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Part 3

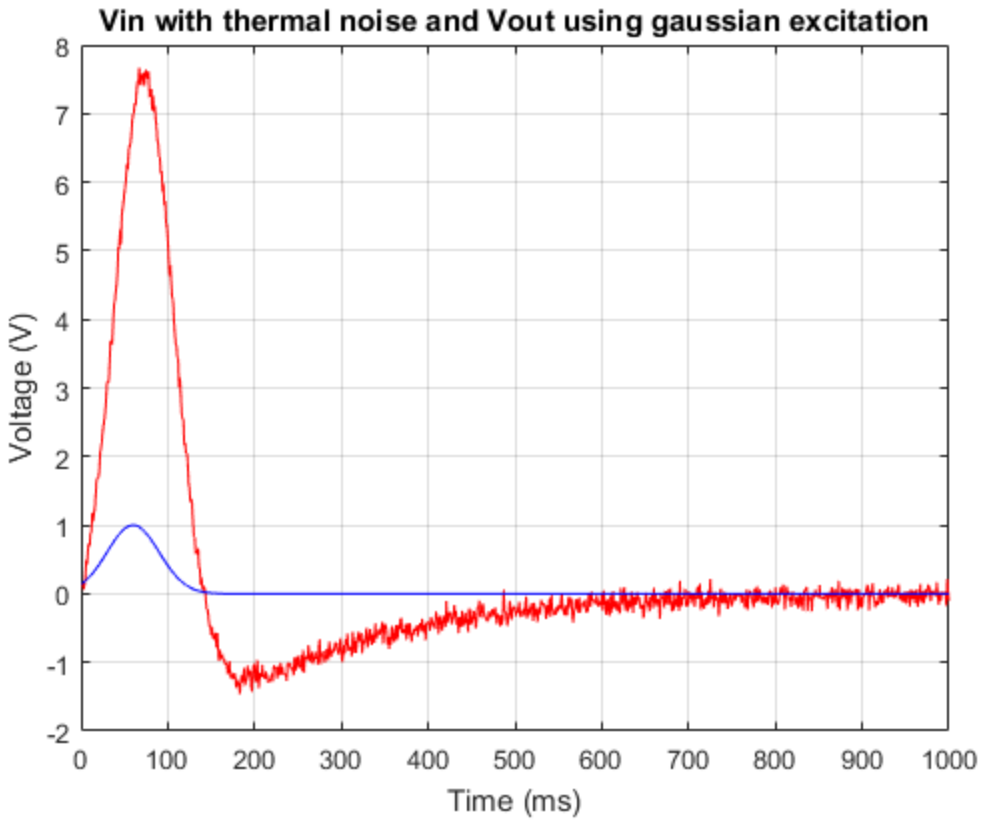
In part 3, we are adding a current source and a capacitor into the circuit and simulate it in order to model thermal noise generated in the resistor R3 and bandwidth limit to noise respectively.

