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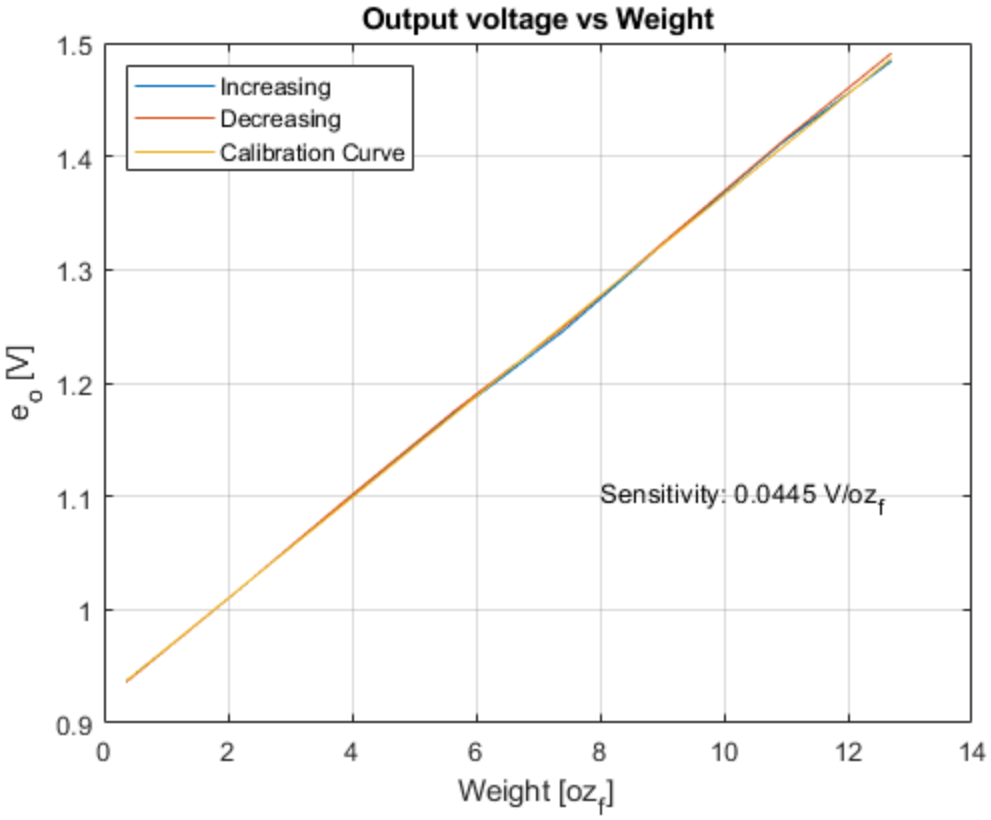
```
%Charlie Nitschelm, 11/13/19
clear all
close all

addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\1');
addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\2.1.3');
addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\2.1.4');
addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\2.2.1');
addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\3.1');
addpath('C:\Users\User\Desktop\Charlie\Classes\Senior Year\S-Lab
\Lab4\3.2');
```

