ECE 5630: Programming #2

Due on Tuesday, November 24, 2014

Scott Budge 3:00pm

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Contents

Problem 1

(a)

Figure 1 shows the Impulse response of the filter h[n].

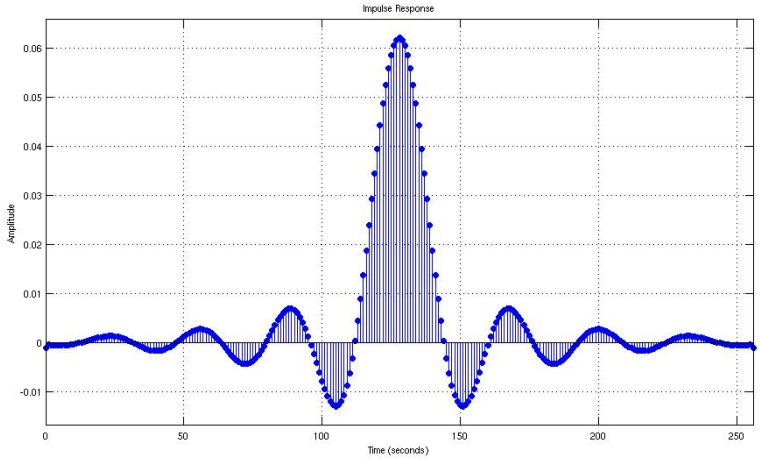


Figure 1: Impulse Response

(b)

Figure 2 shows the Magnitude and Phase response of the filter h[n].

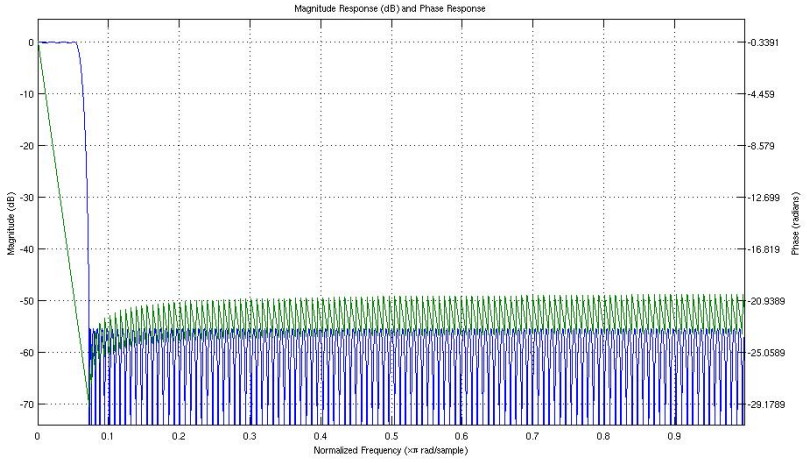


Figure 2: Impulse Response

Problem 2

Listing 1 shows the first program.