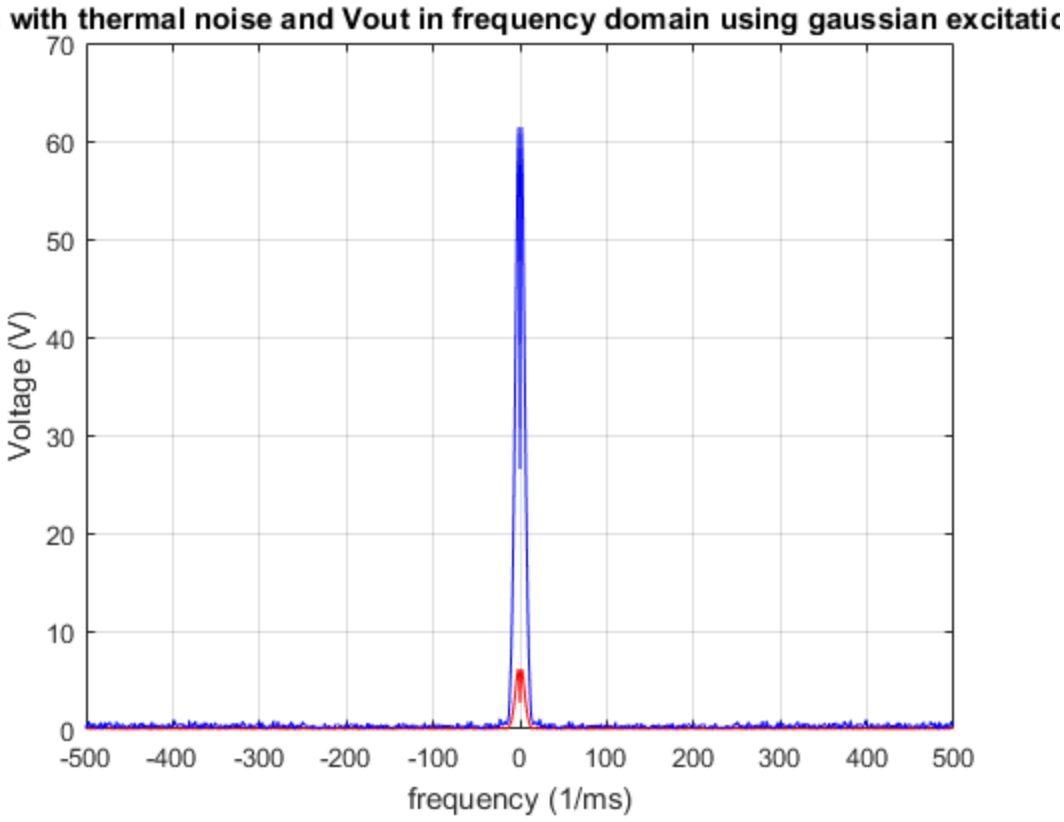
```
% Reset Everything
close all
clear

% Define Constant
R1 = 1;
G1 = 1/R1;
c = 0.25;
R2 = 2;
G2 = 1/R2;
L = 0.2;
R3 = 10;
G3 = 1/R3;
a = 100;
R4 = 0.1;
G4 = 1/R4;
Ro = 1000;
Go = 1/Ro;
Vin = 1;
cn1 = 1e-5;                 % Default capacitances
cn2 = 1e-12;                % Two new capacitances
cn3 = 5.2e-5;

% Creating Matrices
C1 = [0 0 0 0 0 0 0;
    -c c 0 0 0 0 0;
    0 0 -L 0 0 0 0;
    0 0 0 -cn1 0 0 0;
    0 0 0 0 0 0 0;
    0 0 0 -cn1 0 0 0;
    0 0 0 0 0 0 0;];

C2 = [0 0 0 0 0 0 0;
    -c c 0 0 0 0 0;
    0 0 -L 0 0 0 0;
    0 0 0 -cn2 0 0 0;
    0 0 0 0 0 0 0;
    0 0 0 -cn2 0 0 0;
```

