Bset 2: More Frequency Domain, LTI Systems

In[1]:=
```
SetDirectory@NotebookDirectory[];
<< "../MMA library.m"
```

---

1. Moving Average

```
With[{context = "movingaverage`"}, If[Context[] ≠ context, Begin[context]]];
Dynamic[Refresh[Context[], UpdateInterval → 1]]
```

```
p8`
```

```
fs = Import["hallelujah.wav", "SampleRate"]
data = Import["hallelujah.wav", "Data"][[2]];
Dimensions@data
```

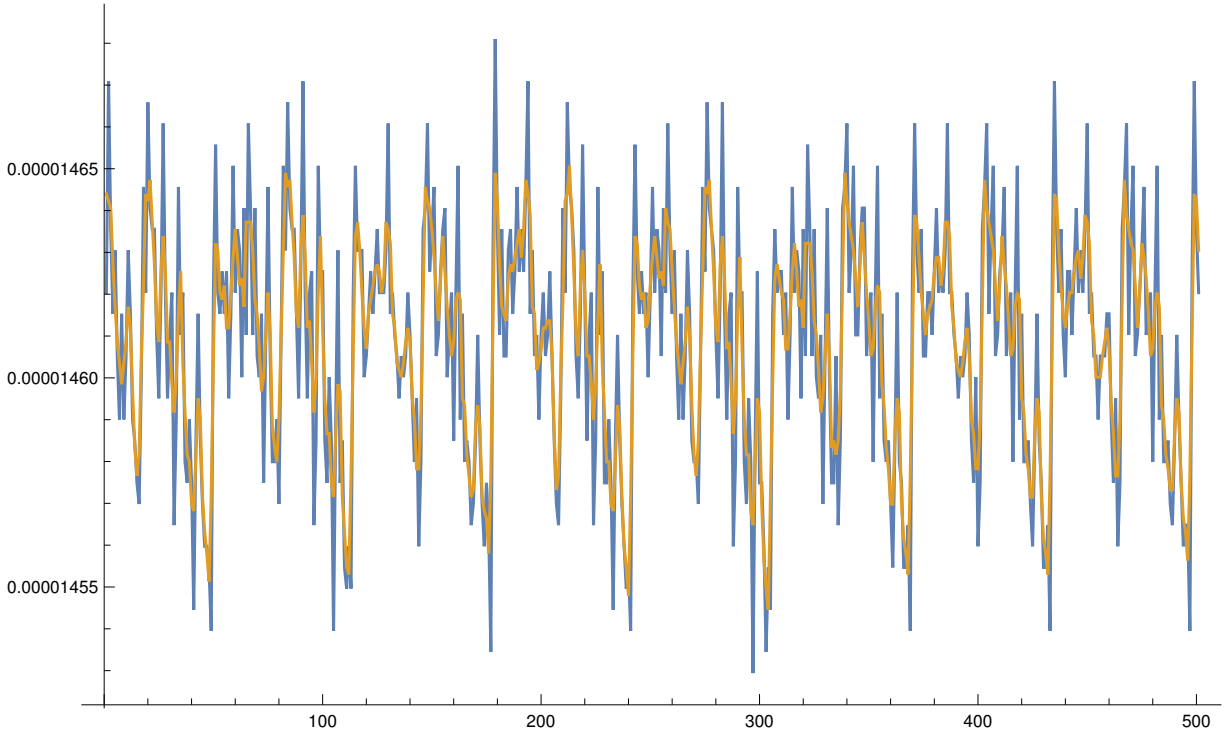
```
44 100
```

```
{791 320}
```

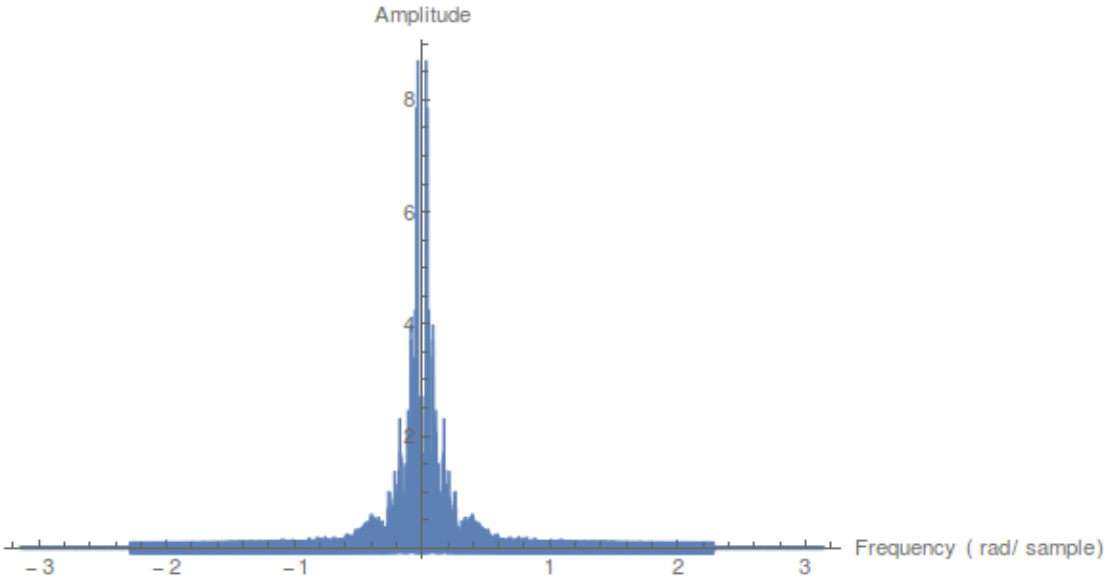
```
movingAverage[data_] := 1 / 3 (RotateLeft[data] + data + RotateRight@data)
```