Listing 1: Program 1 - part1.cpp

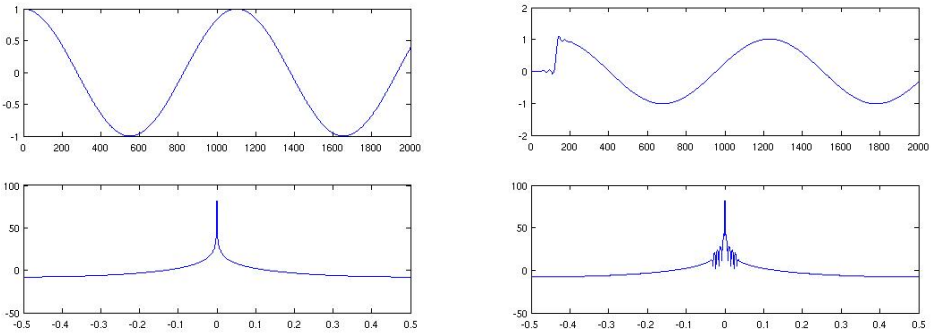
```
#include <iostream>
#include <fstream>
#include <vector>
#include <cstdio>
#include <cstdlib>
#include <cmath>
#include "../includes/fft842.c"

// Filter Length
#define Nf 256
// Length of Signal
#define N 25600
// Sampling frequency
const double Fs = 11025;

int main(int argc, char** argv)
{
  // Input stream for filter
  std::ifstream filterIn("../data/LowPassFilter.dat");

  // filter of length Nf = 256
  double h[Nf];

  // input vairable
  double in;

  // Read in the filter data
  for(int n = 0; n < Nf; ++n)
  {
    filterIn >> in;
    h[n] = in;
  }

  // Output streams for the input x signal
  // and the output y signal
  std::ofstream x_dat("../data/x.dat");
  std::ofstream y_dat("../data/y.dat");

  // input x signal of length N = 25600
  double x[N];

  // output y signal of Length N = 25600
  double y[N];

  // f0 = f/Fs
  // Normalized frequency
  double f = atof(argv[1]);
  double f0 = f/Fs;
```

```
50    // Generate input signal x[n]
      for(int n = 0; n < N; ++n)
      {
        x[n] = cos(2*M_PI*f0*n);
        x_dat << x[n] << std::endl;
55    }

      double temp;
      for(int n = 0; n < N; ++n)
      {
60      temp = 0;
        for(int k = 0; k < Nf; ++k)
        {
          temp += x[n-k]*h[k];
        }
65      y[n] = temp;
        y_dat << y[n] << std::endl;
      }

      return 0;
70  }
```

(a)

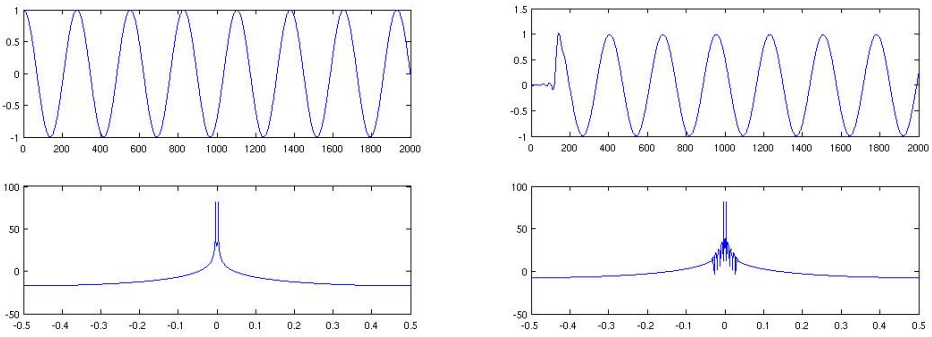
The number of multiples is

(b)



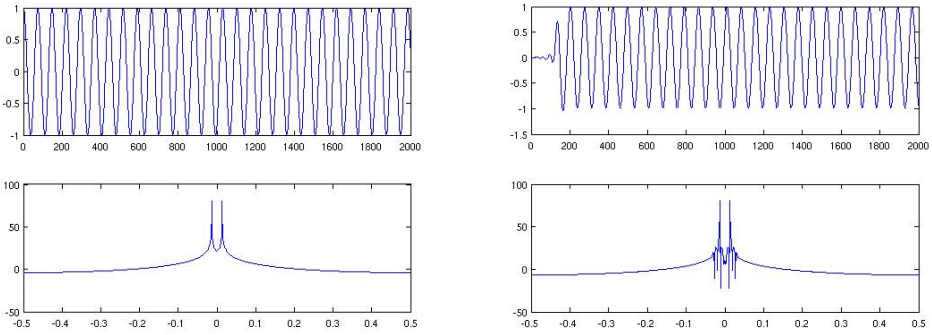
(a) x[n] (b) y[n]