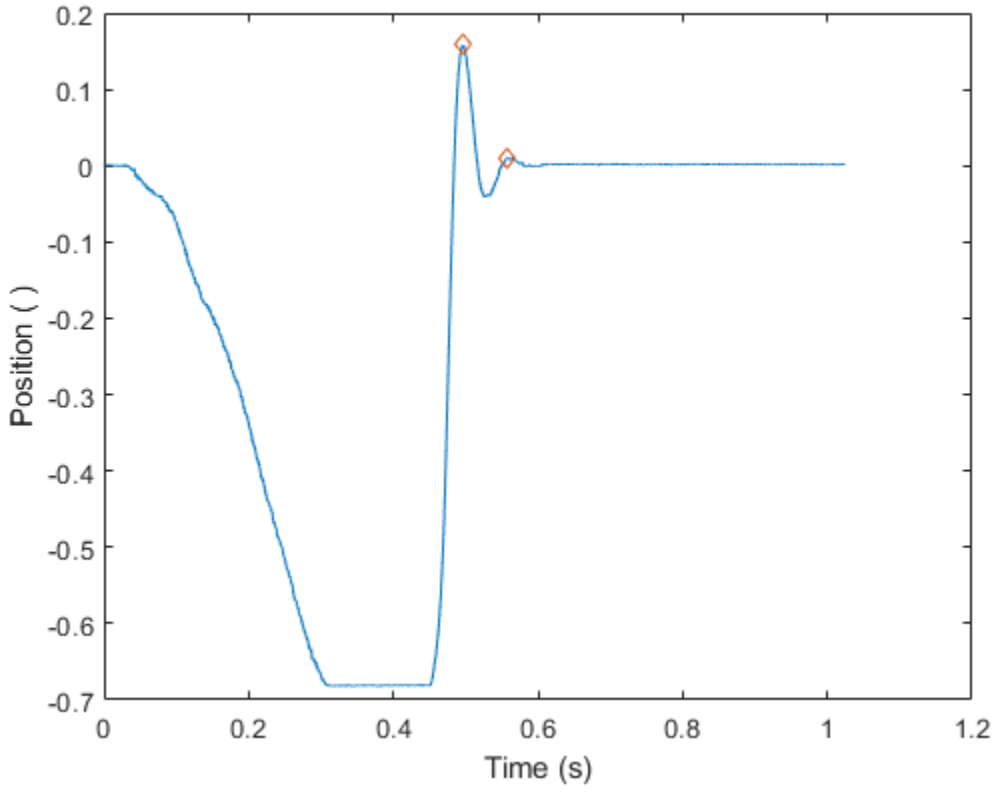
Part 1

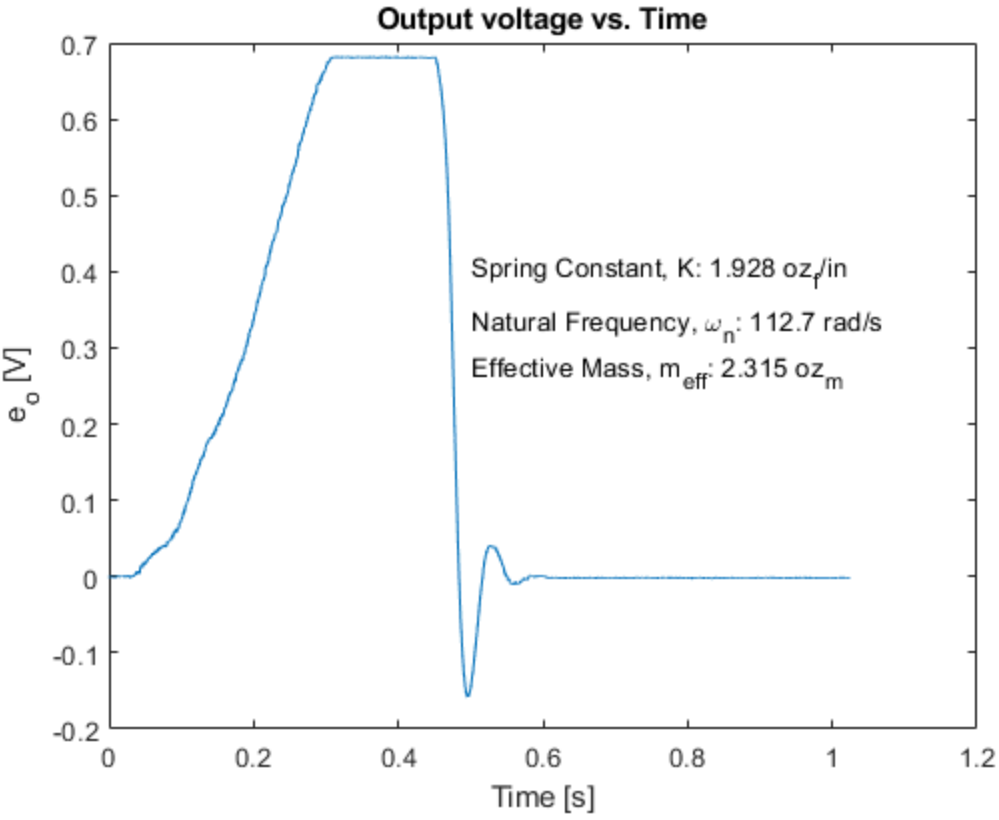
```
% a.)
Weight     = [10.1 60.1 110.1 160.1 210.1 260.1 310.1 360.1]./28.35;
Increasing = [937 1015 1095 1173 1246 1330 1412 1484]./1000;
Decreasing = [936 1015 1096 1175 1249 1331 1413 1491]./1000;

% reading in data from accelerometer
Acc_Volt   = xlsread('Instrument_2 Capture 2019-10-31 15-14-13
 Oscilloscope - Waveform Data.csv', 'A7:A100006');
t          = 0:1.024e-5:(1.024e-5) * 1e5;
t          = t(1:end-1);
dV         = 103/1000;


a          = polyfit(Weight, Increasing, 1);
Sensitivity       = a(1);
Cal_curve  = a(1)*Weight + a(2);

figure(1)
plot(Weight, Increasing, Weight, Decreasing, Weight, Cal_curve);
xlabel('Weight [oz_{f}]');
ylabel('e_{o} [V]')
title('Output voltage vs Weight')
```