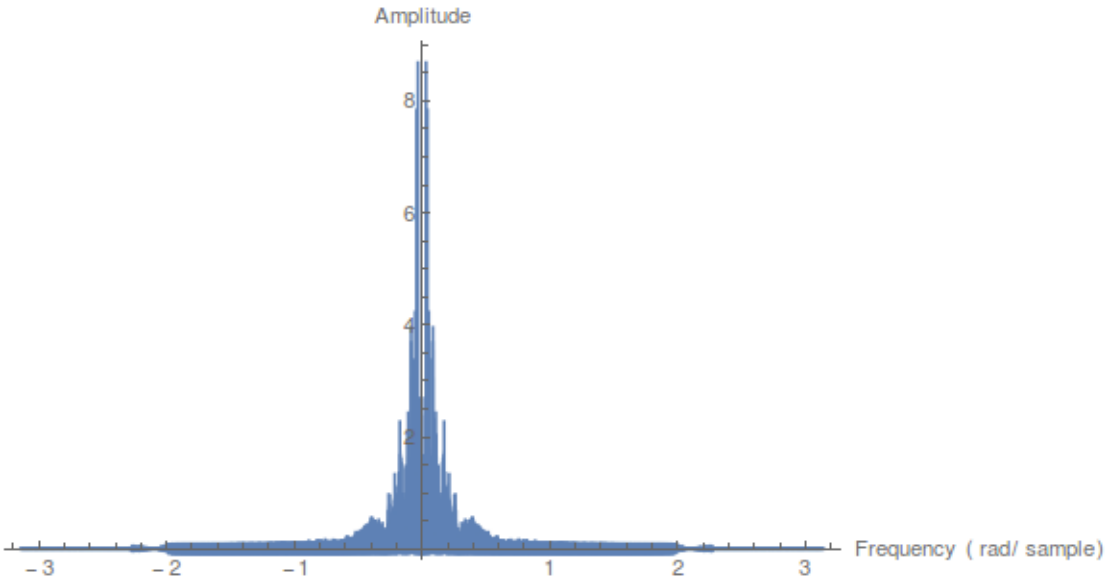
```
averaged = movingaverage`movingAverage@data;
```

```
ListLinePlot[{data[[10 000 ;; 10 500]], averaged[[10 000 ;; 10 500]]},
 PlotLegends → {"Raw data", "Moving average"}, ImageSize → Full]
```



```
plotFFT@data
plotFFT@averaged
```






```
playSound[data, fs]
```

```
playSound[movingAverage@data, fs]
```

```
data[[1000 ;; 1010]]
```

$$\{2.69363\times10^{-6},\ 3.59824\times10^{-6},\ -1.83955\times10^{-6},\ -8.657\times10^{-6},\ -6.34746\times10^{-6},\ -1.00569\times10^{-6},\ -5.12951\times10^{-6},\ -0.0000120531,\ -9.59699\times10^{-6},\ -4.31587\times10^{-6},\ -5.98864\times10^{-6}\}$$

```
With[{context = "movingaverage`"}, If[Context[] == context, End[], "Not in context"]]
```
```
movingaverage`
```

