n', ...
            Q_actual_varied(iter,1), diff_R1_actual_varied);
    fprintf('        R2 = %+11.4f Ohms,     %% diff = %+8.4f (%%).
\n', ...
            Q_actual_varied(iter,2), diff_R2_actual_varied);
    fprintf('        C1 = %+11.4e Farads,  %% diff = %+8.4f (%%).
\n', ...
            Q_actual_varied(iter,3), diff_C1_actual_varied);
    fprintf('        C2 = %+11.4e Farads,  %% diff = %+8.4f (%%).
\n', ...
            Q_actual_varied(iter,4), diff_C2_actual_varied);
    fprintf('            Varied Design H(%+10.4f) = %+8.4f (dB).
\n', ...
            f0, Hw_actual_varied_f0(iter));
    fprintf('            Actual Design H(%+10.4f) = %+8.4f (dB).
\n', ...
            f0, Hw_actual_f0);
    fprintf('                %% diff = %+8.4f (%%).\n', ...
            diff_0_actual_varied(iter));
    fprintf('            Varied Design H(%+10.4f) = %+8.4f (dB).
\n', ...
            f1, Hw_actual_varied_f1(iter));
    fprintf('            Actual Design H(%+10.4f) = %+8.4f (dB).
\n', ...
            f1, Hw_actual_f1);
    fprintf('                %% diff = %+8.4f (%%).\n', ...
            diff_1_actual_varied(iter));
end;


The difference between Varied and Actual designs at the poles:
    Variation Component Set 1 :
        R1 =  +1274.7555 Ohms,     % diff =  +6.2296 (%).
        R2 =  +1058.5701 Ohms,     % diff = -18.5715 (%).
        C1 = +1.1397e-07 Farads,  % diff = +13.9652 (%).
        C2 = +1.1736e-07 Farads,  % diff = +17.3597 (%).
            Varied Design H( +477.4648) =  -3.5840 (dB).
            Actual Design H( +477.4648) =  -2.9469 (dB).
                % diff = -21.6194 (%).
            Varied Design H(+3183.0989) = -20.3720 (dB).
            Actual Design H(+3183.0989) = -19.1496 (dB).
                % diff =  -6.3832 (%).
    Variation Component Set 2 :
        R1 =  +1285.7929 Ohms,     % diff =  +7.1494 (%).
        R2 =  +1434.0249 Ohms,     % diff = +10.3096 (%).
        C1 = +1.0973e-07 Farads,  % diff =  +9.7253 (%).
        C2 = +9.5689e-08 Farads,  % diff =  -4.3109 (%).
            Varied Design H( +477.4648) =  -3.2870 (dB).
            Actual Design H( +477.4648) =  -2.9469 (dB).
                % diff = -11.5401 (%).
```

```
        Varied Design H(+3183.0989) = -20.4103 (dB).
        Actual Design H(+3183.0989) = -19.1496 (dB).
            % diff =  -6.5834 (%).
Variation Component Set 3 :
    R1 =  +1274.6294 Ohms,    % diff =  +6.2191 (%).
    R2 =  +1129.0171 Ohms,    % diff = -13.1525 (%).
    C1 = +1.0824e-07 Farads,  % diff =  +8.2418 (%).
    C2 = +8.1273e-08 Farads,  % diff = -18.7267 (%).
        Varied Design H( +477.4648) =  -2.5165 (dB).
        Actual Design H( +477.4648) =  -2.9469 (dB).
            % diff = +14.6066 (%).
        Varied Design H(+3183.0989) = -17.8502 (dB).
        Actual Design H(+3183.0989) = -19.1496 (dB).
            % diff =  +6.7857 (%).
Variation Component Set 4 :
    R1 =  +1092.9230 Ohms,    % diff =  -8.9231 (%).
    R2 =  +1064.0091 Ohms,    % diff = -18.1531 (%).
    C1 = +8.3885e-08 Farads,  % diff = -16.1147 (%).
    C2 = +1.1294e-07 Farads,  % diff = +12.9383 (%).
        Varied Design H( +477.4648) =  -2.6084 (dB).
        Actual Design H( +477.4648) =  -2.9469 (dB).
            % diff = +11.4849 (%).
        Varied Design H(+3183.0989) = -17.5260 (dB).
        Actual Design H(+3183.0989) = -19.1496 (dB).
            % diff =  +8.4789 (%).
Variation Component Set 5 :
    R1 =  +1293.5177 Ohms,    % diff =  +7.7931 (%).
    R2 =  +1204.8917 Ohms,    % diff =  -7.3160 (%).
    C1 = +1.1801e-07 Farads,  % diff = +18.0089 (%).
    C2 = +8.1378e-08 Farads,  % diff = -18.6222 (%).
        Varied Design H( +477.4648) =  -2.7626 (dB).
        Actual Design H( +477.4648) =  -2.9469 (dB).
            % diff =  +6.2544 (%).
        Varied Design H(+3183.0989) = -18.7825 (dB).
        Actual Design H(+3183.0989) = -19.1496 (dB).
            % diff =  +1.9173 (%).
```

# Problem 6

**Problem 6.** Assemble the designed circuit and measure $|H(j\omega)|$ for a range of relevant frequencies. Use the data to plot $20\log|H(j\omega)|$ in Matlab, and compare this with your simulation results.

