Contents

MNPA

```
DC and AC analysis of a linear circuit using MNA techniques

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Structure and Problem provided by: Professor Smy, 2021
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```
set(0,'DefaultFigureWindowStyle','docked')
set(0, 'defaultaxesfontsize', 12)
set(0, 'defaultaxesfontname', 'Times New Roman')
set(0, 'DefaultLineLineWidth',2);

clear all
close all
```

Defining Circuit Parameters

The capacitor and inductor in the circuit give it a Bandpass-like filter. There are no non-linear capacitors (hence no charge designations are needed)

```
R1 = 1;
C_1 = 0.25;
R2 = 2;
L = 0.2;
R3 = 10;
alpha = 100;
R4 = 0.1;
Ro = 1000;

% DC sweep for 100 Vin values
Vin = -10:0.1:10;
%Vin = Vin';
```

Breaking the circuit down into Differential Equations

Assuming V1 is the current that flows thru Node 1, V2 is the current that flows thru Node 2, Iin is the current going into the circuit, Il is the current thru inductor, etc, the differential equations become:

```
G1 = 1/R1;
G2 = 1/R2;
G3 = 1/R3;
G4 = 1/R4;
Go = 1/Ro;

% V1 = Vin;
% G1(V1 - V2) + sC_1(V1 - V2) + Iin = 0;
% G1(V2 - V1) + sC_1(V2 - V1) + V2*G2 + Il = 0;
% V2 - V3 -sL = 0
% G3*V3 - Il = 0
% V4 - G3*alpha*V3 = 0
% G4*(V4 - V5) + I_alpha = 0
% G4*(V5 - V4) + V5*Go = 0

% These equations were used to construct the G conductance matrix and the C
% capacitance matrix. The F vector is for the source.
G = zeros(6,6);
C = zeros(6,6);
F = zeros(6,1);

G(1,1) = 1;
G(2,1) = G1;
G(2,2) = -(G1+G2);
G(2,6) = -1;
G(3,3) = -G3;
G(3,6) = 1;
G(4,3) = -G3*alpha;
G(4,4) = 1;
G(5,5) = -(G4+Go);
G(5,4) = G4;
G(6,2) = -1;
G(6,3) = 1;

C(2,1) = C_1;
C(2,2) = -C_1;
C(6,6) = L;

index = 0;
for Vin = linspace(-10,10,100)
   index = index + 1;
```

```
    F(1) = Vin;
    V = G\F;
    Vout(index) = V(5);
    V_3(index) = V(3);
    Vin_vector(index) = Vin;
end
```

Outputs

Plot 1: Vout vs Vin DC simulation (circuit has some visible gain)

```
figure
subplot(3,2,1)
plot(Vin_vector, Vout);
title('Vout and V3 vs. Vin DC Sim');
xlabel('Vin (V)');
ylabel('V (V)');
hold on;
plot(Vin_vector, V_3);
legend('Vout', 'V3')
grid on;

% Converting to frequency domain requires the taking the time derivative
% which can then be solved for any omega
index = 0;
F(1) = 1;
for w = linspace(0,100,100)
    index = index + 1;
    omega(index) = w;
    V_ac = (G + 1j*omega(index).*C)\F;
    V_out_ac(index) = V_ac(5);
    gain(index) = 20*log10(abs(V_ac(5))/F(1));
end

% Plot 2: Voltage as a function of omega (going from 0 to 100) with a peak
% at approx 18 showing Bandpass filter-like behaviour
subplot(3,2,2)
plot(omega, abs(V_out_ac));
title('Vout as a fucntion of omega');
xlabel('omega (rad/s)');
ylabel('Vout (V)');
grid on;

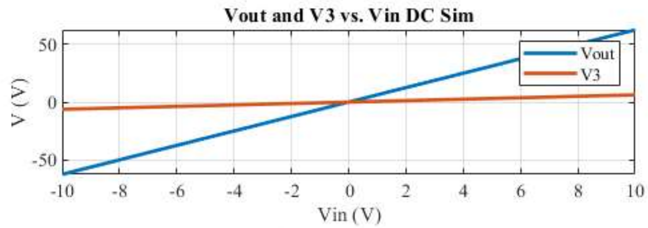
%Plot 3: Gain in dB
subplot(3,2,3)
plot(omega, gain);
title('Gain Vo/Vin dB');
xlabel('omega (rads/s)');
ylabel('Gain (dB)');
grid on;

% Plot 4 and 5: Monte-Carlo simulation of the circuit multiple times with a
% given standard deviation = 0.05 and normal distribution centered around the
% given values of C = 0.25 and Gain figures, with omega = pi
std = 0.05;

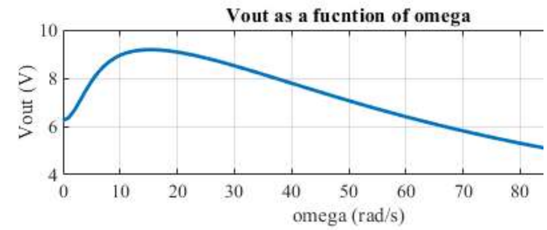
index = 0;
for i = linspace(0,100,1000)
    index = index + 1;
    C(2,1) = C_1 + std*randn();
    C(2,2) = -(C_1 + std*randn());
    C(6,6) = L + std*randn();
    C_o(index) = C_1 + std*randn();
    V_vector = (G + 1j*pi.*C_o(index))\F;
    V_vec = (G + 1j*pi.*C)\F;
    gain_d(index) = 20*log10(abs(V_vec(5))/F(1));
end

subplot(3,2,5)
histogram(C_o)
xlim([0.10,0.40])
xlabel('C');
ylabel('Number');
grid on;

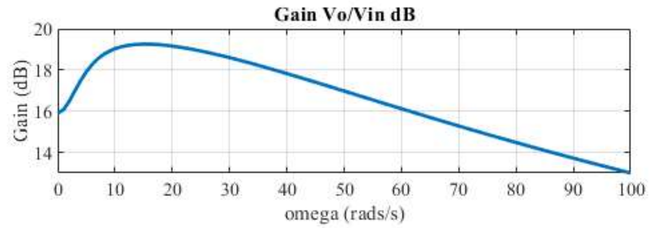
subplot(3,2,6)
histogram(gain_d)
xlabel('V_o/V_i (dB)');
ylabel('Number');
grid on;
```



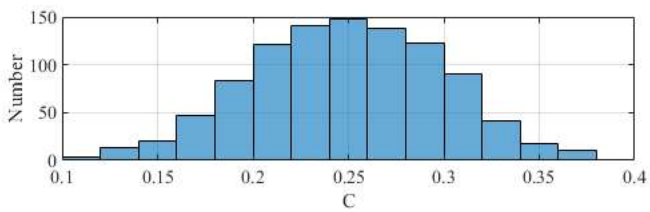
Vout and V3 vs. Vin DC Sim
V (V)
Vin (V)
Vout
V3



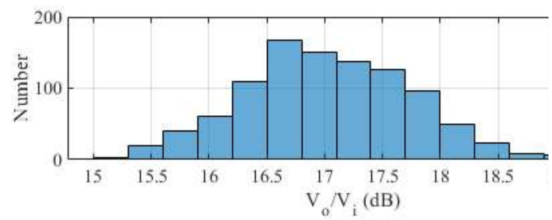
Vout as a fucntion of omega
Vout (V)
omega (rad/s)



Gain Vo/Vin dB
Gain (dB)
omega (rads/s)



Number
C



Number
V_o/V_i (dB)