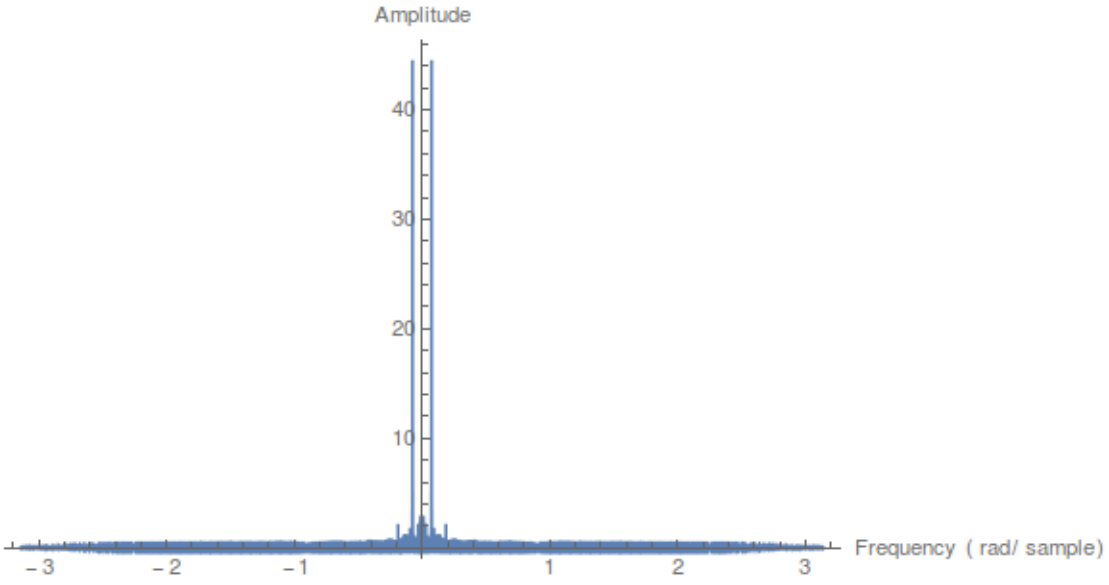
2. Remove Disturbances

In[13]:=
```
With[{context = "p2`"}, If[Context[] ≠ context, Begin[context]]];
Dynamic[Refresh[Context[], UpdateInterval → 1]]
```
Out[13]=
```
p8`
```

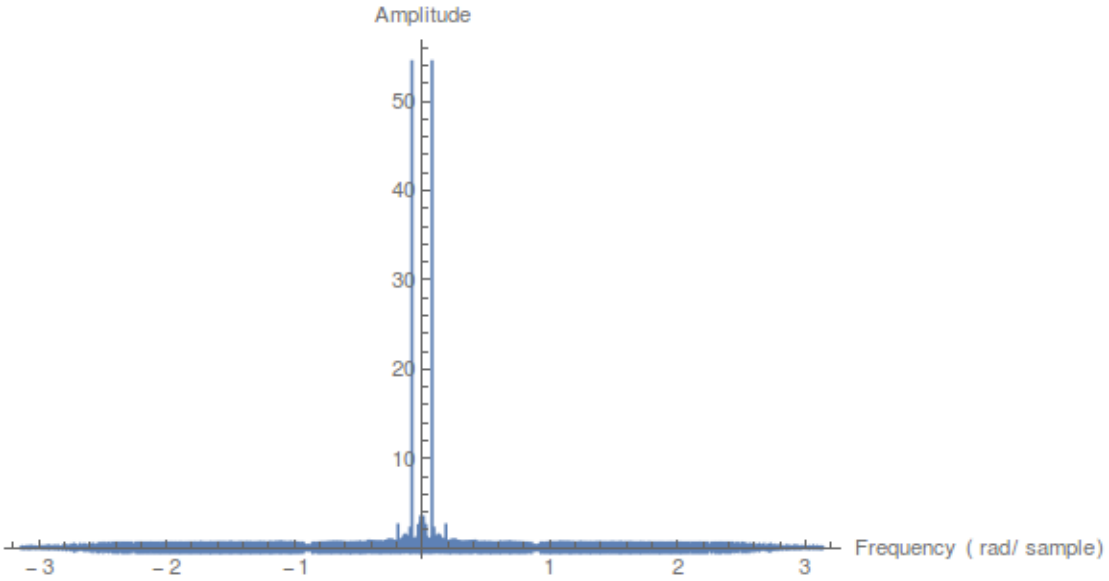
In[14]:=
```
fs = Import["provided files/Disturbance261.wav", "SampleRate"]
x275 = Import["provided files/Disturbance275.wav", "Data"];
x275freq = 275.6181;
x261 = Import["provided files/Disturbance261.wav", "Data"];
x261freq = 261.626;
xOrig = Import["provided files/DisturbanceOrig.wav", "Data"];
```
Out[14]=
```
22 050
```