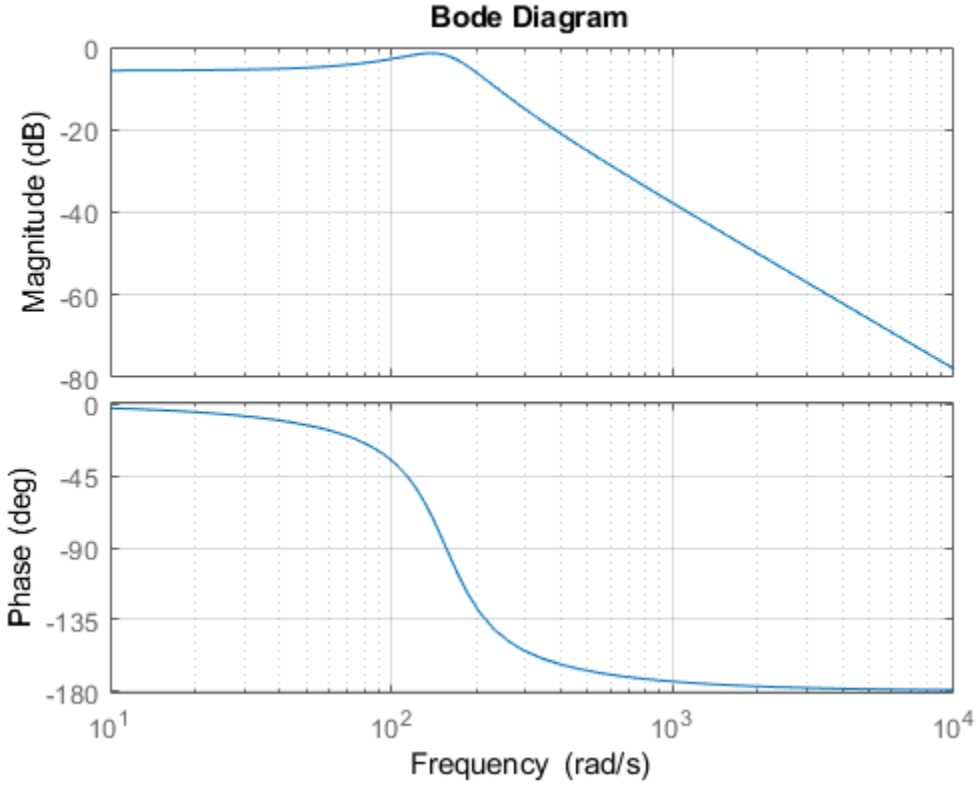
```
legend('Increasing', 'Decreasing', 'Calibration
 Curve','Location', 'northwest')
text(8, 1.1, strcat({'Sensitivity: '}, num2str(Sensitivity,4), ' V/
oz_{f}'))
grid on



% b.)

smooth               = 4;
[Acc_Volt, smooth]   = wsmooth(Acc_Volt, t, smooth);
Acc_Volt             = Acc_Volt - Acc_Volt(1);


min = -.1;
for j = 1:length(Acc_Volt)
    if Acc_Volt(j) <= min
        min = Acc_Volt(j);
    else
    end
end

zeta_overshoot    = 0.45;
p_overshoot = 0.1524/0.6819;
meff              = (dV/a(1));
Acc_Volt          = Acc_Volt.*-1;

%find peaks now
th = 0.01;
[peakLoc, peakMag] = peakfinder(Acc_Volt, th);
peakLoc(1)         = [];
peakMag(1)         = [];
% finding damped natural frequency
Td                 = 1/(t(peakLoc(2)) - t(peakLoc(1)));
wd                 = Td*2*pi;                          % wd

figure(2)
plot(t, Acc_Volt, t(peakLoc), peakMag, 'd')
xlabel('Time (s)')
ylabel('Position ( )')


for j = 1:length(peakLoc)
    y(j)          = log(peakMag(1)/peakMag(j));
end

n = 0:length(y)-1;
dampr         = zeros(1, length(peakLoc));

for jj = 1:length(peakLoc)
    num            = ((1/length(n))*log(peakMag(1)/peakMag(jj)));
    dampr(jj) = num/(sqrt(4*pi^2 + num^2));
end
```

```
zeta                = mean(dampr);
wn                  = wd/(sqrt(1 - zeta_overshoot^2));    % wd =
 wn*sqrt(1-zeta^2) [rad/s]
spring_Const        = (meff*(wn/(2*pi))^2)/(32.2 * 12);   % ozf/in


figure(4)
plot(t, -1*Acc_Volt);
title('Output voltage vs. Time')
xlabel('Time [s]');
ylabel('e_{o} [V]')
text(0.5, 0.4, strcat({'Spring Constant, K: '},
 num2str(spring_Const,4), ' oz_{f}/in'));
text(0.5, 0.33, strcat({'Natural Frequency, \omega_{n}: '},
 num2str(wn,4), ' rad/s'));
text(0.5, 0.27, strcat({'Effective Mass, m_{eff}: '},
 num2str(meff,4), ' oz_{m}'));


% c.)
sens1               = (meff*Sensitivity)/386;                    % V/
(in/s2)
% d.)
max_acc             = (Increasing(end))/sens1;
% e.)
num                 = [1];
den                 = [1/(wn^2) ((2*zeta_overshoot)/wn) spring_Const];
sys                 = tf(num, den);


% bode plot of data motherfucker!
figure(3)
bode(sys)
grid on


% da plots
```


Output voltage vs Weight
Increasing
Decreasing
Calibration Curve
Sensitivity: 0.0445 V/oz_f
e_o [V]
Weight [oz_f]
1.5
1.4
1.3
1.2
1.1
1
0.9
0
2
4
6
8
10
12
14


Position ( )
Time (s)
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
0
0.2
0.4
0.6
0.8
1
1.2


Output voltage vs. Time
Spring Constant, K: 1.928 oz$_f$/in
Natural Frequency, ω_n: 112.7 rad/s
Effective Mass, m_{eff}: 2.315 oz$_m$
e_o [V]
Time [s]
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0
0.2
0.4
0.6
0.8
1
1.2


Bode Diagram
Magnitude (dB)
0
-20
-40
-60
-80
Phase (deg)
0
-45
-90
-135
-180
10^1
10^2
10^3
10^4
Frequency (rad/s)

