EE 201C

Project 1 (due Feb 8)

Wei Wu

Submit code and report to:

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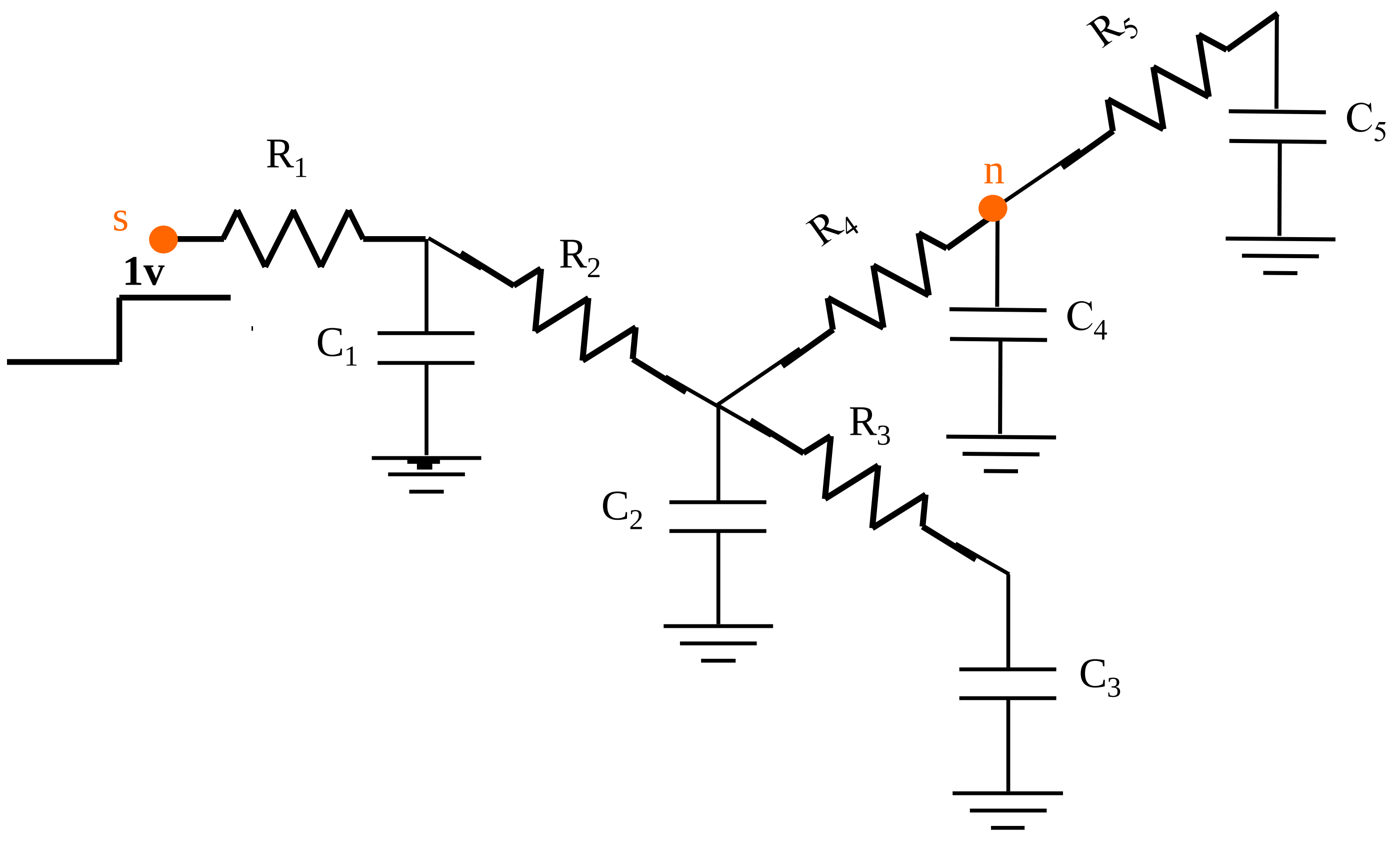
Email Subject: EE201C_PRJ1_Name_UID

Project 1 [due Feb 8]

[Problem #1] For the same circuit, use DC analysis method in SPICE to get the 0th -3rd moments for C4.



$R_1 = 2m\Omega$
$R_2 = 2m\Omega$
$R_3 = 3m\Omega$
$R_4 = 3m\Omega$
$R_5 = 4m\Omega$

$C_1 = 2nF$
$C_2 = 2nF$
$C_3 = 4nF$
$C_4 = 4nF$
$C_5 = 2nF$

Steps for Problem 1

1. Follow the DC analysis method to reconstruct the circuit (e.g. replace C with zero current source for 0th moment calculation, etc).