```
fignum = fignum+1;
```

Display the measured values for the components used in the Actual design.

```
R1_meas =    1.1980*10^3       ;   % Ohms
R2_meas =    1.2841*10^3       ;   % Ohms
C1_meas =    0.1048*10^-6      ;   % Farads
C2_meas =    0.0989*10^-6      ;   % Farads

disp(' ');
```

```
fprintf('Measured component values are:\n');
fprintf('    R1 = %+11.4f Ohms.\n', R1_meas);
fprintf('    R2 = %+11.4f Ohms.\n', R2_meas);
fprintf('    C1 = %+11.4e Farads.\n', C1_meas);
fprintf('    C2 = %+11.4e Farads.\n', C2_meas);
```

```
Measured component values are:
    R1 =  +1198.0000 Ohms.
    R2 =  +1284.1000 Ohms.
    C1 = +1.0480e-07 Farads.
    C2 = +9.8900e-08 Farads.
```

Compute the percent differences between the Measured and Actual design component values.

```
diff_R1_meas_actual =  (R1_meas - R1_actual)/abs(R1_actual)*100;
diff_R2_meas_actual =  (R2_meas - R2_actual)/abs(R2_actual)*100;
diff_C1_meas_actual =  (C1_meas - C1_actual)/abs(C1_actual)*100;
diff_C2_meas_actual =  (C2_meas - C2_actual)/abs(C2_actual)*100;

disp(' ');
disp('The percent difference between Measured and Actual design');
disp('component values:');
fprintf('    %% diff R1 = %+8.4f (%%).\n', diff_R1_meas_actual);
fprintf('    %% diff R2 = %+8.4f (%%).\n', diff_R2_meas_actual);
fprintf('    %% diff C1 = %+8.4f (%%).\n', diff_C1_meas_actual);
fprintf('    %% diff C2 = %+8.4f (%%).\n', diff_C2_meas_actual);
```

```
The percent difference between Measured and Actual design
component values:
    % diff R1 =  -0.1667 (%).
    % diff R2 =  -1.2231 (%).
    % diff C1 =  +4.8000 (%).
    % diff C2 =  -1.1000 (%).
```

Import the measured data for processing.

The measured values for frequency response are contained in the external Excel spreadsheet file named "ELEN100L_Project_1_Measured_Results_Lab.xlsx". These measured values are imported into MATLAB at run-time using MATLAB's **Import** feature. For the solution shown below, the initial "import" was executed to generate an external function file which can be called at run-time.

```
[freq_meas,Vg_meas,Vo_meas] = importfile_problem6...
    ('ELEN100L_Project_1_Measured_Results_Lab.xlsx','Sheet1',2,81);

% Convert the measured column vectors to single row vectors.
dim = size(freq_meas);   rows = 1;     columns = dim(1,1);
freq_meas = reshape(freq_meas, rows, dim(1,1));
Vg_meas   = reshape(Vg_meas  , rows, dim(1,1));
Vo_meas   = reshape(Vo_meas  , rows, dim(1,1));
```

Locate the poles in the frequency vector for plotting purposes.

