Lab #2
ECE-2026 Fall-2023
LAB COMPLETION REPORT

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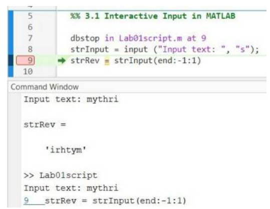
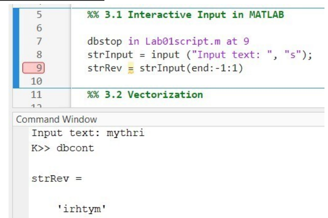
Part 1a: Did you attend the lab in week 1? Yes

Part 1b: Did you attend the lab in week 2? Yes

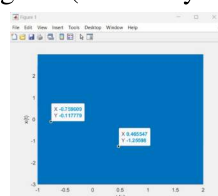
Part 2: Did you get full check-offs for in-lab demo? Yes

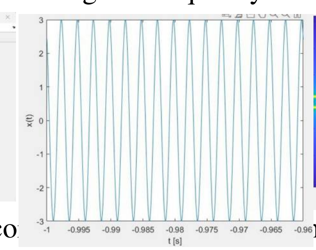
Part 3.1 Show a few of the debugging features.

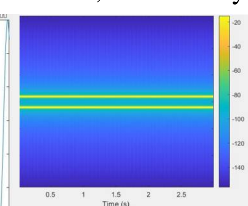




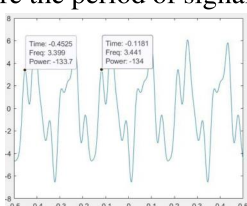
Part 3.2 Write the MATLAB code for generating a single sinusoid with varying amplitude, frequency and phase. Show the signal and spectrogram (Note: if your assigned frequency is too low, then it may be not audible, why?).







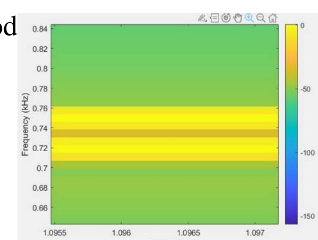
Part 3.3.1 Show that your `addCosVals.m` function is co Section 3.3.1 and plotting the result. Measure the period of signal in the structure `ssOut`, and explain its relationship to the fundamental frequency.



T = -0.119 + -0.4525 = 0.3333 sec

Fundamental freq = 1 / T = 3 Hz

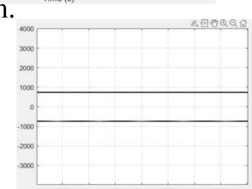
Part 3.3.2: Write the MATLAB code for calculating `nStart` and `nStop` needed in the cod



`nStart` = round(tStart(kk) * fs)+1;

`nStop` = nStart + Lnew - 1;

Part 3.4 Write the MATLAB code for generating the beat signal. Show the signal and spectrogram.

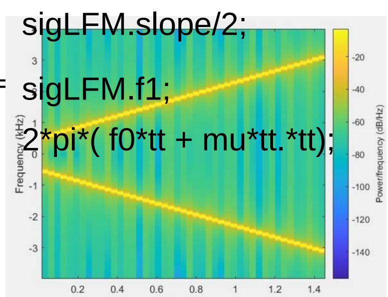


Part 3.5 Run the testing code to demonstrate your chirp signal and its spectrogram.

μ = sigLFM.slope/2;

f_0 = sigLFM.f1;

φ = 2*pi*(f0*tt + mu*tt.*tt);



3.2

```
mySig.freq = 400; %-- (in hertz)
mySig.complexAmp = 3*exp(j*pi/5);
dur = 3;
start = -1;
fs = 32*mySig.freq;
dt = 1/(32*mySig.freq);
mySigWithVals = makeCosVals( mySig, dur, start, dt );
%- Plot the values in sigWithVals
plot(mySigWithVals.times,mySigWithVals.values)%<--- complete the plot
 statement
xlim([-1, -0.96])
xlabel('t [s]')
ylabel('x(t)')


figure;
spectrogram(mySigWithVals.values, 256, 200, [], fs , 'centered', 'yaxis');
colorbar;



function sigOut = makeCosVals(sigIn, dur, tstart, dt ) %
freq = sigIn.freq;
X = sigIn.complexAmp;

A = abs(X);
phi = angle(X)
N = ceil(dur/dt);
T = N*dt;

tt = tstart: dt : tstart + T;  %-- Create the vector of times
xx = A*cos(2*pi*freq*tt + phi);     %-- Vectorize the cosine evaluation
sigOut.times = tt;     %-- Put vector of times into the output structure
sigOut.values = xx;    %-- Put values into the output structure

end
```

```
phi =

    0.6283
```