2. Write the corresponding netlist for SPICE analysis.

3. Run DC analysis in SPICE to get the voltage across the capacitance as the moment.

4. The above should be done repeatedly until all the desired moments are acquired.

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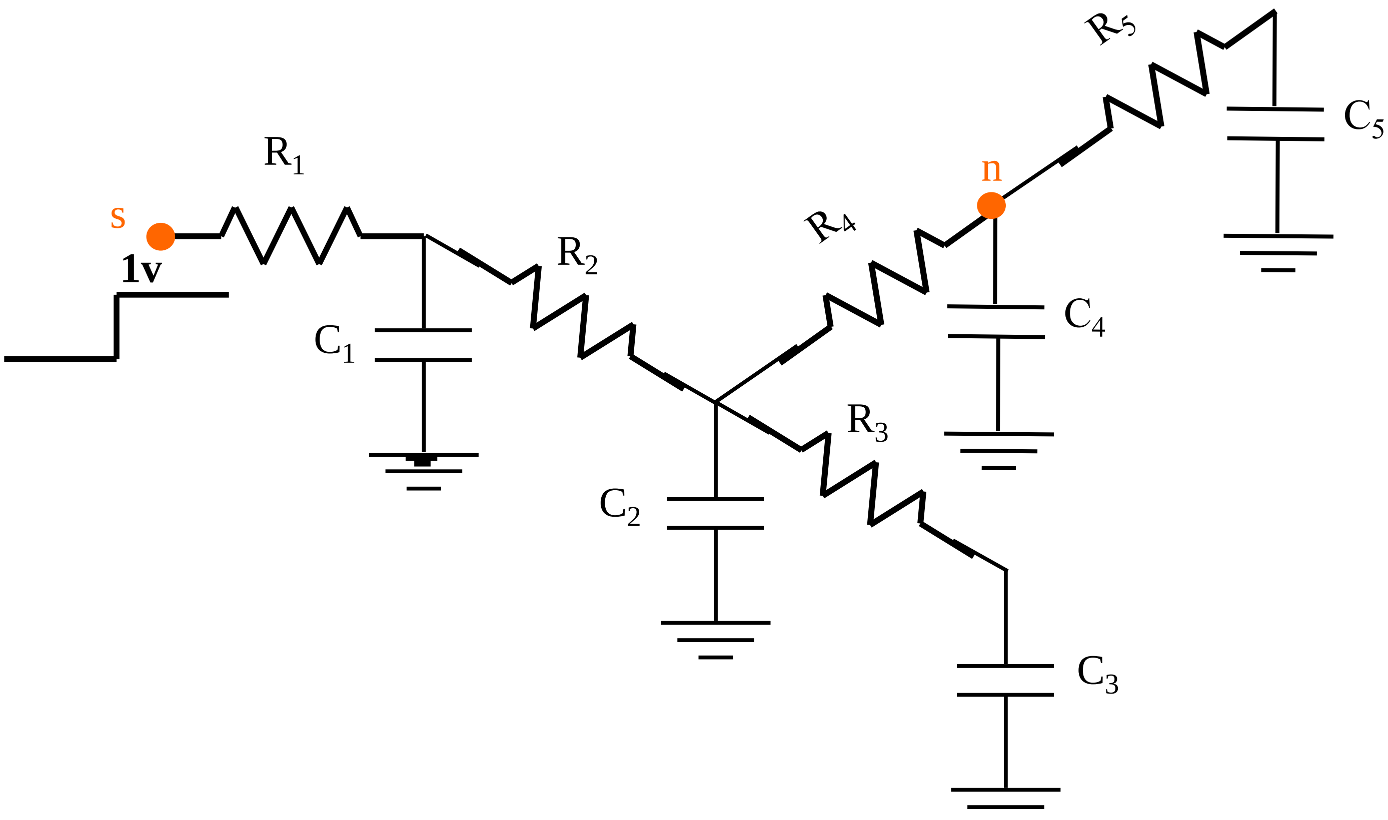
- [Problem #2] Given the circuit as shown below and a unit step voltage source at the input node s, use SPICE to simulate the circuit and obtain the accurate 50% delay at node n. Also analytically calculate the delay using Elmore method and S2P method. How do they compare with the result obtained by SPICE?



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$C_2 = 2nF$
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$C_4 = 4nF$
$C_5 = 2nF$

Steps for Problem 2

1. Write the SPICE net-list of the circuit, run transient simulation, and probe the voltage response at node n.

2. Record the time when the voltage at node n reaches 0.5V. That time is the 50% delay.

3. Elmore Delay: Use the Elmore delay formula to calculate the Elmore delay.

$$\tau_{Di} = 0.69 \cdot \sum_{k=1}^{N} C_k R_{ik}$$

(find the shared path between each node and node n).

