ELEN 100L (Electric Circuits II): Project 1, Christian Garcia and Logan Barnes

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To Submit:

1. Scanned copy of ALL hand calculations.

2. A MATLAB script and publish the solution using MATLAB's **publish** feature.%

3. Turn in all MATLAB files.

4. Turn in all LTSpice files.

5. Turn in Screenshot of LTSpice measurement.

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           ;    % Ohms
C1_ideal =      0.1e-6           ;    % Farads
C2_ideal =      0.1e-6           ;    % Farads

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

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

```
f1 =     w1/(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

```
% 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 =  +1333.0000 Ohms.
    C1 = +1.0000e-07 Farads.
    C2 = +1.0000e-07 Farads.

The Actual Design component values are:
    R1 =  +1300.0000 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 =  -2.4756 (%).
    % 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)];

G3_ideal = [ 0,0,0;0,0,0;0,0,0 ];

G2_ideal = [ 0,0,0;0,C1_ideal,0;0,0,C2_ideal ];

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

G3_actual = [ 0,0,0;0,0,0;0,0,0 ];
```

```
G2_actual = [ 0,0,0;0,C1_actual,0;0,0,C2_actual ];

B = [ 1;0;0 ];
```

Locate the poles in the frequency vector for plotting purposes.

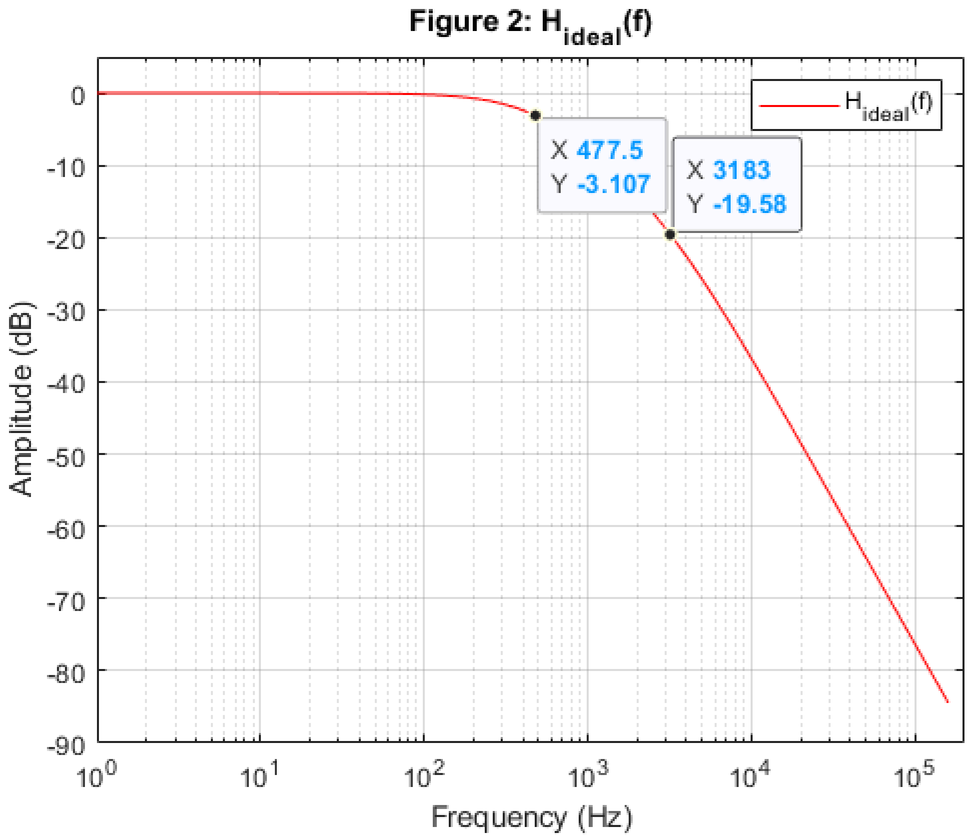
```
% Find the pole values.
pole_1 = 0;
for iter = 1:length(f)                % Locate the first pole
    if (f(iter) == f0)
        pole_1 = iter;
        break;
    end
end