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3.3.1

```
ss(1).freq = 27; ss(1).complexAmp = exp(1j*pi/3);
ss(2).freq = 18; ss(2).complexAmp = 2i;
ss(3).freq = 6; ss(3).complexAmp = -4;
%
dur = 1;
tstart = -0.5;
dt = 1/(27*32); %-- use the highest frequency to define delta_t
%
ssOut = addCosVals( ss, dur, tstart, dt );
%
plot( ssOut.times, ssOut.values ) %



function sigOut = addCosVals( cosIn, dur, tstart, dt )
%ADDCOSVALS Synthesize a signal from sum of sinusoids
%(do not assume all the frequencies are the same)
%
% usage: sigOut = addCosVals( cosIn, dur, tstart, dt )
%
% cosIn = vector of structures; each one has the following fields:
%   cosIn.freq = frequency (in Hz), usually none should be negative
%   cosIn.complexAmp = COMPLEX amplitude of the cosine
%
% dur = total time duration of all the cosines
% start = starting time of all the cosines
% dt = time increment for the time vector
%
% The output structure has only signal values because it is not necessarily a
 sinusoid
%   sigOut.values = vector of signal values at t = sigOut.times
%   sigOut.times = vector of times, for the time axis
%
% The sigOut.times vector should be generated with a small time increment that
%   creates 32 samples for the shortest period, i.e., use the period
%   corresponding to the highest frequency cosine in the input array of
 structures.

% <--- Write your code here --->
n = length(cosIn); % number of sinusoids
t = tstart:dt:tstart+dur; % time vector
x = zeros(1, length(t)); % initialize sum of sinusoids

% calculate sum of sinusoids
for k = 1:n
    x = x + cosIn(k).complexAmp * exp(1j * 2 * pi * cosIn(k).freq * t );
end

% store results in output structure
sigOut.values = x;
```

3.3.2

Modify the following code from Prelab 2.6

```
amps = [1, 1]
freqs = [900,1450]
phases = [0, 0]
fs = 8000;
tStart = [0.2, 0.6];
durs = [1.6,0.5];
maxTime = max(tStart+durs) + 0.1; %-- Add time to show signal ending
durLengthEstimate = ceil(maxTime*fs);
tt = (0:durLengthEstimate)*(1/fs); %-- be conservative (add one)
xx = 0*tt; %--make a vector of zeros to hold the total signal
for kk = 1:length(amps)
    nStart = round(tStart(kk) * fs)+1; %-- add one to avoid zero index
    xNew = shortSinus(amps(kk), freqs(kk), phases(kk), fs, durs(kk));
    Lnew = length(xNew);
    nStop = nStart + Lnew - 1; %<========== Add code
    xx(nStart:nStop) = xx(nStart:nStop) + xNew;
end
tt = (1/fs)*(0:length(xx)-1);
figure
spectrogram(xx,256,[ ],[ ],fs,'yaxis'); colorbar


function xs = shortSinus(amp, freq, pha, fs, dur)
% amp = amplitude
% freq = frequency in cycle per second
% pha = phase, time offset for the first peak
% fs = number of sample values per second
% dur = duration in sec
%
tt = 0 : 1/fs : dur; % time indices for all the values
xs = amp * cos( freq*2*pi*tt + pha );
end
```

```
amps =

     1     1


freqs =

         900        1450


phases =

     0     0
```