4. S2P*: Write down the transfer function H(s) and driving point admittance Y(s) of the circuit with input s and output n.

5. Expand the *transfer function* to get the moments m_0* and m_1*.

$$H(s) = m^*_{(0)} + s m^*_{(1)} + s^2 m^*_{(2)} + s^3 m^*_{(3)} + \ldots \qquad m^*_{(j)} = \frac{1}{j!} \frac{d^j}{ds^j} H(s)\Big|_{s=0}$$

*Emrah Acar, Altan Odabasioglu, Mustafa Celik, and Lawrence T. Pileggi. 1999. “S2P: A Stable 2-Pole RC Delay and Coupling Noise Metric”. In Proceedings of the Ninth Great Lakes Symposium on VLSI(GLS '99).

Steps for Problem 2

6. Expand the *driving point admittance* to get m1, m2, m3, and m4.

$$Y(s) = \sum_{n=1}^{q} \frac{k_n}{s - p_n} + k_0 \qquad m_i = \sum_{n=1}^{q} \frac{k_n}{p_n^{i+1}} \qquad i > 0$$

7. Follow the S2P algorithm to get S2P approximation $\hat{h}(s)$ in frequency domain.

8. Use the frequency domain expression ($\hat{h}(s)$) to derive the time domain expression ($\hat{h}(t)$).

9. Plot the obtained time domain waveform to get the 50% delay for the S2P model.

10. Compare the results.

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[Problem #3] Modify the PRIMA code with single frequency expansion to multiple points expansion. You should use a vector fspan to pass the frequency expansion points. Compare the waveforms of the reduced model between the following two cases:

1. Single point expansion at s=1e4.

2. Four-point expansion at s=1e3, 1e5, 1e7, 1e9.

Matlab Files

We provide two matlab files:

- prima.m

  PRIMA on single point expansion

- demo2_11.m

  perform single-point MOR, calculate and compare corresponding time and frequency domain response between original matrix and MATLAB reduced matrix. prima function is called.

Format of the input matrices for test

```
1 1  19.4595 1.43391e-14
1 2  0.000464141 -2.9702e-15
1 3 -0.000542882 0.0
1 4  0.000152585 -7.5288e-15
1 5  0.000464074 -2.9702e-15
1 6 -0.000542801 0.0
1 68 -19.4595 0.0
2 1  0.0  -2.9702e-15
2 2  3.66672 2.44291e-13
2 3  0.0  -2.3594e-13
2 4  0.0  -5.3806e-15
2 72 -1.425 0.0
2 329 -2.06075 0.0
2 341 -0.091255 0.0
2 343 -0.0897199 0.0
3 1 -2.44188e-06 0.0
3 2  -0.000464141 -2.3594e-13
3 3  40.8898 2.42089e-13
.....
```

The input files GC8 and GC9 each has 4 columns. They are:

row number m, column number n, (m,n) entry in G matrix - G(m,n), (m,n) entry in C matrix - C(m,n) .

If both G(m,n) and C(m,n) are zero, that entry is omitted in input file.

Editor - C:\Users\Yiyu Shi\Desktop\PRIMA\PRIMA\demo2_11.m*

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Stack: Base

```
clear;

%load G,C matrices
a=load('GC9.txt');
G=sparse(a(:,1),a(:,2),a(:,3));
C=sparse(a(:,1),a(:,2),a(:,4));
kv=3;   %number of current sources (number of input ports)

%define matched moments, size of original system, number of input sources
q=5;          %define matched moments
N=size(G,1);
gmin=0; %perturbation to make reduced G nonsigular

%define start frequency, end frequency, and step
fspan=[1e6];         %span vectors at the frequency of 1MHz
fe=1e9;

%set parameters for time domain response calculation
h=2e-9;       %step for back-ward time domain simulation
inputno=8000;     %the number of time steps for input
outputno=inputno;  %the number of time steps for output; for simplicity we make it equal to the number for inpu

%Generate L
L=zeros(N,1);
L(8)=1;

%Generate B
B=zeros(size(G,1),kv);
B(6,1)=-1;
B(10,2)=-1;
B(11,3)=-1;

%Generate U
```