```
converge_criteria = 1.0;
```

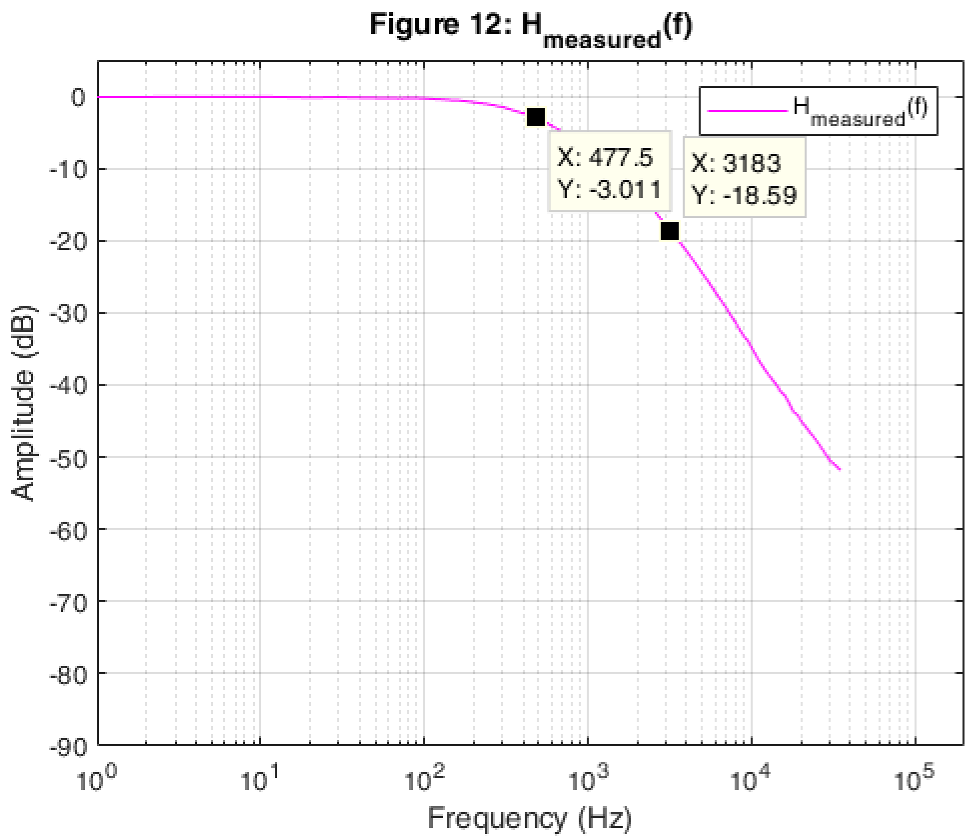
```
% Find the pole values.
pole_1_meas = 0;
for iter = 1:length(freq_meas)            % Locate the first pole
    if (abs(freq_meas(iter) - f0) <= converge_criteria)
        pole_1_meas = iter;
        break;
    end;
end;

pole_2_meas = 0;
for iter = pole_1_meas+1:length(freq_meas)     % Locate the second
 pole
    if (abs(freq_meas(iter) - f1) <= converge_criteria)
        pole_2_meas = iter;
        break;
    end;
end;
```

Calculate the frequency response for the Measured Actual design.

```
Hw_meas_actual = 20*log10(abs(Vo_meas)./abs(Vg_meas)) ;  % |H(w)| in
 decibels (dB) is a function9
% of Vo_meas and Vg_meas

% This section of code is used to generate an expected frequency
 response
% based upon the measured component values.
G1_sim_meas_actual = [ ...
      (1)            (0)                         (0); ...
      (-1/R1_meas)   (1/R1_meas + 1/R2_meas)     (-1/R2_meas); ...
      (0)            (-1/R2_actual)              (1/R2_meas)];

G2_sim_meas_actual = [ ...
      (0)            (0)                         (0); ...
      (0)            (C1_meas)                   (0); ...
      (0)            (0)                         (C2_meas)];