3.4

Table of Contents

Template of sigBeat Struct

sigBeat.Amp = 10; %-- B in Equation (3) sigBeat.fc = 480; %-- center frequency in Eq. (3) sigBeat.phic = 0; %-- phase of 2nd sinusoid in Eq. (3) sigBeat.fDelt = 20; %-- modulating frequency in Eq. (3) sigBeat.phiDelt = -2*pi/3; %-- phase of 1st sinusoid Eq. (3) sigBeat.t1 = 1.1; %-- starting time sigBeat.t2 = 5.2; %-- ending time %

```
%----- extra fields for the parameters in Equation (4)
%
% sigBeat.f1        %-- frequencies in Equation (4)
% sigBeat.f2        %--
% sigBeat.X1        %-- complex amps for sinusoids in Equation (4)
% sigBeat.X2        %-- derived from A's and phi's
%
% sigBeat.values    %-- vector of signal values sigBeat.times
% sigBeat.times     %-- vector of corresponding times
```

3.4(a)

Complete the sum2BeatStruct function at the end

3.4(b)

Create a beat signal with two frequency components: one at 720 Hz and one at 750 Hz

```
fs = 8000;
sigBeat.Amp = 10; %-- B in Equation (3)
sigBeat.fc = 735; %-- center frequency in Eq. (3)
sigBeat.phic = pi/4; %-- phase of 2nd sinusoid in Eq. (3)
sigBeat.fDelt = 15; %-- modulating frequency in Eq. (3)
sigBeat.phiDelt = 0; %-- phase of 1st sinusoid Eq.~(3)
sigBeat.t1 = 0; %-- starting time
sigBeat.t2 = 4.04; %-- ending time %

testingBeat = sum2BeatStruct( sigBeat );
testingBeat.times = sigBeat.t1:1/fs:sigBeat.t2;
testingBeat.values =
 real( testingBeat.X1*exp(1j*2*pi*testingBeat.f1*testingBeat.times) ...
```

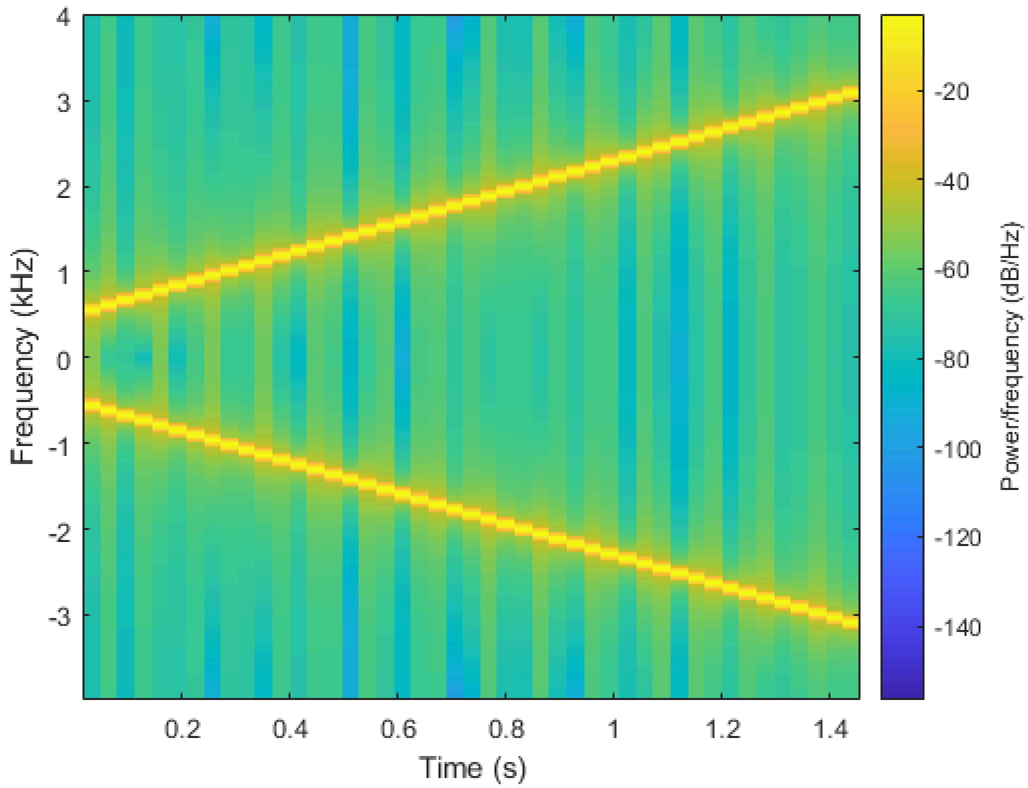