In[20]:=
```
playSound[x261, fs]
```

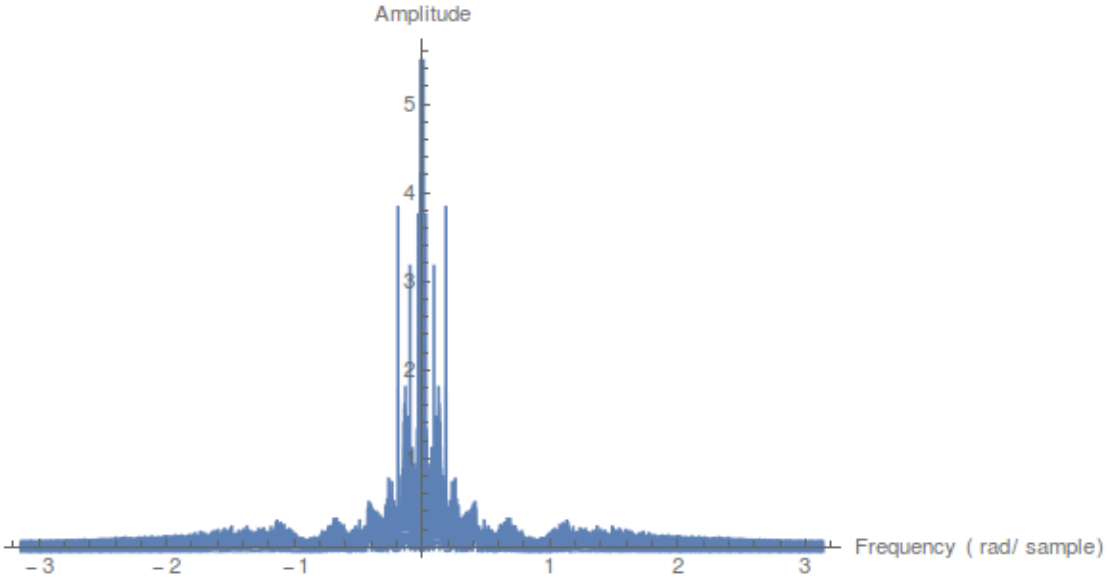
In[21]:=
```
playSound[x275, fs]
```
```
playSound[xOrig, fs]
```
```
plotFFT[x261]
```



```
plotFFT@x275
```




```
plotFFT@xOrig
```



Remove noise from 275hz signal: naive approach

```
(N@Ordering[Fourier@x275, -1][[1]] - 1) * (2 Pi / Length@x275) * fs / (2 Pi)
```

```
275.618
```

```
fft = Fourier@x275;
```

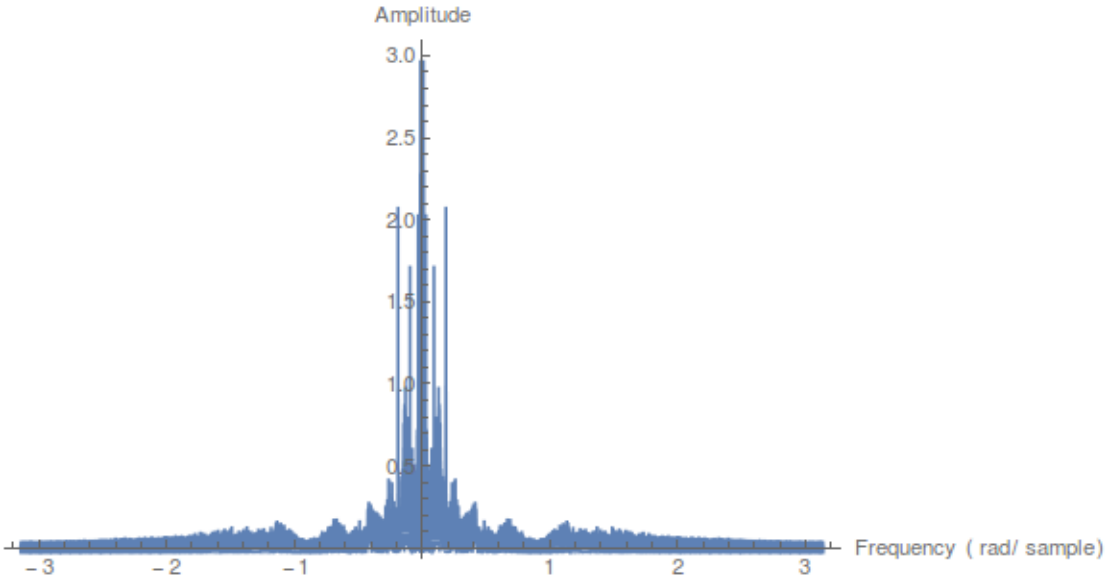
Replace the top two magnitudes with zero

```
fft[[Ordering[fft, -2]]] = 0;
```

Rebuild sound

```
sound = InverseFourier@fft;
```

```
plotFFT@sound
```



Compare the results

```
playSound[Re@x275, fs]
```

```
playSound[Re@sound, fs]
```

```
With[{context = "p2`"}, If[Context[] == context, End[], "Not in context"]]
```

```
Not in context
```

Remove 275hz noise: notch filter

notchFilter removes frequencies near freq (specified in radians per sample) with aggressiveness q (range 0-1)

In[3]:=
```
notchFilter[data_, freq_, q_] :=
 Module[{a, b, p, qq, r, y},
  a = 2 q Cos@freq;
  b = -q^2;
  p = 1;
  qq = -2 Cos@freq;
  r = 1;
  y = ConstantArray[0, Length@data];
  Do[
   y[[n]] = a y[[n - 1]] + b y[[n - 2]] + p data[[n]] + qq data[[n - 1]] + r data[[n - 2]],
   {n, 3, Length@data}];
  y
 ]
```