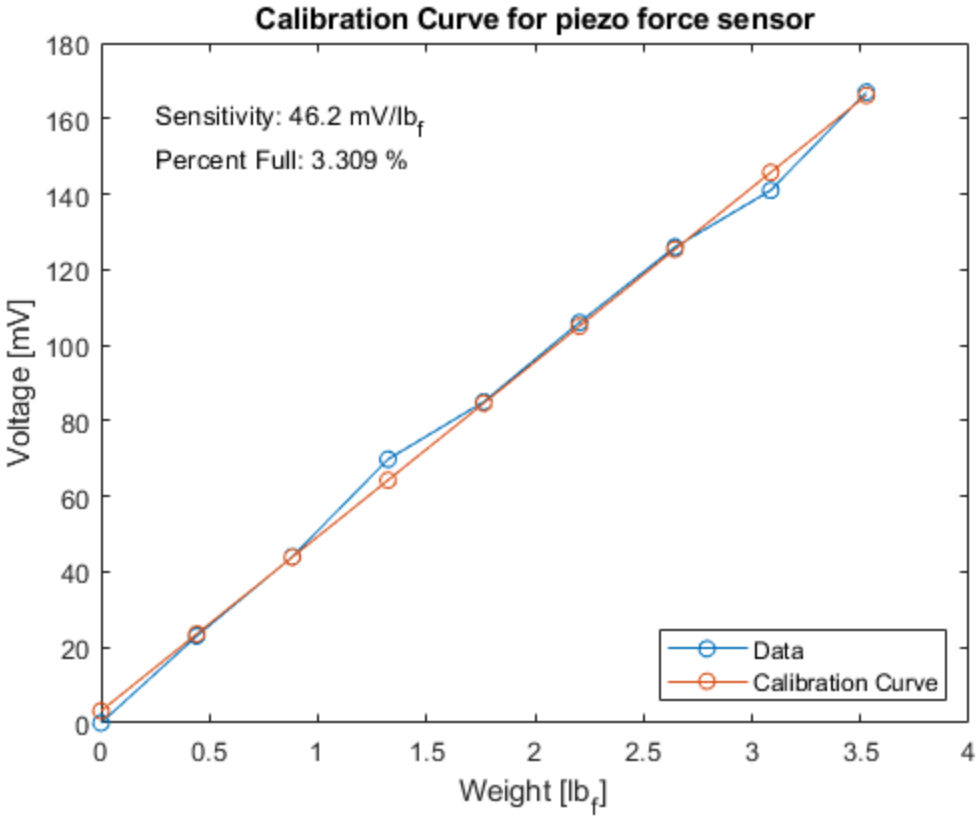
Part 2 Piezoelectric Force Sensor

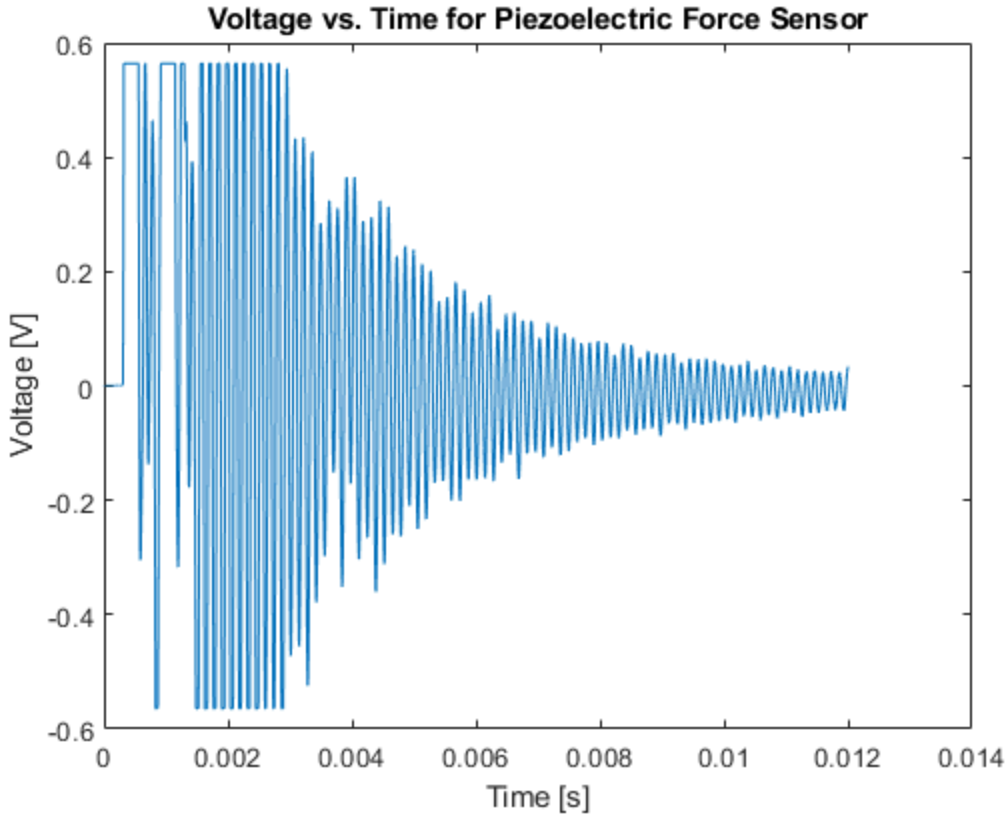
Part 2.1

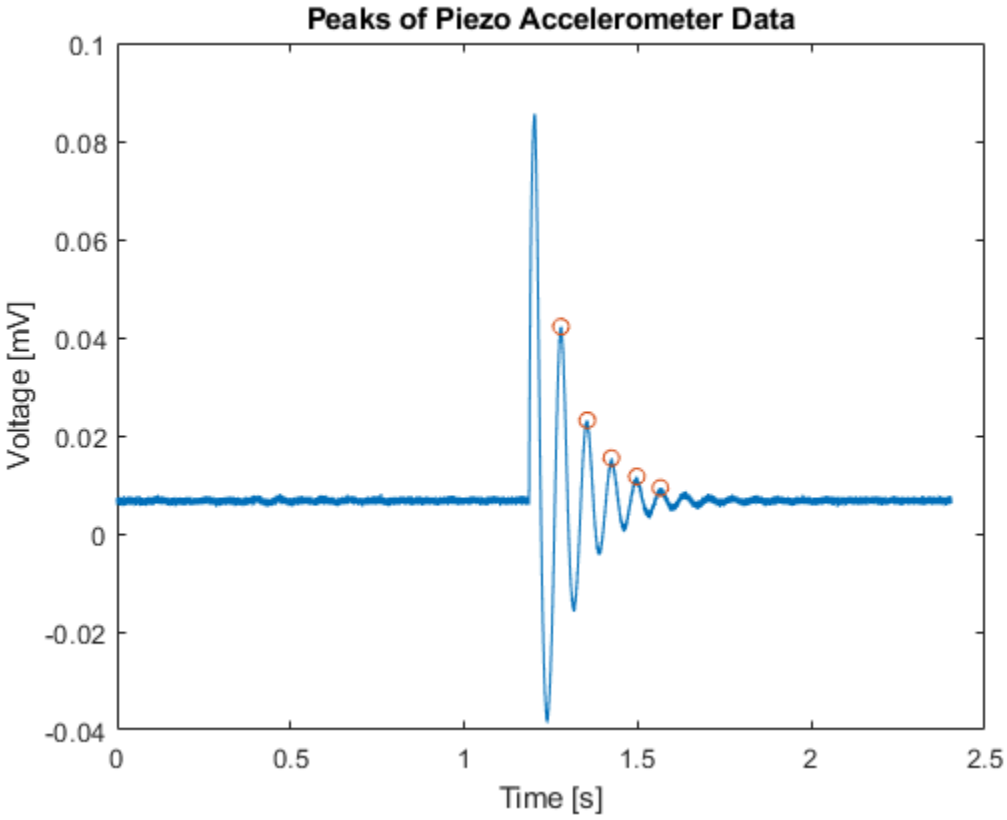
```
piezo_weight    = 0:200:1600;                          % grams
piezo_weight    = (piezo_weight./453.6);
voltage    = [0 23 44 69.8 85 106 126 141 167]; % mV

b          = polyfit(piezo_weight, voltage, 1);
sensitivity2      = b(1);
cal_curve2 = b(1)*piezo_weight + b(2);

for j = 1:length(voltage)

    residual(j) = abs(voltage(j) - cal_curve2(j));

end

max_error  = max(residual);
percent_FS = max_error/voltage(end);

% Plots
figure(5)
plot(piezo_weight, voltage, '-o', piezo_weight, cal_curve2, '-o')
text(0.25, 160, strcat({'Sensitivity: '}, num2str(sensitivity2,4), '
 mV/lb_{f}'));
text(0.25, 150, strcat({'Percent Full: '},
 num2str(percent_FS*100,4), ' %'));
title('Calibration Curve for piezo force sensor');
xlabel('Weight [lb_{f}]');
ylabel('Voltage [mV]');
legend('Data', 'Calibration Curve', 'Location', 'southeast');

num_peaks  = 2;
time_e     = .00460 - .00446;
nat_freq   = 2*pi*(num_peaks/time_e);

%reading in data of voltage
volt_data  = xlsread('Instrument Capture 2019-10-31 14-39-55
 Oscilloscope - Waveform Data.csv', 'A6:A12008'); % Volt
t          = 0:1e-6:(1e-6)*12002;
t          = t(1:end-1);



figure(6)
plot(t, volt_data);
xlabel('Time [s]');
ylabel('Voltage [V]');
title('Voltage vs. Time for Piezoelectric Force Sensor');

% Part 2.2
impulse_mass  = 2; %in lbf
```