G3_sim_meas_actual = [ ...
      (0)            (0)                         (0); ...
      (0)            (0)                         (0); ...
      (0)            (0)                         (0)];

Hw_sim_meas_actual = ...
    proj1E100_freqresp(G1_sim_meas_actual, G2_sim_meas_actual,...
                       G3_sim_meas_actual, B, 2*pi*freq_meas, VG);

% Capture the values at the poles.
Hw_meas_actual_f0 = Hw_meas_actual(pole_1_meas);
Hw_meas_actual_f1 = Hw_meas_actual(pole_2_meas);

Hw_sim_meas_actual_f0 = Hw_sim_meas_actual(pole_1_meas);
Hw_sim_meas_actual_f1 = Hw_sim_meas_actual(pole_2_meas);
```

Generate the plot for $H_{measured}(f)$ and indicate where the two poles occur.

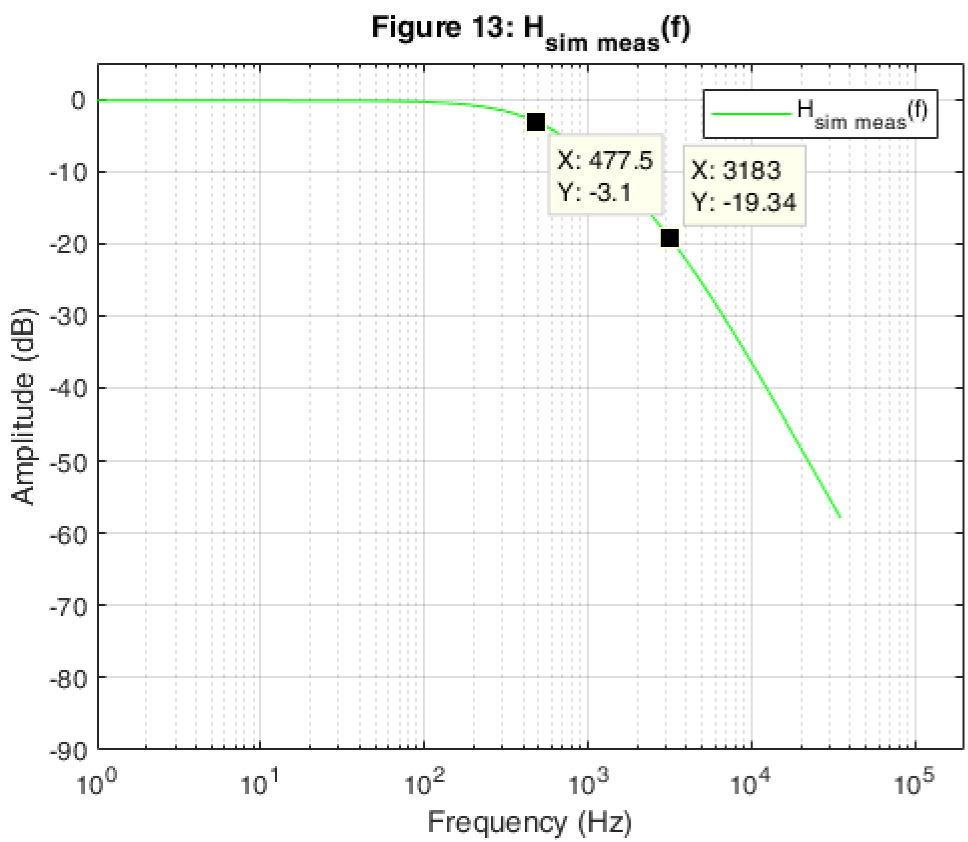
```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name', ...
    ['H(f) Measured Actual Design']);        % Name the figure

Hw_meas_actual_Plot = semilogx(...
          freq_meas , Hw_meas_actual,'-m');      % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
       ': H_m_e_a_s_u_r_e_d(f)']);
legend('H_m_e_a_s_u_r_e_d(f)', 'Location', 'NorthEast');

% Add cursors to the plot.
makedatatip(Hw_meas_actual_Plot, [pole_1_meas; pole_2_meas]);
```




Generate the plot for $H_{simulatemeasured}(f)$ and indicate where the two poles occur.