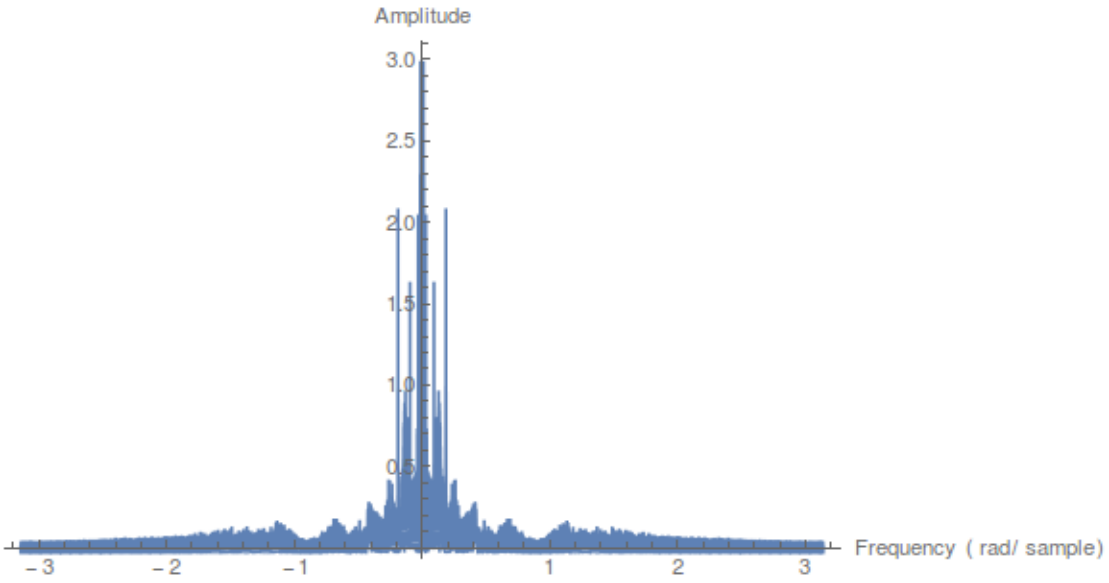
Pass the x275 through a notch filter

```
freq = x275freq * 2 Pi / fs
```

```
0.0785379
```

```
filtered = notchFilter[x275, freq, .999];
```

```
plotFFT@filtered
```




```
playSound[filtered, fs]
```

```
playSound[xOrig, fs]
```

Remove noise from 261hz signal: naive approach

```
(N@Ordering[Fourier@x261, -1][[1]] - 1) * (2 Pi / Length@x261) * fs / (2 Pi)
```

```
261.837
```

```
fft = Fourier@x261;
```

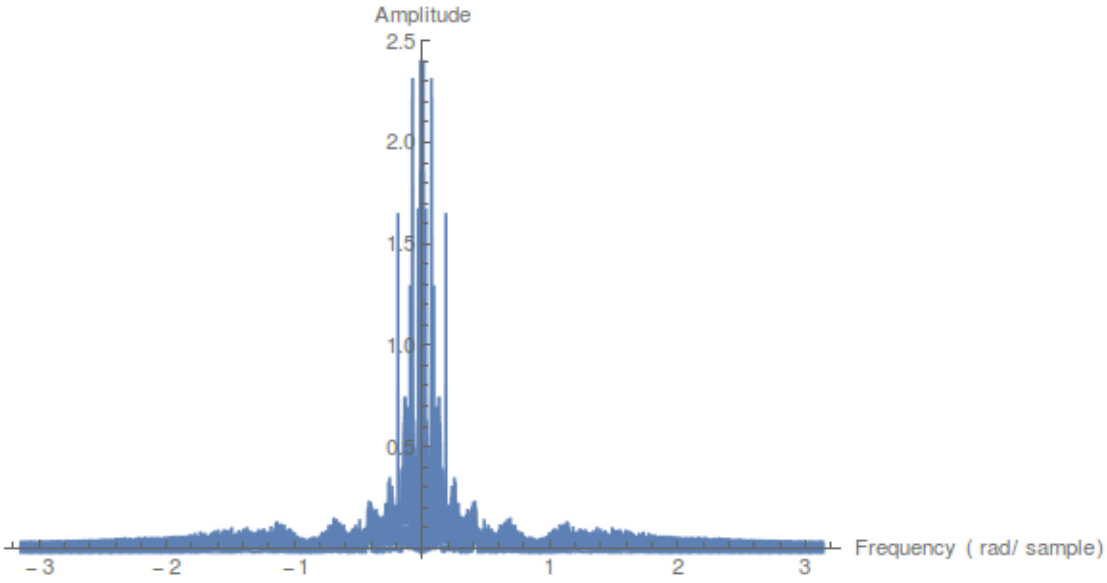
Replace the top bunch of magnitudes with zero

```
fft[[Ordering[Abs@fft, -30]]] = 0;
```