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);
```

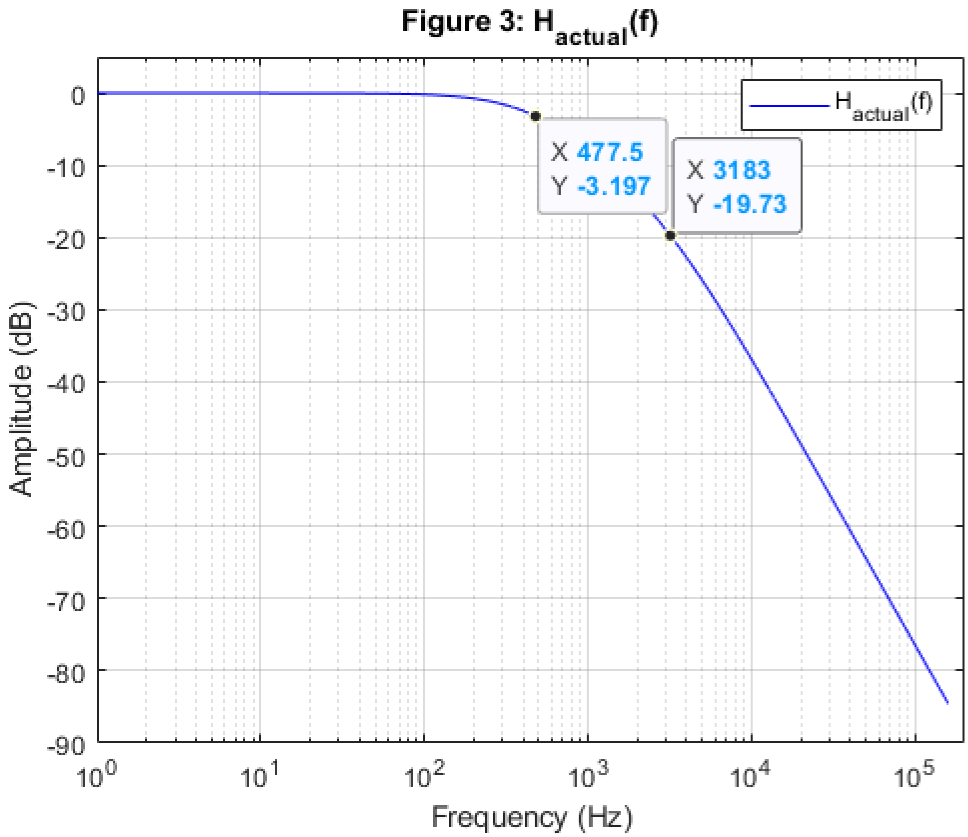
Generate the plot for $H_{ideal}(f)$ and indicate where the two poles occur.

```
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]);
```



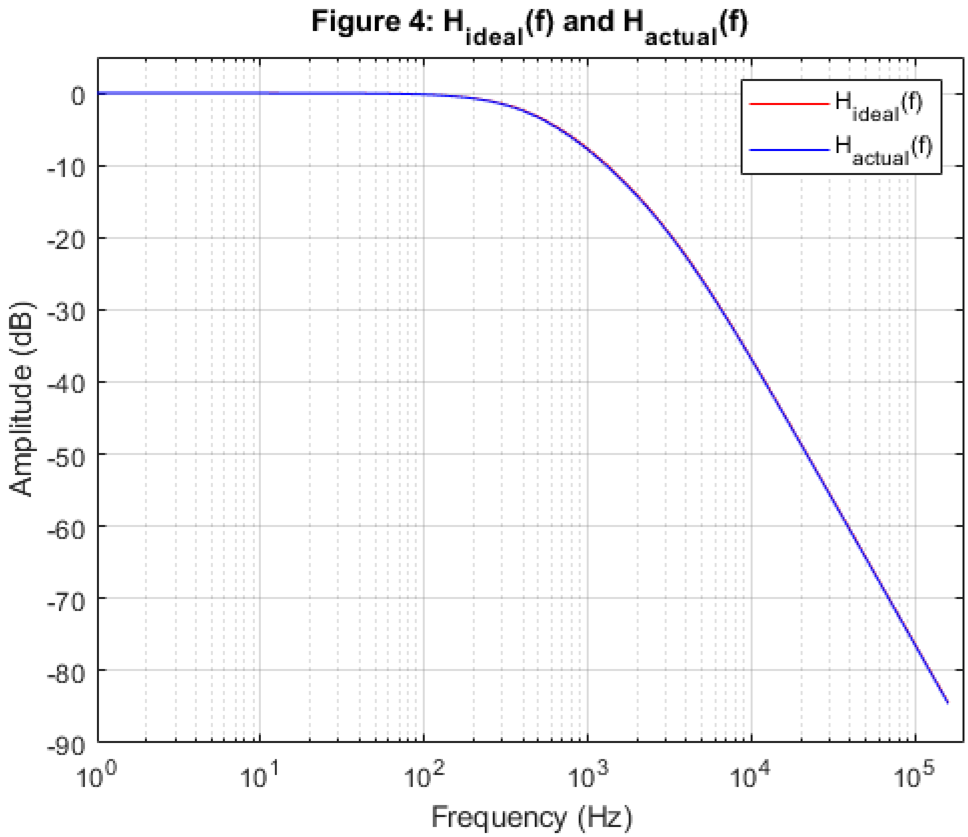
Generate the plot for $H_{actual}(f)$ and indicate where the two poles occur.