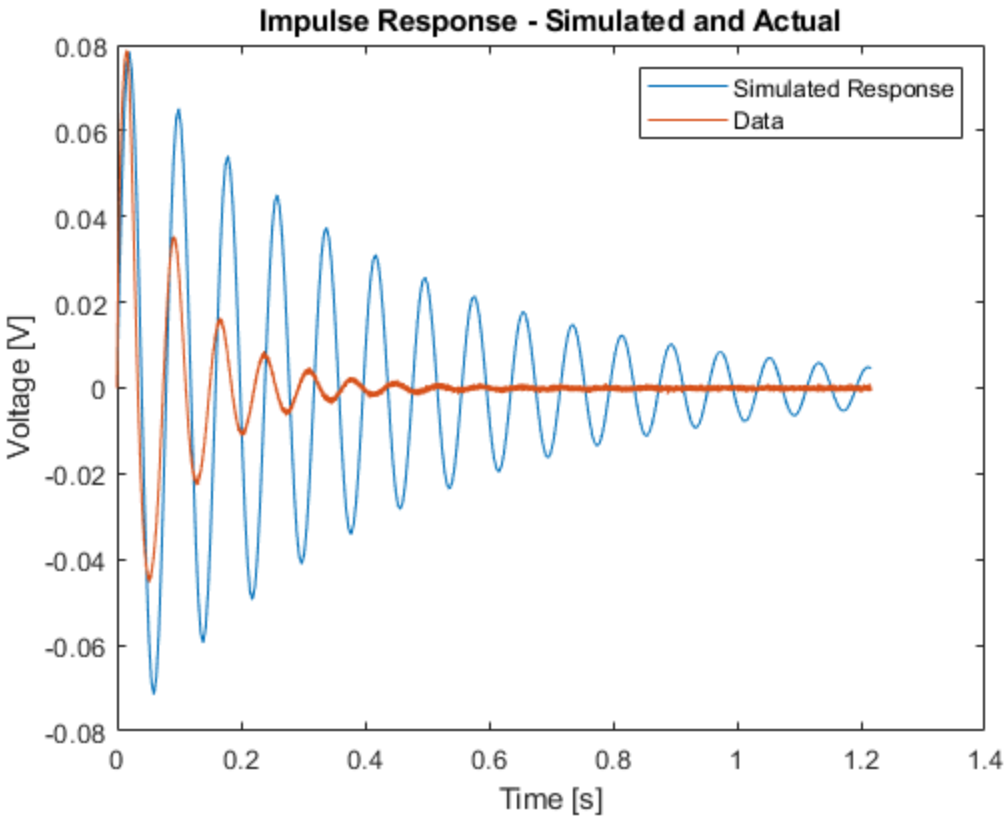
```
impulse_volt  = xlsread('Impulse Loading.xlsx' ,'A7:A100007');
impulse_t  = t:2.4030e-5:(2.4030e-5)*100000;
impulse_t  = impulse_t(1:end-1);

%plot(impulse_time, impulse_volt)

th = 0.005;
[peakLoc, peakMag] = peakfinder(impulse_volt, th);
peakLoc(1)         = [];
peakMag(1)         = [];
% Damped Natural Frequency
n_peaks            = length(peakLoc);
Td                 = 1/(impulse_t(peakLoc(2)) -
 impulse_t(peakLoc(1)));
wd                 = Td*2*pi;                          % wd
%
figure(7)
plot(impulse_t, impulse_volt, impulse_t(peakLoc), peakMag, 'o')
xlabel('Time [s]')
ylabel('Voltage [mV]')
title('Peaks of Piezo Accelerometer Data')


for j = 1:length(peakLoc)
    y(j)          = log(peakMag(1)/peakMag(j));
end

n = 0:length(y)-1;
dampr         = zeros(1, length(peakLoc));

for jj = 1:length(peakLoc)
    num            = ((1/length(n))*log(peakMag(1)/peakMag(jj)));
    dampr(jj) = num/(sqrt(4*pi^2 + num^2));
end

impulse_zeta               = mean(dampr);
impulse_wn                 = wd/(sqrt(1 - impulse_zeta ^2));  % 6/
(1.6396 - 1.2787)  % this comes from counting

impulse_springConst        = (impulse_mass*(impulse_wn/(2*pi))^2)/
(32.2*12);
impulse_dampCoeff          = ((2*impulse_zeta)/impulse_wn);

impulse_volt = impulse_volt(49393:end);
impulse_volt = impulse_volt - impulse_volt(1);
impulse_t = impulse_t(49393:end);
impulse_t = impulse_t - impulse_t(1);


impulse_num                = [1];
impulse_den                = [1/(impulse_wn^2) (2*impulse_zeta)/
impulse_wn impulse_springConst];
impulse_sys                = tf(impulse_num, impulse_den);
[force, x]                 = impulse(impulse_sys, impulse_t(end));
```

```
figure(8)
plot(x, 0.00094*force, impulse_t, impulse_volt)
xlabel('Time [s]'); ylabel('Voltage [V]');
title('Impulse Response - Simulated and Actual')
legend('Simulated Response', 'Data')
```