Rebuild sound

```
sound = InverseFourier@fft;
```

```
plotFFT@sound
```



Compare the results

```
playSound[Re@x261, fs]
```

```
playSound[Re@sound, fs]
```

```
playSound[Re@xOrig, fs]
```

```
With[{context = "p2`"}, If[Context[] == context, End[], "Not in context"]]
```

```
p2`
```

Remove 261hz noise: notch filter

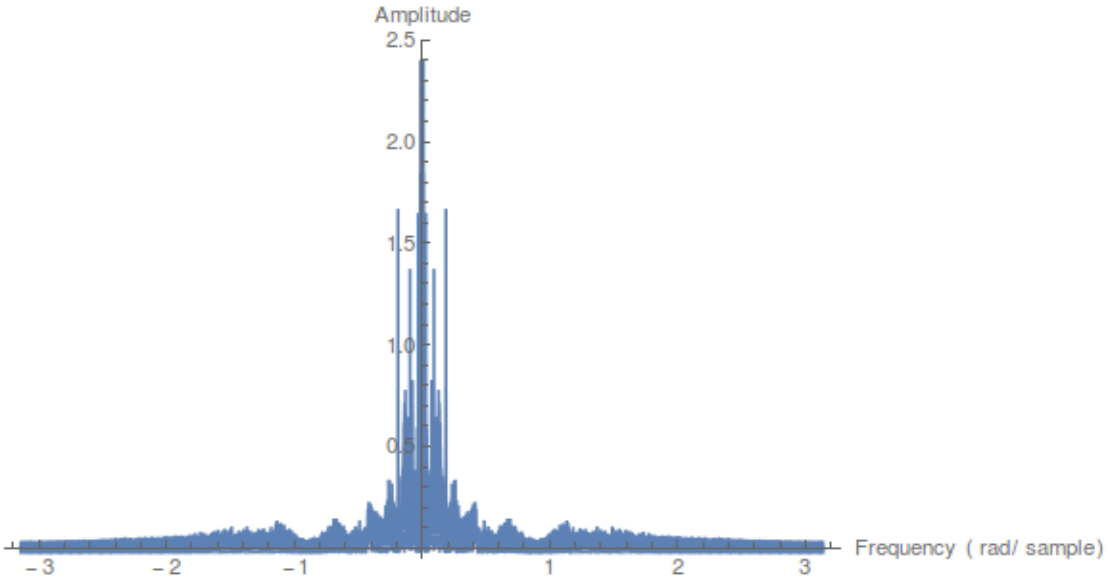
Pass the x275 through a notch filter

```
freq = x261freq * 2 Pi / fs
```

```
0.0745508
```

```
filtered = notchFilter[x261, freq, .999];
```

```
plotFFT@filtered
```




```
playSound[filtered, fs]
```

```
playSound[xOrig, fs]
```

```
With[{context = "p2`"}, If[Context[] == context, End[], "Not in context"]]
```

3. CTFT

In[5]:=
```
With[{context = "p3`"}, If[Context[] ≠ context, Begin[context]]];
Dynamic[Refresh[Context[], UpdateInterval → 1]]
```

Out[5]= p8`

In[37]:=
```
Integrate[Exp[-t (I ω + 1 / τ)], {t, 0, Infinity}, Assumptions → {τ > 0, ω > 0}]
```

Out[37]=
$$\frac{i\,\tau}{i-\tau\,\omega}$$

In[38]:=
```
With[{context = "p3`"}, If[Context[] == context, End[], "Not in context"]]
```

Out[38]= p3`

8.Circuits

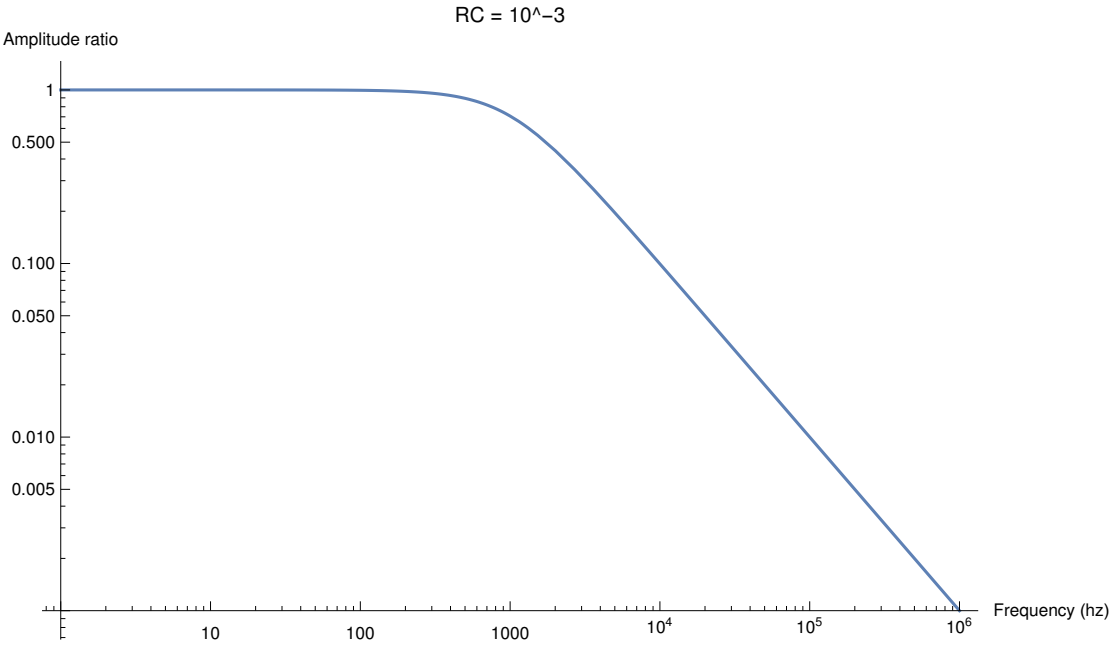
In[45]:=
```
With[{context = "p8`"}, If[Context[] ≠ context, Begin[context]]];
Dynamic[Refresh[Context[], UpdateInterval → 1]]
```