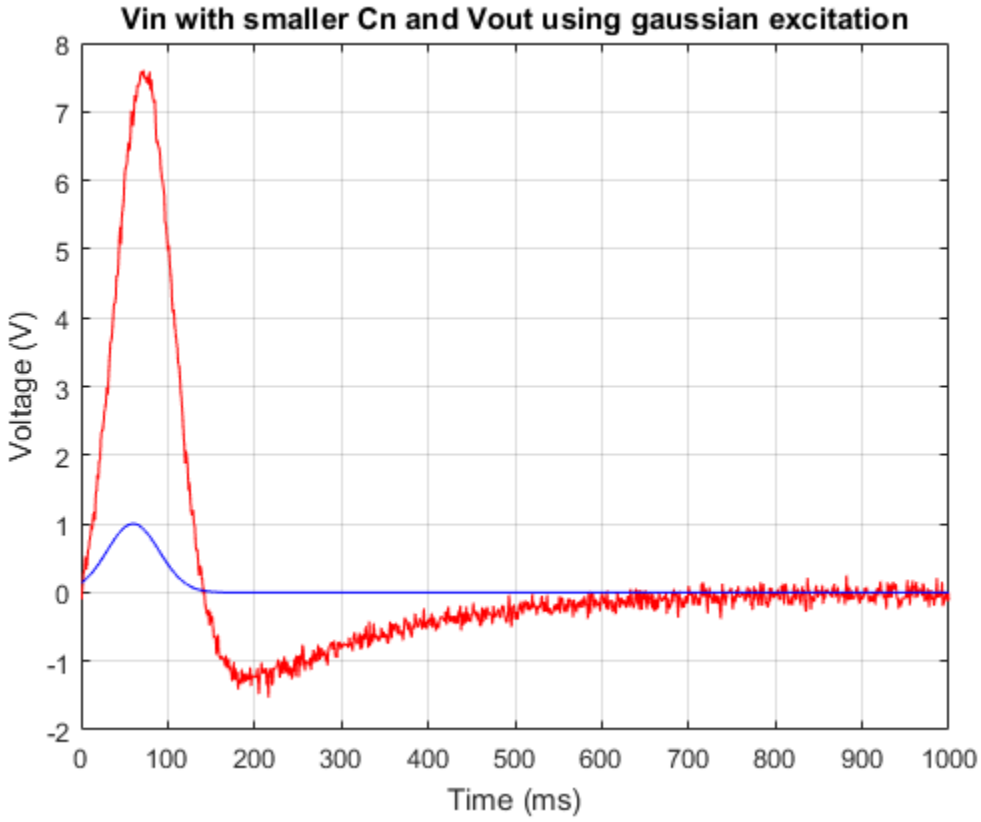
```
    0 0 0 0 0 0 0;];

C3 = [0 0 0 0 0 0 0;
    -c c 0 0 0 0 0;
    0 0 -L 0 0 0 0;
    0 0 0 -cn3 0 0 0;
    0 0 0 0 0 0 0;
    0 0 0 -cn3 0 0 0;
    0 0 0 0 0 0 0;];

G = [1 0 0 0 0 0 0;
    -G2 G1+G2 -1 0 0 0 0;
    0 1 0 -1 0 0 0;
    0 0 -1 G3 0 0 0;
    0 0 0 0 -a 1 0;
    0 0 0 G3 -1 0 0;
    0 0 0 0 0 -G4 G4+Go];

F = [Vin;
    0;
    0;
    0;
    0;
    0;
    0;];

Foff = [Vin-Vin;
        0;
        0;
        0;
        0;
        0;
        0;];

ts1 = 1000;              % Default Time step
ts2 = 1.9898e4;          % New Time step

V1 = zeros(7, ts1);
Vstart = zeros(7, 1);
dt1 = 1e-3;
dt2 = 1.9898e-4;

% Circuit with Noise simulation with default time step
% Time domain simulation
V1 = zeros(7, ts1);
Fgauss = zeros(7,1);
for i = 1:ts1

    Fgauss(1,1) = exp(-1/2*((i/ts1-0.06)/(0.03))^2);
    Fgauss(4,1) = 0.001*randn();
    Fgauss(7,1) = 0.001*randn();
    if i == 1
        V1(:,i) = (C1./dt1+G)\(Fgauss+C1*Vstart/dt1);
    else
```