demo2_11.m* × prima.m ×

Editor - C:\Users\Yiyu Shi\Desktop\PRIMA\PRIMA\demo2_11.m

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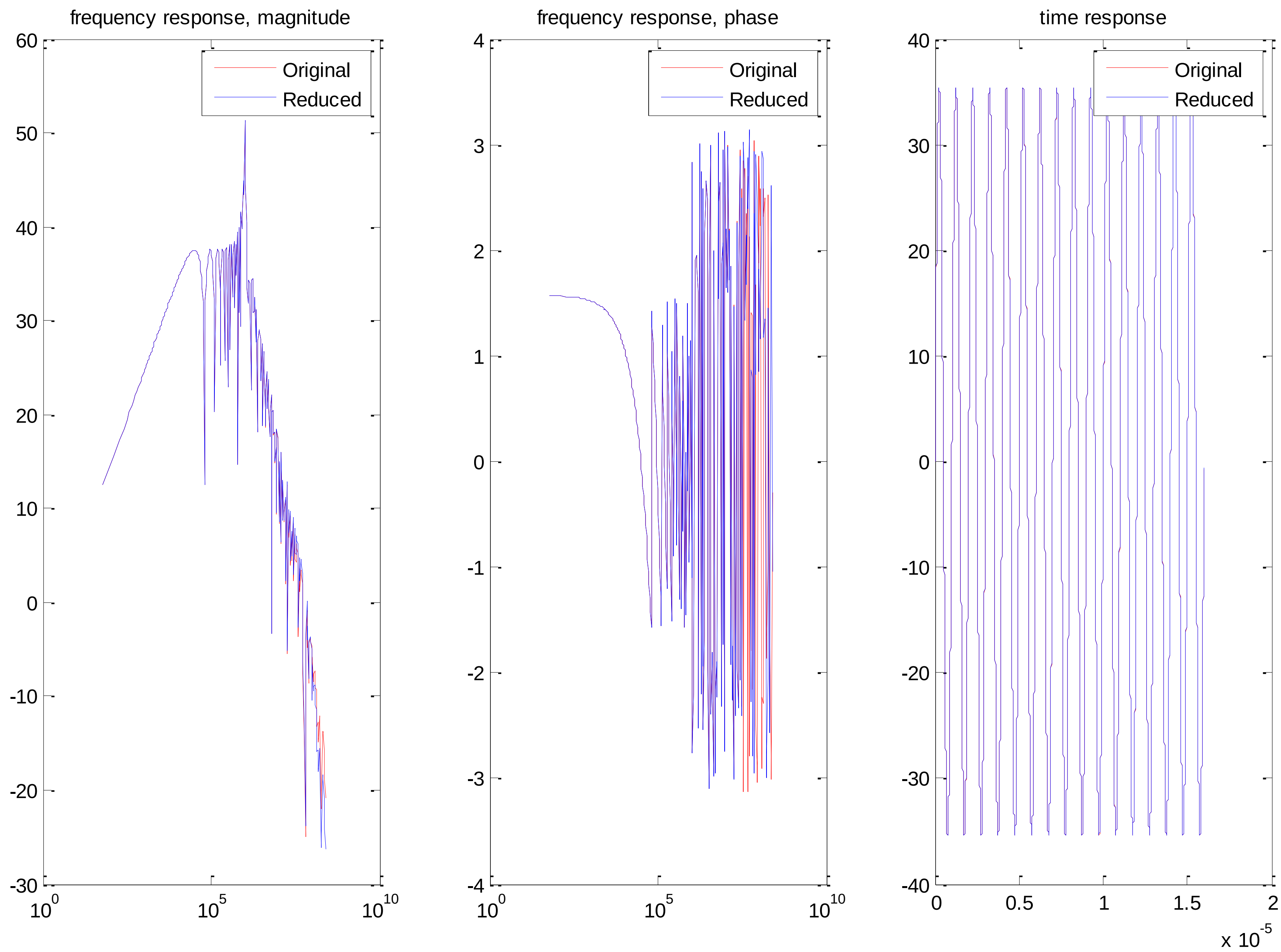
Stack: Base