```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name', ...
  ['H(f) Simulate Measured Actual Design']); % Name the figure
```

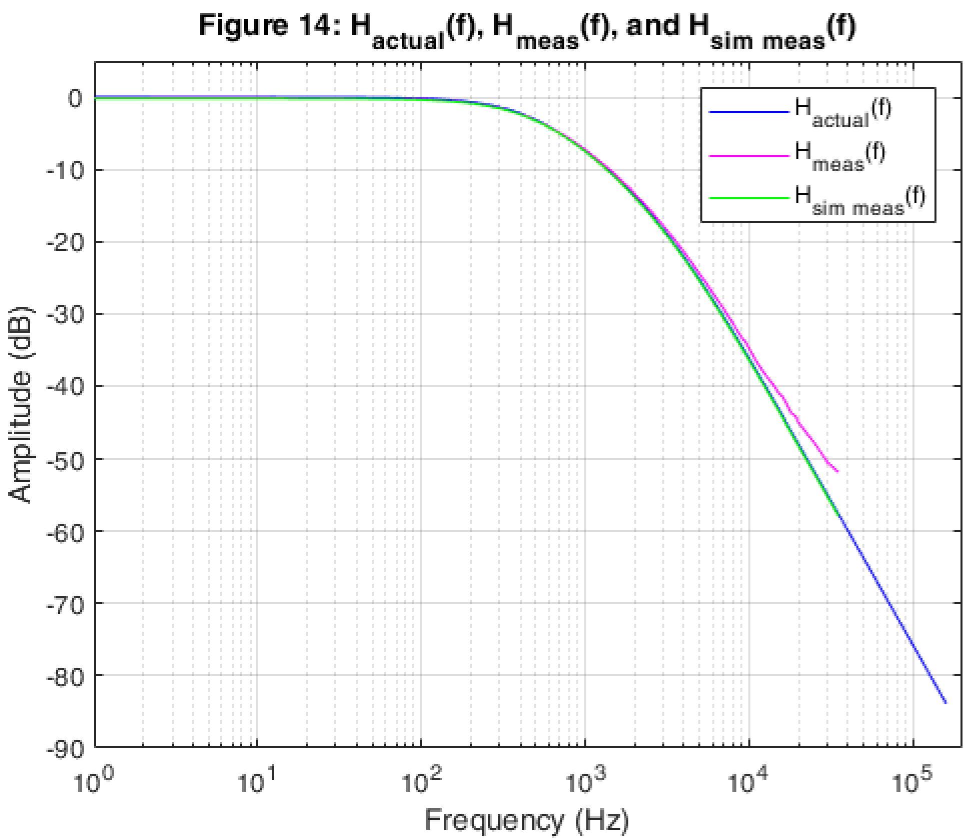
```
Hw_sim_meas_actual_Plot = semilogx(...
         freq_meas , Hw_sim_meas_actual,'-g');       % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
       ': H_s_i_m_ _m_e_a_s(f)']);
legend('H_s_i_m_ _m_e_a_s(f)', 'Location', 'NorthEast');

% Add cursors to the plot.
makedatatip(Hw_sim_meas_actual_Plot, [pole_1_meas; pole_2_meas]);
```




Generate the plot for comparing $H_{measured}(f)$, $H_{simulatemeasured}(f)$ and $H_{actual}(f)$.

```
fignum = fignum+1; figObj = figure(fignum);  % Establish a figure
 number
set(fignum, 'Name', ...
    ['H(f) Measured and Actual Design']);    % Name the figure

semilogx( f, Hw_actual,'-b',...
          freq_meas, Hw_meas_actual,'-m', ...
          freq_meas, Hw_sim_meas_actual,'-g');       % Generate plot
grid on;                                     % Turn grid on
xlabel('Frequency (Hz)');                    % Label the x-axis
```

```
ylabel('Amplitude (dB)');                    % Label the y-axis
axis([plot_left, plot_right, ...
      plot_bottom, plot_top]);               % Bound plot
title(['Figure ',num2str(fignum,'%-2.u'),...
       ': H_a_c_t_u_a_l(f), H_m_e_a_s(f), and H_s_i_m_ _m_e_a_s(f)']);
legend('H_a_c_t_u_a_l(f)', 'H_m_e_a_s(f)', ...
       'H_s_i_m_ _m_e_a_s(f)',...
       'Location', 'NorthEast');
```




Calculate the percent difference between $H_{measured}(f)$, $H_{simulatemeasured}(f)$, and $H_{actual}(f)$ actual designs at the two poles.