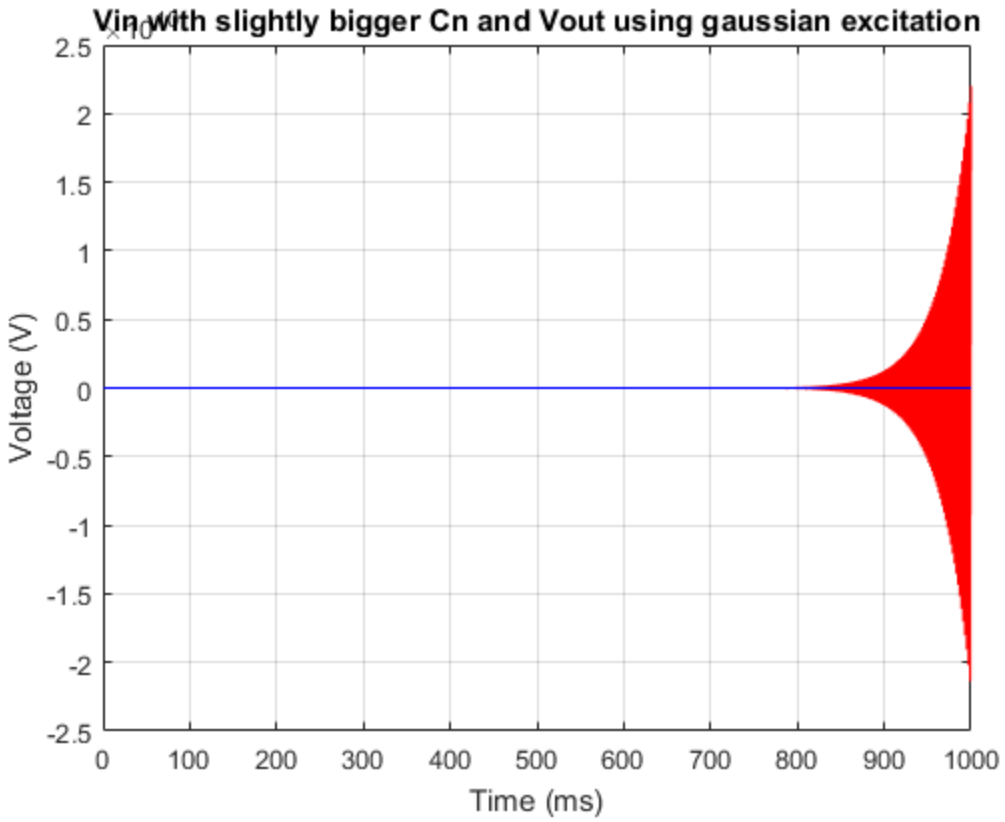
```
        V1(:,i) = (C1./dt1+G)\(Fgauss+C1*Vpast/dt1);
    end
    Vpast = V1(:, i);

end
figure(1)
plot(1:ts1, V1(7,:), 'r')
hold on
plot(1:ts1, V1(1,:), 'b')
title('Vin with thermal noise and Vout using gaussian excitation')
xlabel('Time (ms)')
ylabel('Voltage (V)')
grid on

% Frequency domain simulation
f = (-ts1/2:ts1/2-1);               % Frequency range

fV1 = fft(V1.');
fsV1 = fftshift(fV1);
figure(2)
plot(f, abs(fsV1(:, 1)), 'r')
hold on
plot(f, abs(fsV1(:, 7)), 'b')
title('Vin with thermal noise and Vout in frequency domain using
 gaussian excitation')
xlabel('frequency (1/ms)')
ylabel('Voltage (V)')
grid on

% Time domain simulation with smaller capacitance than default one
V2 = zeros(7, ts1);
Fgauss = zeros(7,1);
for j = 1:ts1

    Fgauss(1,1) = exp(-1/2*((j/ts1-0.06)/(0.03))^2);
    Fgauss(4,1) = 0.001*randn();
    Fgauss(7,1) = 0.001*randn();
    if j == 1
        V2(:,j) = (C2./dt1+G)\(Fgauss+C2*Vstart/dt1);
    else
        V2(:,j) = (C2./dt1+G)\(Fgauss+C2*Vpast/dt1);
    end
    Vpast = V2(:, j);

end
figure(3)
plot(1:ts1, V2(7,:), 'r')
hold on
plot(1:ts1, V2(1,:), 'b')
title('Vin with smaller Cn and Vout using gaussian excitation')
xlabel('Time (ms)')
ylabel('Voltage (V)')
grid on
```

```
% Time domain simulation with slighter bigger capacitance than default
 one
V3 = zeros(7, ts1);
Fgauss = zeros(7,1);
for k = 1:ts1

    Fgauss(1,1) = exp(-1/2*((k/ts1-0.06)/(0.03))^2);
    Fgauss(4,1) = 0.001*randn();
    Fgauss(7,1) = 0.001*randn();
    if k == 1
        V3(:,k) = (C3./dt1+G)\(Fgauss+C3*Vstart/dt1);
    else
        V3(:,k) = (C3./dt1+G)\(Fgauss+C3*Vpast/dt1);
    end
    Vpast = V3(:, k);

end
figure(4)
plot(1:ts1, V3(7,:), 'r')
hold on
plot(1:ts1, V3(1,:), 'b')
title('Vin with slightly bigger Cn and Vout using gaussian
 excitation')
xlabel('Time (ms)')
ylabel('Voltage (V)')
grid on
```




Vin with thermal noise and Vout in frequency domain using gaussian excitatio
Voltage (V)
frequency (1/ms)
70
60
50
40
30
20
10
0
-500
-400
-300
-200
-100
0
100
200
300
400
500


Vin with smaller Cn and Vout using gaussian excitation
Voltage (V)
Time (ms)
8
7
6
5
4
3
2
1
0
-1
-2
0
100
200
300
400
500
600
700
800
900
1000