1.0 1.1

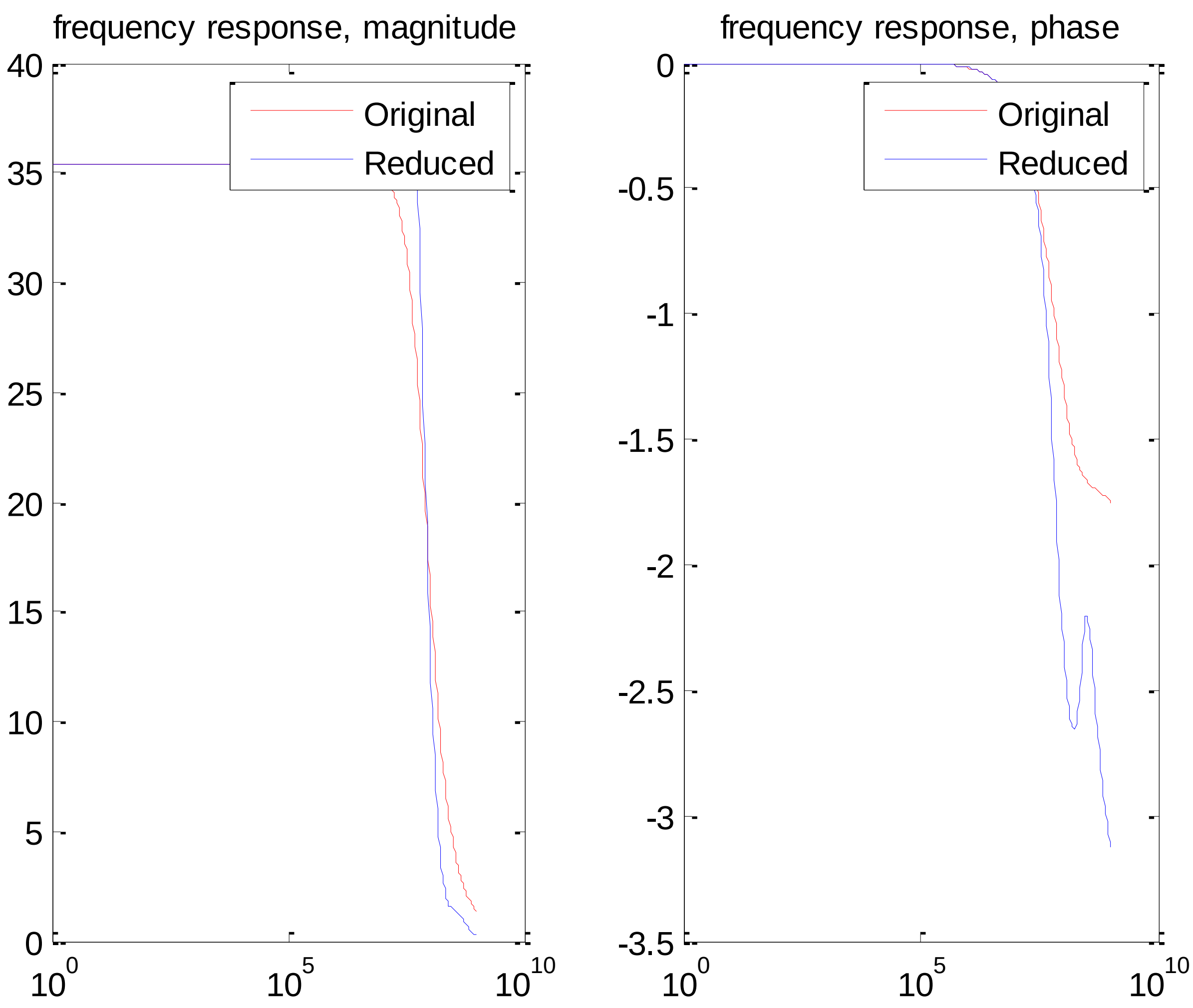
```
%
%Voltage source 1       0V    ---------------------
%Voltage source 2        0.5V*sin(2*pi*1MHz*t)
%Voltage source 3       -0.5V*sin(2*pi*1MHz*t)
U=[0*[h:h:h*inputno];0.5*sin(2*pi*1e6*[h:h:h*inputno]);-0.5*sin(2*pi*1e6*[h:h:h*inputno])];
Us=fft(U,inputno*1000,2);
f=1/h/2*linspace(0,1,inputno*1000/2);

G=G+gmin*eye(length(G));

%Prima reduction
fprintf('\n\n\n\n');
fprintf('G,C,B,U,L matrices have been generated.');

fprintf('\n');
fprintf('Prima begins:\n');
tic
[Gr,Cr,Br,Lr,V]=prima(G,C,B,L,q,2*pi*fspan,gmin);
toc
fprintf('Prima done!\n');

%calculate original time domain response
fprintf('\n');
fprintf('Calculate original time domain response:\n');
tic
vo=-1e-9*ones(N,1);
A=G+1/h*C;
[LA,UA]=lu(A);

for j=1:outputno
    if (j<=inputno)
        b=1/h*C*vo(:,end) + B*U(:,j);
    else
```

demo2_11.m × prima.m ×

Frequency and time domain response for single point expansion



Impulse response for single point expansion



THANK YOU!

Due on Feb 8, 2016

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