```
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 = ( Hw_actual_f0 - Hw_ideal_f0 )/
abs(Hw_ideal_f0)*100;
diff_1_ideal_actual = ( Hw_actual_f1 - 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) =  -3.1066 (dB).
    Actual Design H( +477.4648) =  -3.1970 (dB).
        % diff =  -2.9093 (%).
    Ideal  Design H(+3183.0989) = -19.5837 (dB).
```

```
    Actual Design H(+3183.0989) = -19.7321 (dB).
        % diff =  -0.7576 (%).
```

Problem 4

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

Hw_ltspice_f0 =     -3.167      ;      % dB
Hw_ltspice_f1 =     -19.73      ;      % dB
f0_ltspice =      3000/(2*pi)    ;          % Hertz
f1_ltspice =      20000/(2*pi)    ;          % Hertz

diff_0_actual_ltspice =  ( Hw_ideal_f0 - Hw_actual_f0 )/
abs(Hw_actual_f0)*100;
diff_1_actual_ltspice =  ( Hw_ideal_f1 - 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) =  -3.1970 (dB).
    Actual LTSpice H( +477.4648) =  -3.1670 (dB).
        % diff =  +2.8271 (%).
    Actual  MATLAB H(+3183.0989) = -19.7321 (dB).
    Actual LTSpice H(+3183.0989) = -19.7300 (dB).
        % diff =  +0.7519 (%).
```