3.5

```
myLFMsig.f1 = 500;
myLFMsig.t1 = 0;
myLFMsig.t2 = 1.5;
myLFMsig.slope = 1800;
myLFMsig.complexAmp = 10*exp(j*0.3*pi);
dt = 1/8000; % 8000 samples per sec is the sample rate
outLFMsig = makeLFMvals(myLFMsig,dt);
%- Plot the values in outLFMsig
plot(outLFMsig.times(1:500), outLFMsig.times(1:500))
%- Make a spectrogram for outLFMsig to see the linear frequency change
spectrogram(outLFMsig.values, 512,[ ],[ ],1/dt,'centered','yaxis')


function sigOut = makeLFMvals( sigLFM, dt )
% MAKELFMVALS       generate a linear-FM chirp signal
%
% usage: sigOut = makeLFMvals( sigLFM, dt )
% sigLFM.f1 = starting frequency (in Hz) at t = sigLFM.t1
% sigLFM.t1 = starting time (in secs)
% sigLFM.t2 = ending time
% sigLFM.slope = slope of the linear-FM (in Hz per sec)
% sigLFM.complexAmp = defines the amplitude and phase of the FM signal
% dt = time increment for the time vector, typically 1/fs (sampling frequency)
%
% sigOut.values = (vector of) samples of the chirp signal
% sigOut.times = vector of time instants from t=t1 to t=t2
%
if( nargin < 2 ) %-- Allow optional input argument for dt
    dt = 1/8000; %-- 8000 samples/sec
end

%--------NOTE: use the slope to determine mu needed in psi(t)
%-------- use f1, t1 and the slope to determine f0 needed in psi(t)
tt = sigLFM.t1:dt:sigLFM.t2;
mu = sigLFM.slope/2;
f0 = sigLFM.f1;
psi = 2*pi*( f0*tt + mu*tt.*tt);
xx = real( sigLFM.complexAmp * exp(1j*psi) );
sigOut.times = tt;
sigOut.values = xx;

end
```