Voltage vs. Time for Piezoelectric Force Sensor
Voltage [V]
Time [s]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014


Peaks of Piezo Accelerometer Data
Voltage [mV]
Time [s]
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
0
0.5
1
1.5
2
2.5

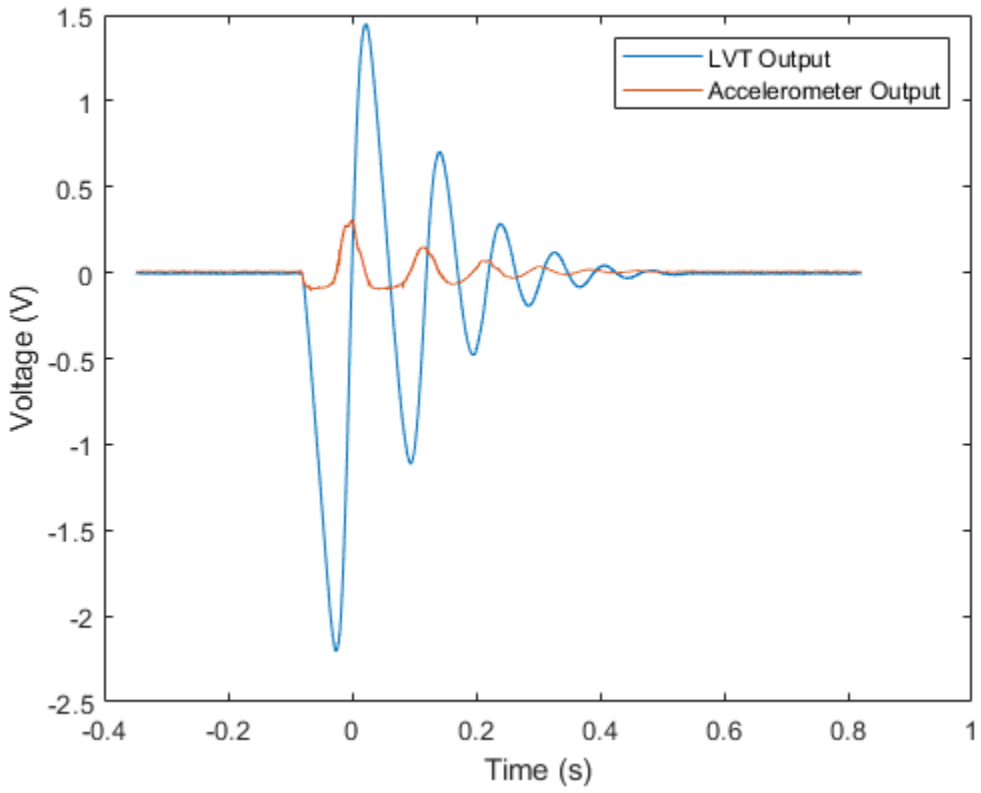


Part 3

```
LVT_Acc = xlsread('LVTandAccel.csv', 'A8:A100007');
Acc = xlsread('LVTandAccel.csv', 'B8:B100007');
Time = linspace(-.34745,-.34745+0.00001168*100000,100000)';

%part a
figure(9)
plot(Time,LVT_Acc)
hold on
plot(Time,Acc)
xlabel('Time (s)')
ylabel('Voltage (V)')
legend('LVT Output','Accelerometer Output')


Acc_Fall = -.09; %Volts for 1g
Sens_Acc = abs(Acc_Fall/(32.2*12)) %volts/in/sec2

% At t = -.06, object starts falling and is constant till t=-.04
for x = 1:100000
    if Time(x)>-.06
        t1_x = x;
        break
    end
```

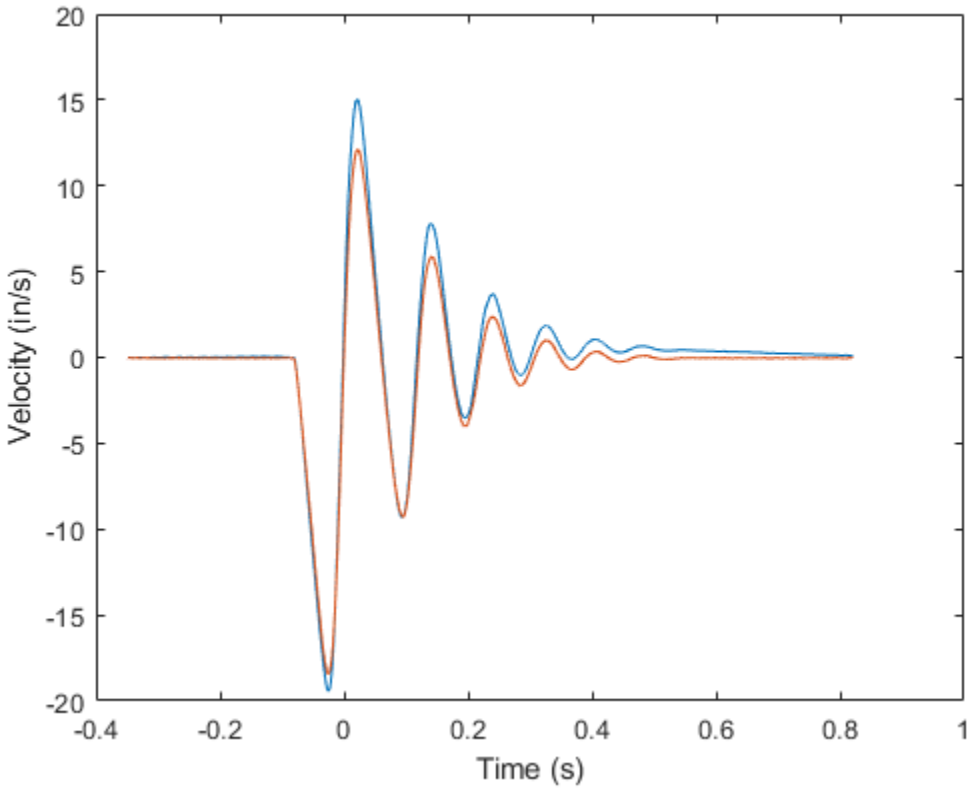
```
end

for x = 1:100000
    if Time(x)>-.04
        t2_x = x;
        break
    end
end

Change_V = (32.2*12)*.02;
Delta_Voltage = abs(LVT_Acc(t2_x) - LVT_Acc(t1_x));
Sens_LVT_Acc = Delta_Voltage/Change_V %volt/in/sec
```

```
Sens_Acc =

   2.3292e-04


Sens_LVT_Acc =

    0.1196
```




```
%b

Acc_In = Acc./Sens_Acc;
```