Problem 5

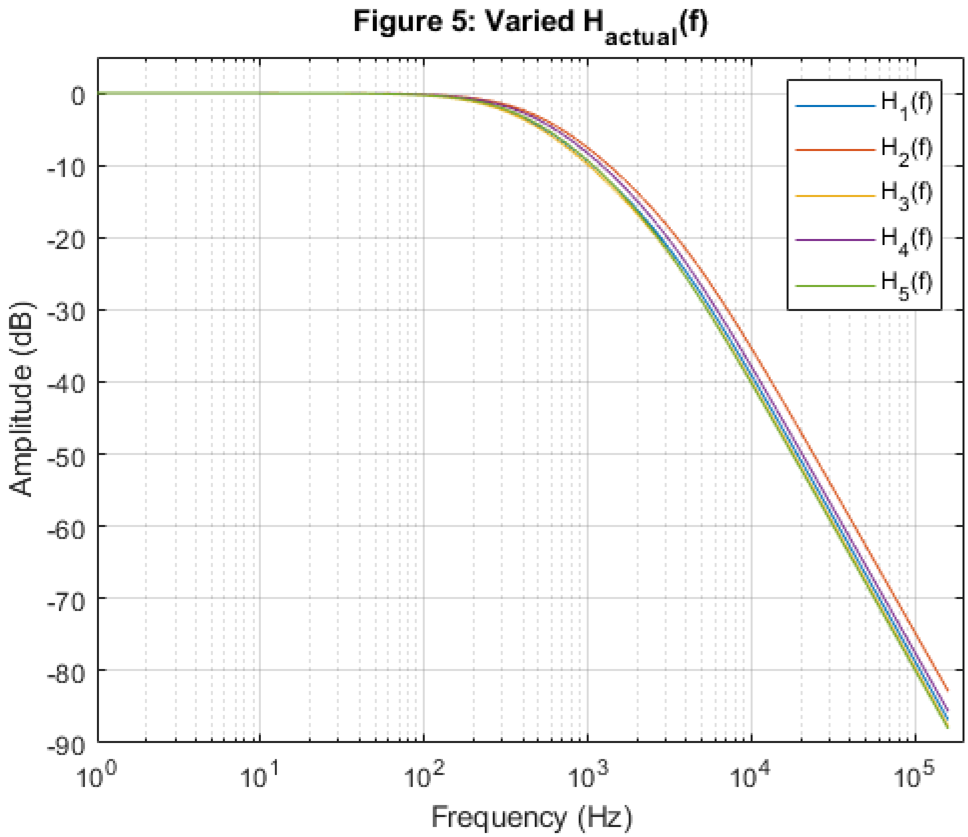
Vary the Actual design component values and calculate the frequency response for each variation.

```
% 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 =  +1463.6563 Ohms,    % diff = +12.5889 (%).
        R2 =  +1511.0118 Ohms,    % diff = +16.2317 (%).
        C1 = +8.5079e-08 Farads,  % diff = -14.9205 (%).
        C2 = +1.1654e-07 Farads,  % diff = +16.5350 (%).
            Varied Design H( +477.4648) =  -4.2199 (dB).
            Actual Design H( +477.4648) =  -3.1970 (dB).
                % diff = -31.9973 (%).
            Varied Design H(+3183.0989) = -21.7375 (dB).
            Actual Design H(+3183.0989) = -19.7321 (dB).
                % diff = -10.1630 (%).
    Variation Component Set 2 :
        R1 =  +1368.8268 Ohms,    % diff =  +5.2944 (%).
        R2 =  +1090.7210 Ohms,    % diff = -16.0984 (%).
        C1 = +9.1140e-08 Farads,  % diff =  -8.8601 (%).
        C2 = +1.0188e-07 Farads,  % diff =  +1.8753 (%).
            Varied Design H( +477.4648) =  -3.0832 (dB).
            Actual Design H( +477.4648) =  -3.1970 (dB).
                % diff =  +3.5594 (%).
            Varied Design H(+3183.0989) = -18.8651 (dB).
            Actual Design H(+3183.0989) = -19.7321 (dB).
                % diff =  +4.3938 (%).
    Variation Component Set 3 :
        R1 =  +1537.9036 Ohms,    % diff = +18.3003 (%).
        R2 =  +1541.7420 Ohms,    % diff = +18.5955 (%).
        C1 = +8.6305e-08 Farads,  % diff = -13.6955 (%).
        C2 = +1.1882e-07 Farads,  % diff = +18.8237 (%).
```

```
        Varied Design H( +477.4648) =  -4.5457 (dB).
        Actual Design H( +477.4648) =  -3.1970 (dB).
            % diff = -42.1883 (%).
        Varied Design H(+3183.0989) = -22.4455 (dB).
        Actual Design H(+3183.0989) = -19.7321 (dB).
            % diff = -13.7512 (%).
Variation Component Set 4 :
    R1 =  +1537.7268 Ohms,    % diff = +18.2867 (%).
    R2 =  +1292.3953 Ohms,    % diff =  -0.5850 (%).
    C1 = +1.1201e-07 Farads,  % diff = +12.0112 (%).
    C2 = +8.5675e-08 Farads,  % diff = -14.3245 (%).
        Varied Design H( +477.4648) =  -3.4910 (dB).
        Actual Design H( +477.4648) =  -3.1970 (dB).
            % diff =  -9.1961 (%).
        Varied Design H(+3183.0989) = -20.5206 (dB).
        Actual Design H(+3183.0989) = -19.7321 (dB).
            % diff =  -3.9961 (%).
Variation Component Set 5 :
    R1 =  +1259.3159 Ohms,    % diff =  -3.1295 (%).
    R2 =  +1516.1825 Ohms,    % diff = +16.6294 (%).
    C1 = +1.1169e-07 Farads,  % diff = +11.6883 (%).
    C2 = +1.1838e-07 Farads,  % diff = +18.3797 (%).
        Varied Design H( +477.4648) =  -4.1140 (dB).
        Actual Design H( +477.4648) =  -3.1970 (dB).
            % diff = -28.6833 (%).
        Varied Design H(+3183.0989) = -22.3258 (dB).
        Actual Design H(+3183.0989) = -19.7321 (dB).
            % diff = -13.1446 (%).
```

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