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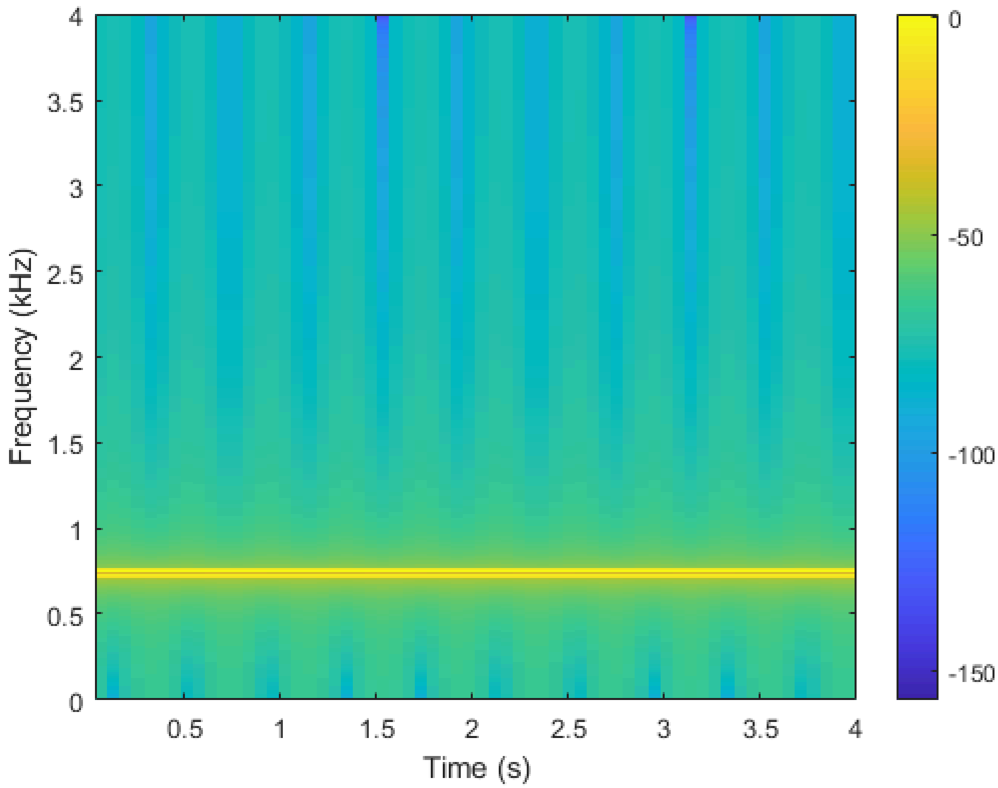
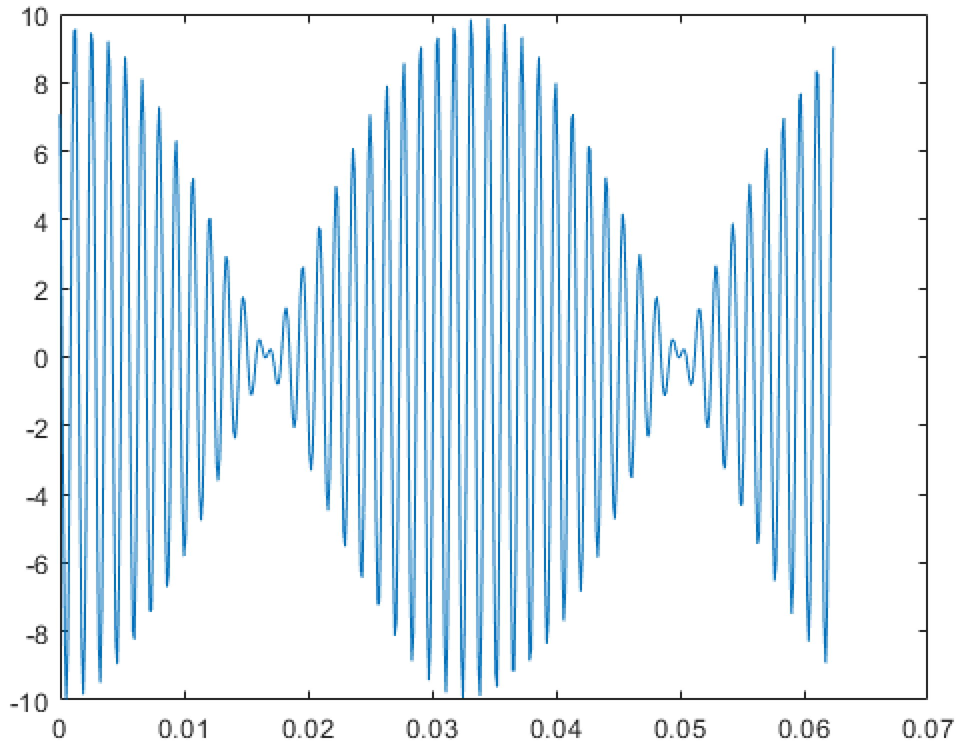
```
    + testingBeat.X2*exp(1j*2*pi*testingBeat.f2*testingBeat.times) );

figure
spectrogram(testingBeat.values,1024,[ ],[ ],fs,'yaxis'); colorbar
soundsc(testingBeat.values, fs)
```