Figure 3: Input(a) and Output(b) with f = 10Hz



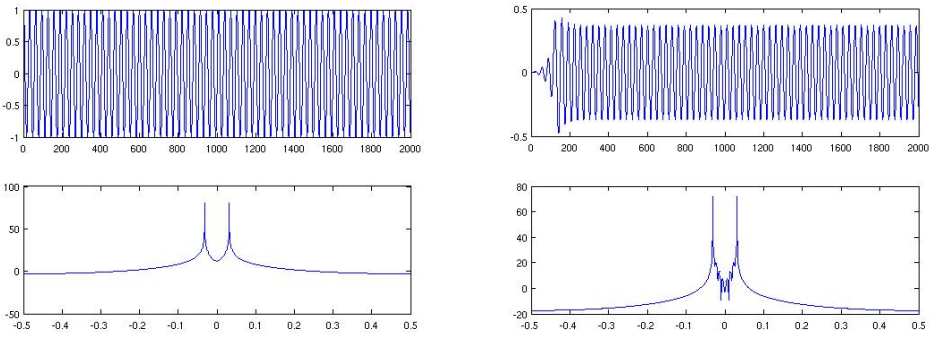
(a) x[n] (b) y[n]

Figure 4: Input(a) and Output(b) with f = 40Hz



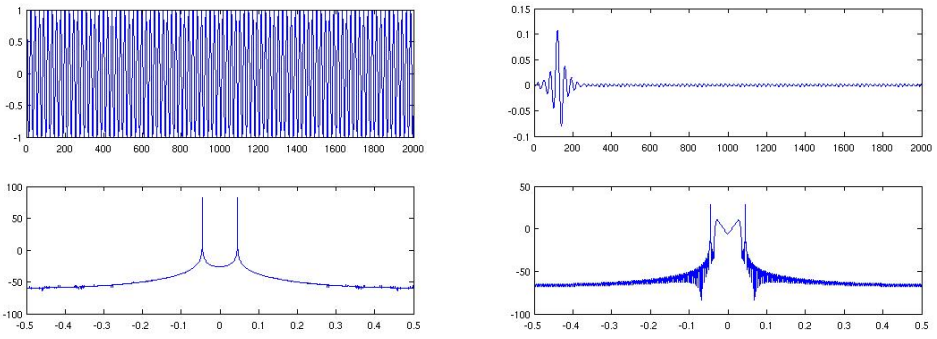
(a) x[n] (b) y[n]

Figure 5: Input(a) and Output(b) with f = 150Hz



(a) x[n] (b) y[n]

Figure 6: Input(a) and Output(b) with f = 350Hz



(a) x[n] (b) y[n]

Figure 7: Input(a) and Output(b) with f = 500Hz

Problem 3

Listing 2 shows the first program.

Listing 2: Program 1 - part2.cpp

```
#include <iostream>
#include <fstream>
#include <vector>
#include <cstdio>
#include <cstdlib>
#include <cmath>
#include <cstring>
#include "../includes/fft842.c"

// Filter Length
#define Nf 256
// Length of Signal
#define N 25600
// Sampling frequency
const double Fs = 11025;

complx mult(complx, complx);

int main(int argc, char** argv)
{
  // Input stream for filter
  std::ifstream filterIn("../data/LowPassFilter.dat");

  // filter of length Nf = 256
  // Nf*4 for zero padding
  complx h[4*Nf];

  // input vairable
  double in;

  // Read in the filter data
  for(int n = 0; n < Nf; ++n)
  {
    filterIn >> in;
    h[n].re = in;
    h[n].im = 0;
    h[n+Nf].re = 0;
    h[n+Nf].im = 0;
    h[n+2*Nf].re = 0;
    h[n+2*Nf].im = 0;
    h[n+3*Nf].re = 0;
    h[n+3*Nf].im = 0;
  }

  // Output streams for the input x signal
  // and the output y signal
  std::ofstream x_dat("../data/x.dat");
  std::ofstream y_dat("../data/y.dat");
```

Problem 3 continued on next page...