```
f0_measured = freq_meas(pole_1_meas);         % Hertz
f1_measured = freq_meas(pole_2_meas);         % Hertz

diff_0_meas_actual = ...
    (Hw_meas_actual_f0 - Hw_actual_f0)/abs(Hw_actual_f0)*100;
diff_1_meas_actual = ...
    (Hw_meas_actual_f1 - Hw_actual_f1)/abs(Hw_actual_f1)*100;

diff_0_sim_meas_actual = ...
    (Hw_sim_meas_actual_f0 - Hw_actual_f0)/abs(Hw_actual_f0)*100;
diff_1_sim_meas_actual = ...
    (Hw_sim_meas_actual_f1 - Hw_actual_f1)/abs(Hw_actual_f1)*100;

disp(' ');
```

```
disp('The percent difference between MATLAB and Measured Actual');
disp('designs at the poles:');
fprintf('    Actual     MATLAB H(%+10.4f) = %+8.4f (dB).\n', ....
        f0, Hw_actual_f0);
fprintf('    Actual   Measured H(%+10.4f) = %+8.4f (dB).\n', ...
        f0_measured, Hw_meas_actual_f0);
fprintf('        %% diff = %+8.4f (%%).\n', diff_0_meas_actual);
fprintf('    Actual     MATLAB H(%+10.4f) = %+8.4f (dB).\n', ....
        f1, Hw_actual_f1);
fprintf('    Actual   Measured H(%+10.4f) = %+8.4f (dB).\n', ...
        f1_measured, Hw_meas_actual_f1);
fprintf('        %% diff = %+8.4f (%%).\n', diff_1_meas_actual);

disp(' ');
disp('The percent difference between MATLAB and the simulated');
disp('Measured Actual designs at the poles:');
fprintf('    Actual     MATLAB H(%+10.4f) = %+8.4f (dB).\n', ....
        f0, Hw_actual_f0);
fprintf('    Simulate Measured H(%+10.4f) = %+8.4f (dB).\n', ...
        f0_measured, Hw_sim_meas_actual_f0);
fprintf('        %% diff = %+8.4f (%%).\n', diff_0_sim_meas_actual);
fprintf('    Actual     MATLAB H(%+10.4f) = %+8.4f (dB).\n', ...
        f1, Hw_actual_f1);
fprintf('    Simulate Measured H(%+10.4f) = %+8.4f (dB).\n', ...
        f1_measured, Hw_sim_meas_actual_f1);
fprintf('        %% diff = %+8.4f (%%).\n', diff_1_sim_meas_actual);
```

```
The percent difference between MATLAB and Measured Actual
designs at the poles:
    Actual     MATLAB H( +477.4648) =  -2.9469 (dB).
    Actual   Measured H( +477.4648) =  -3.0112 (dB).
        % diff =  -2.1822 (%).
    Actual     MATLAB H(+3183.0989) = -19.1496 (dB).
    Actual   Measured H(+3183.0989) = -18.5927 (dB).
        % diff =  +2.9084 (%).

The percent difference between MATLAB and the simulated
Measured Actual designs at the poles:
    Actual     MATLAB H( +477.4648) =  -2.9469 (dB).
    Simulate Measured H( +477.4648) =  -3.1003 (dB).
        % diff =  -5.2057 (%).
    Actual     MATLAB H(+3183.0989) = -19.1496 (dB).
    Simulate Measured H(+3183.0989) = -19.3426 (dB).
        % diff =  -1.0078 (%).
```

# Program execution complete

```
disp(' ');
disp('Program execution complete....');
```

```
Program execution complete....
```

# MATLAB code listing

*Published with MATLAB® R2017a*