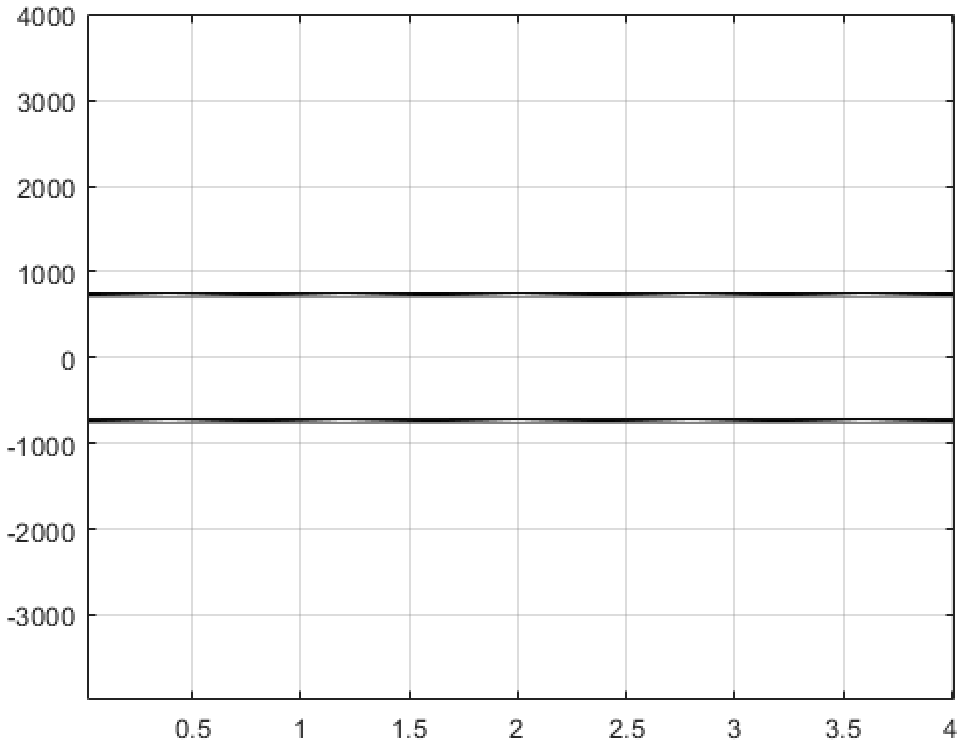
3.4.1(a)

```
fs = 8000;
sigBeat.Amp = 10; %-- B in Equation (3)
sigBeat.fc = 735; %-- center frequency in Eq. (3)
sigBeat.phic = pi/4; %-- phase of 2nd sinusoid in Eq. (3)
sigBeat.fDelt = 15; %-- modulating frequency in Eq. (3)
sigBeat.phiDelt = 0; %-- phase of 1st sinusoid Eq.~(3)
sigBeat.t1 = 0; %-- starting time
sigBeat.t2 = 4.04; %-- ending time %

testingBeat = sum2BeatStruct( sigBeat );
testingBeat.times = sigBeat.t1:1/fs:sigBeat.t2;
testingBeat.values =
 real(testingBeat.X1*exp(1j*2*pi*testingBeat.f1*testingBeat.times) ...
    + testingBeat.X2*exp(1j*2*pi*testingBeat.f2*testingBeat.times) );

figure
plot( testingBeat.times(1:500), testingBeat.values(1:500) )
```