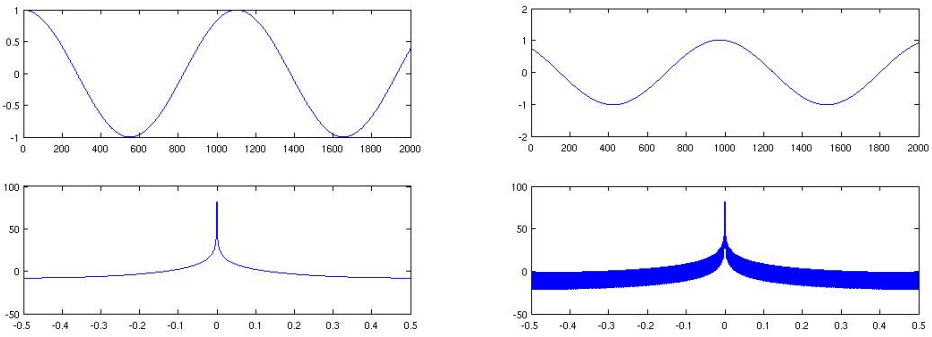
```
  std::ofstream H_dat("../data/H.dat");

  // input x signal of length N = 25600
  complx x[N];

  // output y signal of Length N = 25600
  complx y[N+Nf-1];

  // f0 = f/Fs
  // Normalized frequency
  double f = atof(argv[1]);
  double f0 = f/Fs;

  // Generate input signal x[n]
  for(int n = 0; n < N; ++n)
  {
    x[n].re = cos(2*M_PI*f0*n);
    x[n].im = 0;
    x_dat << x[n].re << std::endl;
  }

  // Cacluating the fft using the overlap and save method
  // using the fft842 with a 1024-point fft
  int M = 256;
  int overlap = M-1;
  int nfft = 1024;
  int stepsize = nfft - overlap;

  complx H[nfft];
  memcpy(H, h, sizeof(h));
  // generate fft of the filter
  fft842(0, nfft, H);

  // Send the data to the corrisponding file
  for(int i = 0; i < nfft; ++i)
  {
    H_dat << H[i].re << "\t" << H[i].im <<std::endl;
  }

  // yt is a temp variable for y - the output
  complx yt[nfft];
  // xt is a temp variable for storing the correct values of x
  // for computing the fft and multiplying it by the filter's resposne
  complx xt[nfft];

  // The process for the computing the convolution
  int position = 0;
  while(position + nfft <= N)
  {
    // Pull out the required data of the x input
    for(int j = 0; j < nfft; ++j)
    {
      xt[j] = x[j + position];
```

```
    }

    // Calculating the corrisponding fft
    fft842(0, nfft, xt);
    // Multiply the points of the x and h magnitude
    for(int k = 0; k < nfft; ++k)
    {
      yt[k] = mult(xt[k], H[k]);
    }
    // Compute the inverse fft
    fft842(1, nfft, yt);
    // The overlap-save portion
    for(int j = M-1; j < nfft; ++j)
    {
      y[j-M+position] = yt[j];
    }
    position += stepsize;
  }
  // Output the data
  for(int n = 0; n < N; ++n)
  {
    y_dat << y[n].re << std::endl;
  }
  return 0;
}

// multiply complex data correctly
complx mult(complx a, complx b)
{
  complx ret;
  ret.re = a.re * b.re - a.im * b.im;
  ret.im = a.re * b.im + a.im * b.re;
  return ret;
}
```

(a)

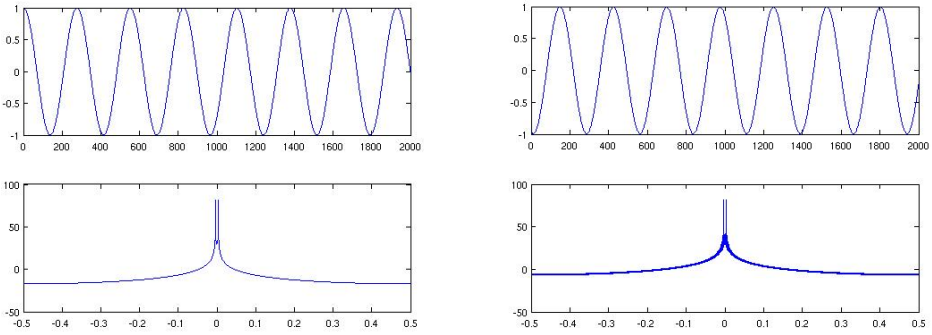
The number of multiples is

(b)