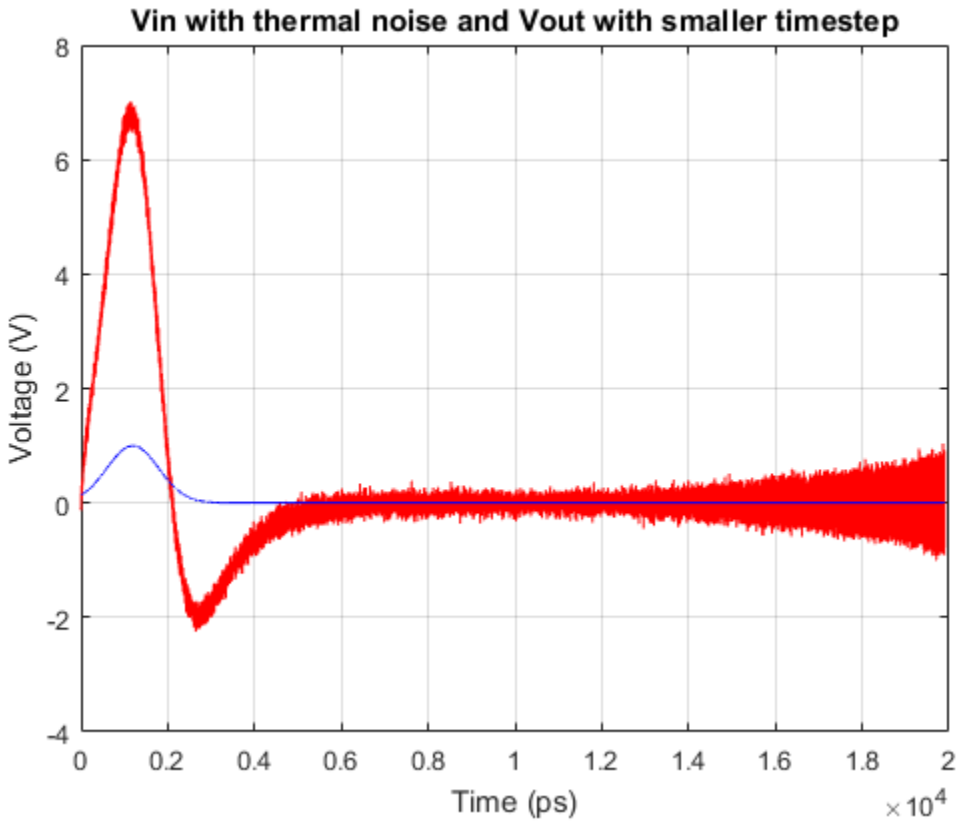


Discussion

By increasing the capacitance just slightly, the simulation breaks down since the circuit is trapped in a feedback loop but nothing is changed when the capacitance is too small.

```
% Time domain simulation with slight smaller time step than default
V4 = zeros(7, ts2);
Fgauss = zeros(7,1);
for m = 1:ts2

    Fgauss(1,1) = exp(-1/2*((m/ts2-0.06)/(0.03))^2);
    Fgauss(4,1) = 0.001*randn();
    Fgauss(7,1) = 0.001*randn();
    if m == 1
        V4(:,m) = (C1./dt2+G)\(Fgauss+C1*Vstart/dt2);
    else
        V4(:,m) = (C1./dt2+G)\(Fgauss+C1*Vpast/dt2);
    end
    Vpast = V4(:, m);

end
figure(5)
plot(1:ts2, V4(7,:), 'r')
hold on
plot(1:ts2, V4(1,:), 'b')
title('Vin with thermal noise and Vout with smaller timestep')
```

```
xlabel('Time (ps)')
ylabel('Voltage (V)')
grid on
```



Discussion

By just decreasing the time step just by a little bit, the simulation also seems to break down since the circuit seems to be trapped in a feedback loop

Part 4

In part 4, we would change the voltage source on the output stage from the equation $V = a * I3$ to $V = alpha * I3 + beta * I3^2 + gamma * I3^3$, this simple change of equation doesn't mean we can just change the matrices we have to fit the new equation. We would have to create new matrices for the Jacobian method on simulating the new equation in the circuit. This would also mean that new equations are iterate and increase the size of the matrices. The beta and gamma can be defined by us, but both of them has to very large in order have effect on the simulation since if I3 is smaller than 1, the square and the cube of I3 will only make it smaller.

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