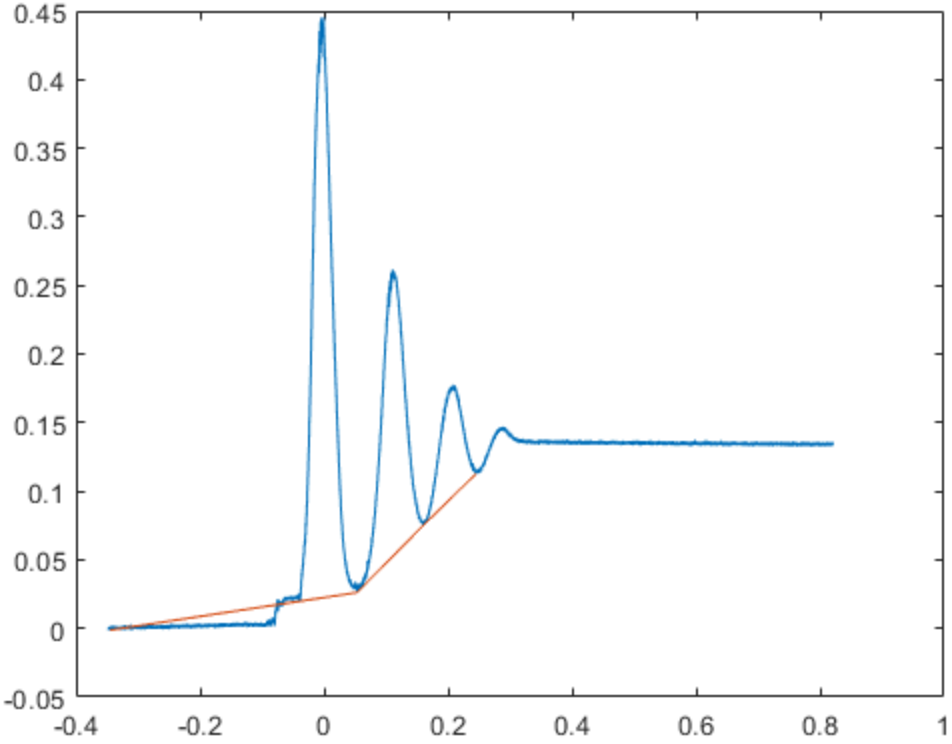
```
Acc_In = Acc_In - mean(Acc_In(1:1500));
LVT_Acc_In = LVT_Acc./Sens_LVT_Acc;


Int_Acc = cumtrapz(Time,Acc_In);
figure(10)
plot(Time,Int_Acc,Time,LVT_Acc_In)
xlabel('Time (s)')
ylabel('Velocity (in/s)')
```

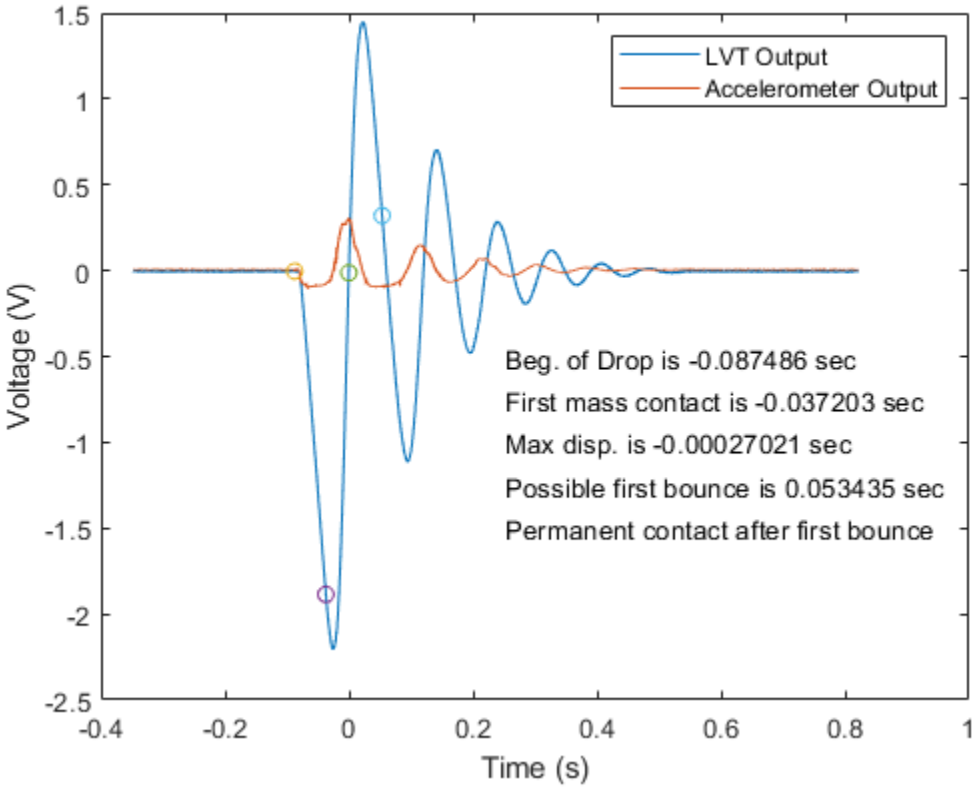


c

```
LVT_Force = xlsread('LVTandForce.csv', 'A8:A100007');
Force = xlsread('LVTandForce.csv', 'B8:B100007');
Force = Force-mean(Force(1:100));
%beginning of the drop
for x = 1:100000
    if Acc_In(x)<-30
        x_drop = x;
        break
    end
end

%first contact of core and foam
for x = 1:100000
    if Force(x)> .03
```