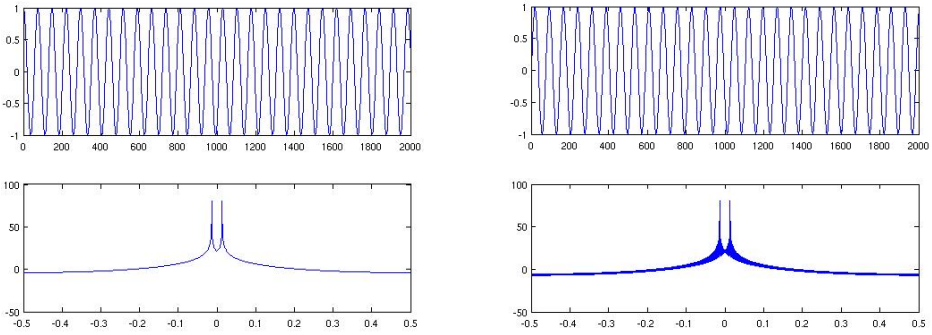
(a) x[n] (b) y[n]

Figure 8: Input(a) and Output(b) with f = 10Hz



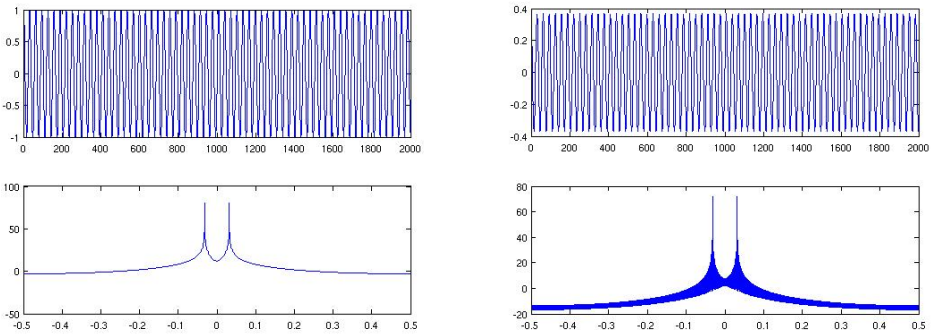
(a) x[n] (b) y[n]

Figure 9: Input(a) and Output(b) with f = 40Hz



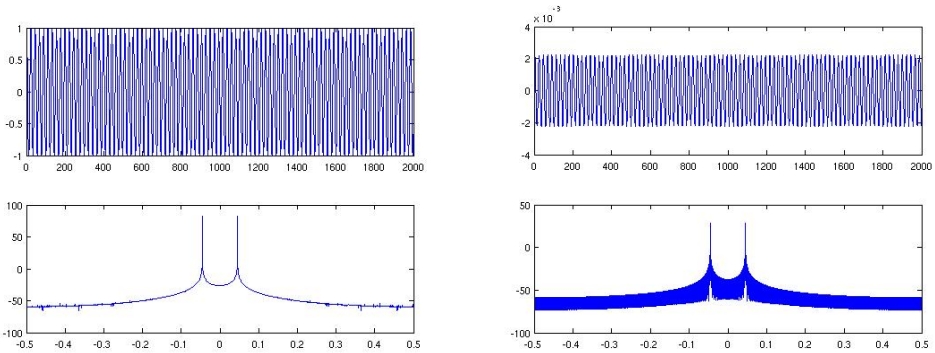
(a) x[n] (b) y[n]

Figure 10: Input(a) and Output(b) with f = 150Hz



(a) x[n] (b) y[n]

Figure 11: Input(a) and Output(b) with f = 350Hz



(a) x[n] (b) y[n]

Figure 12: Input(a) and Output(b) with f = 500Hz