3.4.1(c)

```
plotspec(testingBeat.values+j*1e-12,fs,512); grid on, shg
```




```
function sigBeatSum = sum2BeatStruct( sigBeatIn ) %
%--- Assume the five basic fields are present, plus the starting and ending
 times
%--- Add the four fields for the parameters in Equation (4)
%
% sigBeatSum.f1, sigBeatSum.f2, sigBeatSum.X1, sigBeatSum.X2

sigBeatSum.f1 = sigBeatIn.fc + sigBeatIn.fDelt;
sigBeatSum.f2 = sigBeatIn.fc - sigBeatIn.fDelt;
% Amplitude --> See Eq. (4)
A1 = sigBeatIn.Amp/2;
A2 = sigBeatIn.Amp/2;
% Phase --> See Eq. (4)
phi1 = sigBeatIn.phic + sigBeatIn.phiDelt;
phi2 = sigBeatIn.phic - sigBeatIn.phiDelt;
% Compute complex amplitude
sigBeatSum.X1 = A1 * exp(1j * phi1);
sigBeatSum.X2 = A2 * exp(1j * phi2);

end
```

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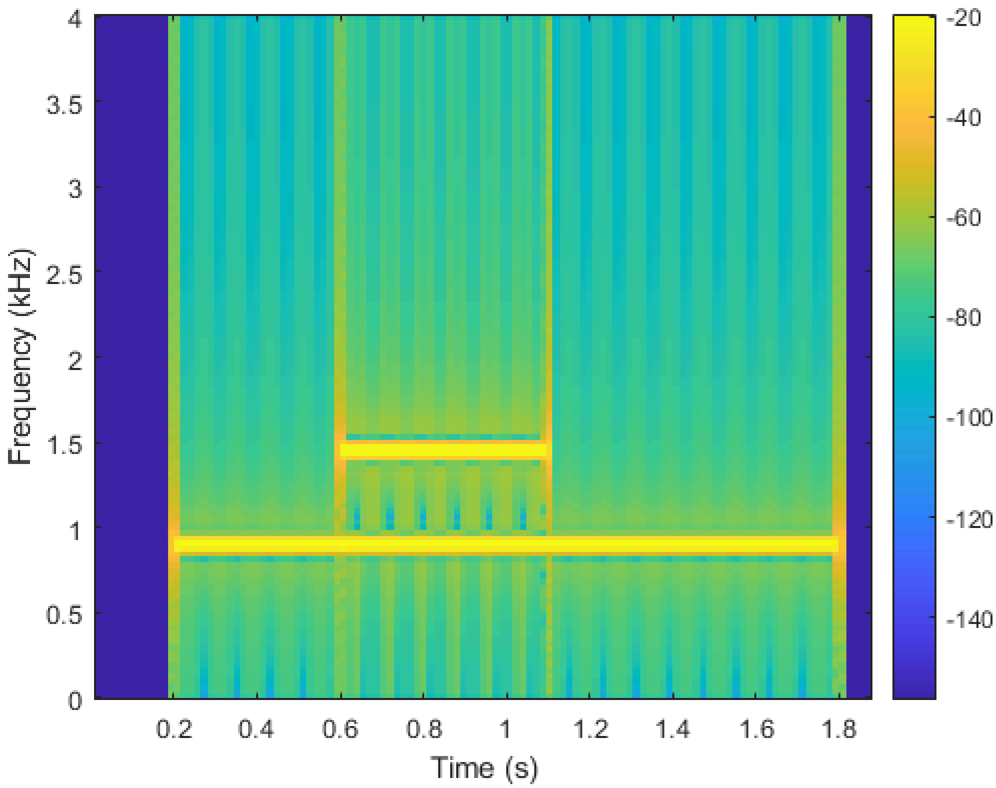

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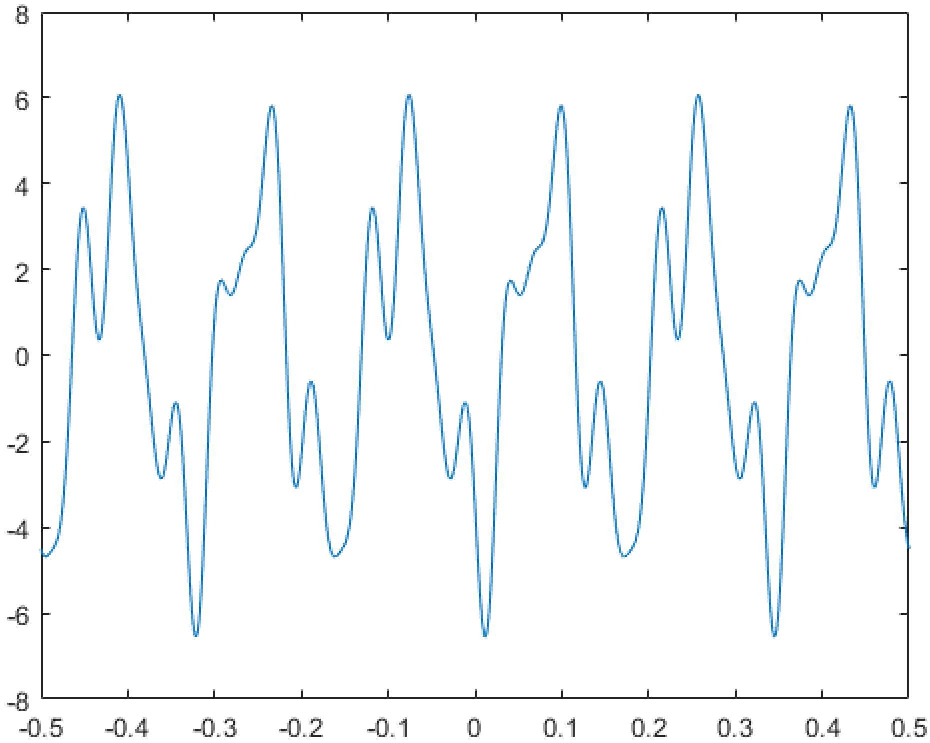
```
sigOut.times = t;
end
```

Warning: Imaginary parts of complex X and/or Y arguments ignored.



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