Out[45]= p8`

In[54]:=
```
RC = 10^-3;
```

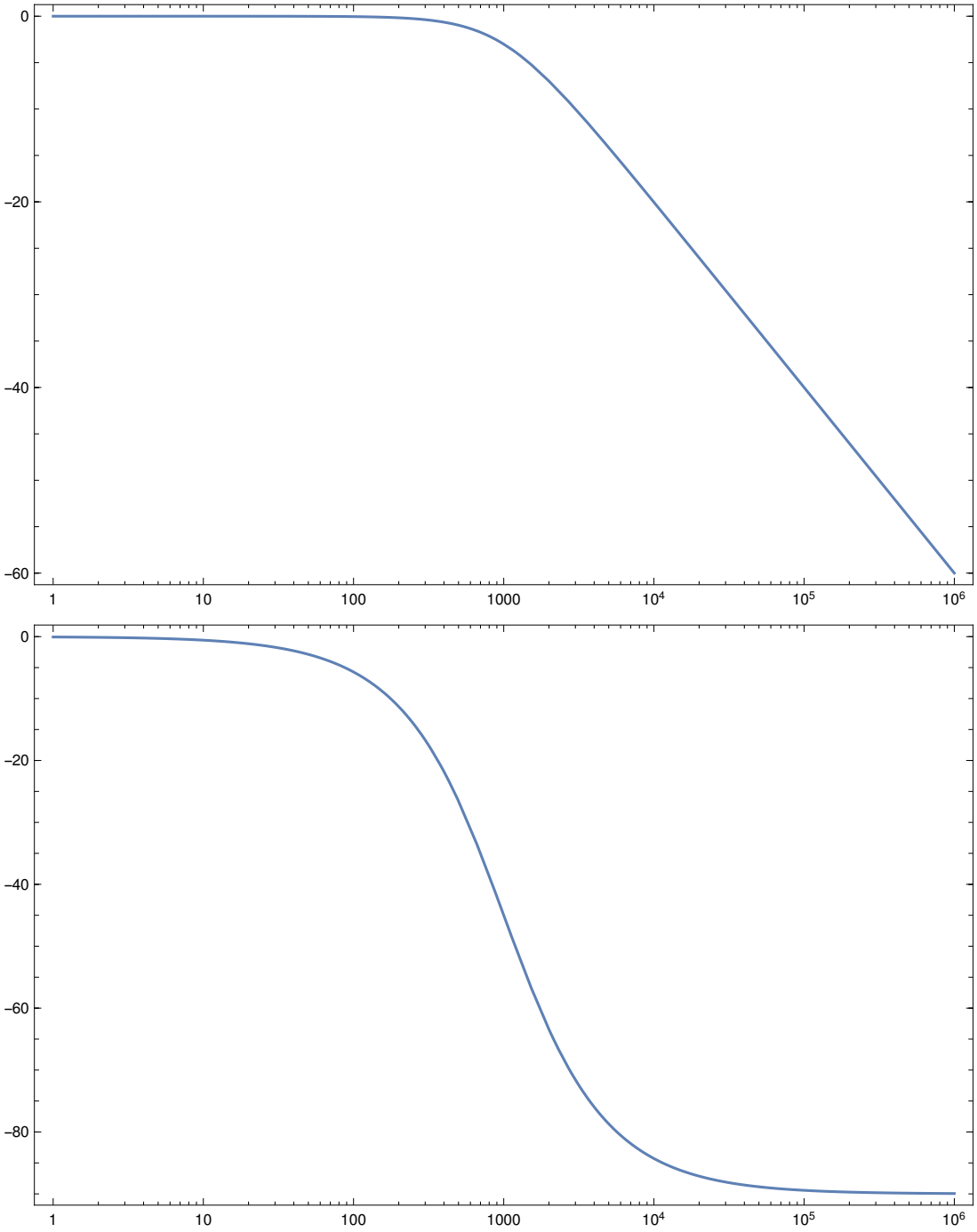
In[60]:=
```
LogLogPlot[Abs[1 / (1 + RC I ω)], {ω, 1, 10^6},
 AxesLabel → {"Frequency (hz)", "Amplitude ratio"},
 ImageSize → Large, PlotLabel → "RC = 10^-3"]
```