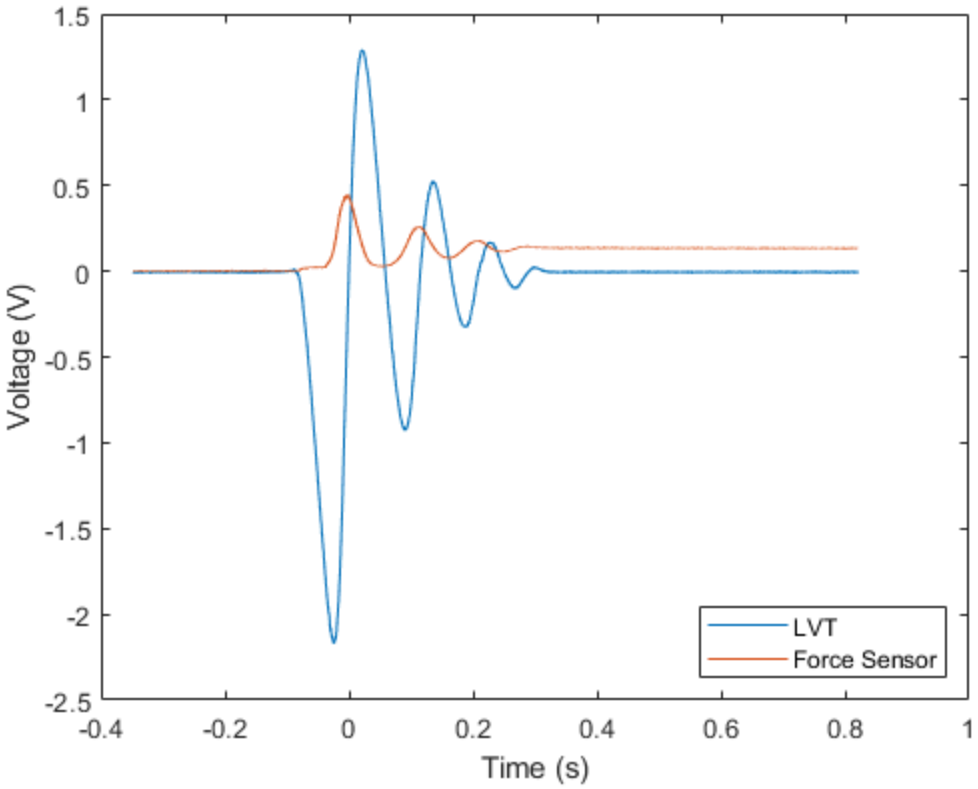
```
        x_hit = x;
        break
    end
end

%max displacement --- max force!

Force_Max = max(Force);
for x = 1:100000
    if Force(x)== Force_Max
        x_maxdisp = x;
        break
    end
end

% finding first bounce
th = 0.03;
[peakLoc, peakMag] = peakfinder(Force, th,'minima',-1);
figure(11)
plot(Time,Force,Time(peakLoc),Force(peakLoc))

x_firstbounce = peakLoc(2); %possible, might not be a bounce, very
 close

%permanent contact
% once it hits foam, it doesnt seem to bounce at all


figure(12)
plot(Time,LVT_Acc)
hold on
plot(Time,Acc)
plot(Time(x_drop),LVT_Acc(x_drop),'o',Time(x_hit),LVT_Acc(x_hit),'o',Time(x_maxdis
text(.25,-.5,strcat('Beg. of Drop is ' ,{' '},num2str(Time(x_drop)),{'
 '}, 'sec'))
text(.25,-.75,strcat('First mass contact is' ,{'
 '},num2str(Time(x_hit)),{' '}, 'sec'))
text(.25,-1,strcat('Max disp. is' ,{' '},num2str(Time(x_maxdisp)),{'
 '}, 'sec'))
text(.25,-1.25,strcat('Possible first bounce is ' ,{'
 '},num2str(Time(x_firstbounce)),{' '}, 'sec'))
text(.25,-1.5,'Permanent contact after first bounce')

xlabel('Time (s)')
ylabel('Voltage (V)')
legend('LVT Output','Accelerometer Output')

Warning: The threshold must be a real scalar. No threshold will be
 used.
```


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


LVT Output
Accelerometer Output
Beg. of Drop is -0.087486 sec
First mass contact is -0.037203 sec
Max disp. is -0.00027021 sec
Possible first bounce is 0.053435 sec
Permanent contact after first bounce
Voltage (V)
Time (s)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

d. maximum velocity of core

```
LVT_Acc_In;

Max_Vel = max(abs(LVT_Acc_In)) %in/s

%%e
figure(13)
plot(Time,LVT_Force,Time,Force)
legend('LVT','Force Sensor','location','southeast')
xlabel('Time (s)')
ylabel('Voltage (V)')



Force_lbf = Force./.491; %lbf

for x = 1:100000
    if abs(LVT_Acc_In(x))== Max_Vel
        x_maxvel = x;
        break
    end
end

Force_maxvel = Force_lbf(x_maxvel)
Force_steady = mean(Force_lbf(end-1000,end))

total_mass = Force_steady/32.2


Max_Vel =

   18.4652


Force_maxvel =

    0.2219


Force_steady =

    0.2740


total_mass =

    0.0085
```



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