Out[60]=



In[64]:=
```
BodePlot[1 / (1 + RC I ω), {ω, 1, 10^6}, ImageSize → Large]
```

Out[64]=



In[44]:=
```
With[{context = "p8`"}, If[Context[] == context, End[], "Not in context"]]
```
Out[44]=
```
p8`
```

Scratch work

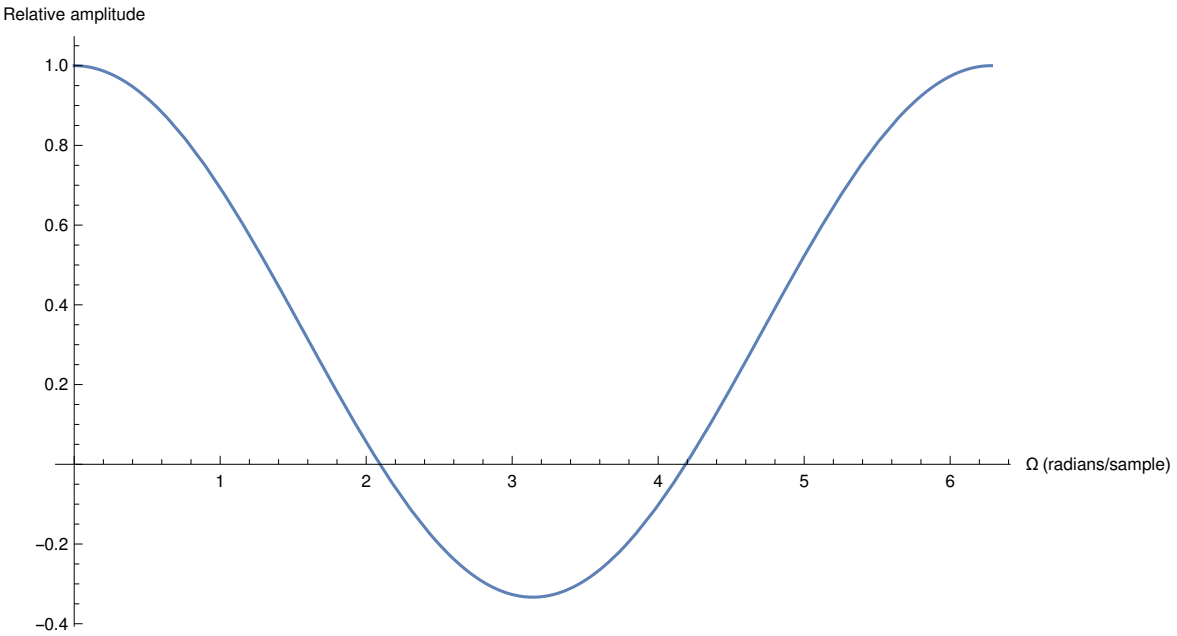
In[65]:=
```
exportNotebookPDF[]
```
```
/home/eric/Documents/School/QEA2/Acoustic Modem/Bset 2/Mathematica scratch.pdf
```

```
NotebookInformation[]
```
```
{FileName → FrontEnd`FileName[
    {$RootDirectory, home, eric, Documents, School, QEA2, Acoustic Modem, Bset 2},
   Mathematica scratch.nb, CharacterEncoding → UTF-8],
 FileModificationTime → 3.68271 × 10^9, WindowTitle → Mathematica scratch.nb,
 MemoryModificationTime → 3.68271 × 10^9, ModifiedInMemory → True,
 StorageSystem → Local, DocumentType → Notebook,
 MIMEType → application/vnd.wolfram.nb, StyleDefinitions → {NotebookObject[ 4 ]}}
```

```
NotebookDirectory[]
```
```
/home/eric/Documents/School/QEA2/Acoustic Modem/Bset 2/
```

```
ExpandFileName["/home/eric/Documents/School/QEA2/Acoustic Modem/Bset 2/"]
```
```
/home/eric/Documents/School/QEA2/Acoustic Modem/Bset 2/
```

```
Plot[1/3 (2 Cos@sig + 1), {sig, 0, 2 Pi},
 AxesLabel → {"Ω (radians/sample)", "Relative amplitude"}]
```



```
StringReplace["/tmp/soundrand.wav", "rand" -> ToString@RandomInteger[999]]
```

```
/tmp/sound203.wav
```

```
RandomInteger[999]
```

```
155
```