RC, RL, AND RLC FILTER DESIGN

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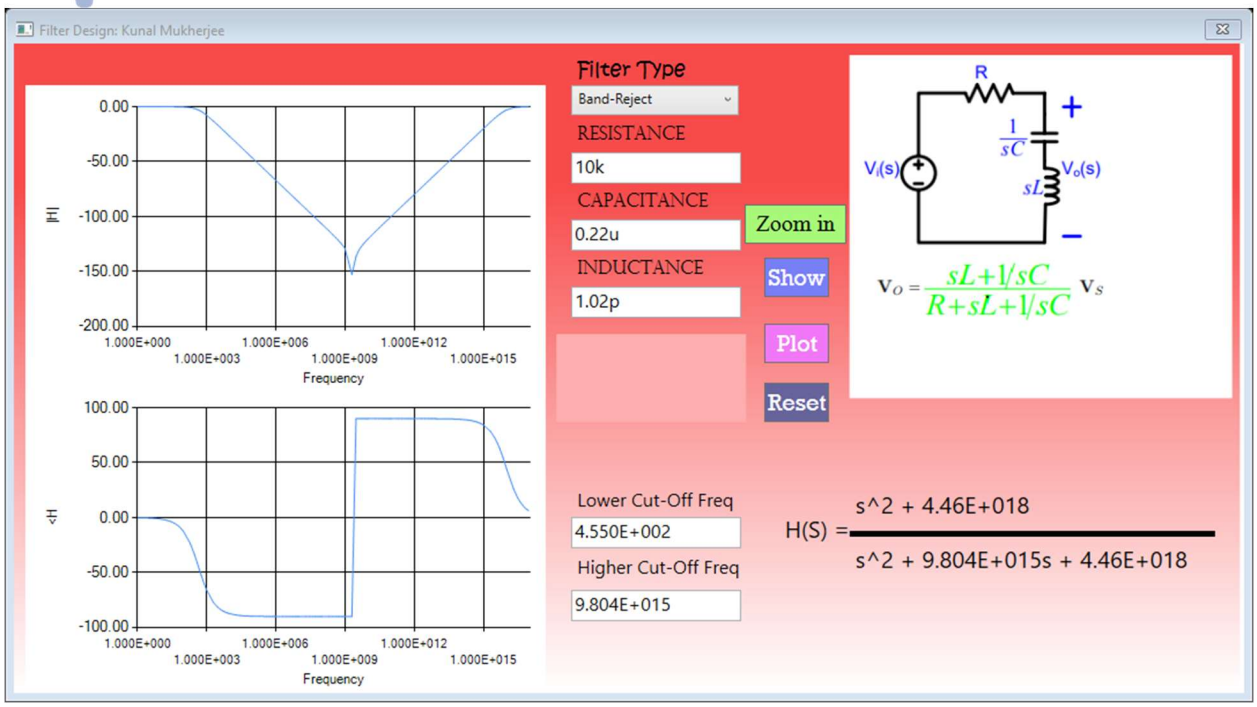

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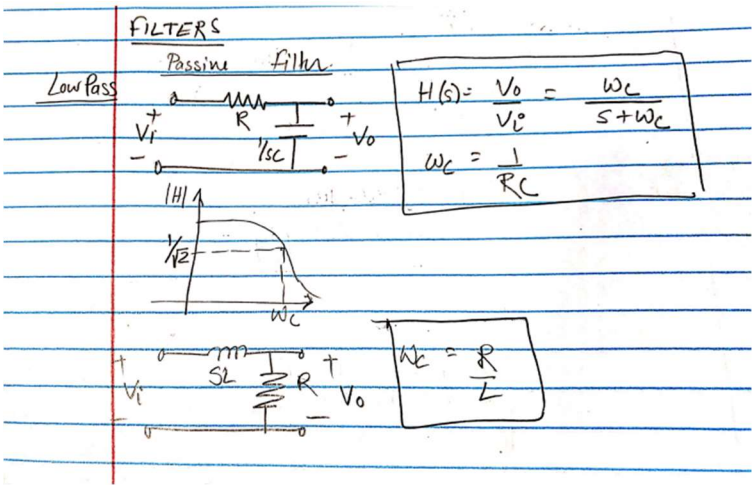
Problem Design

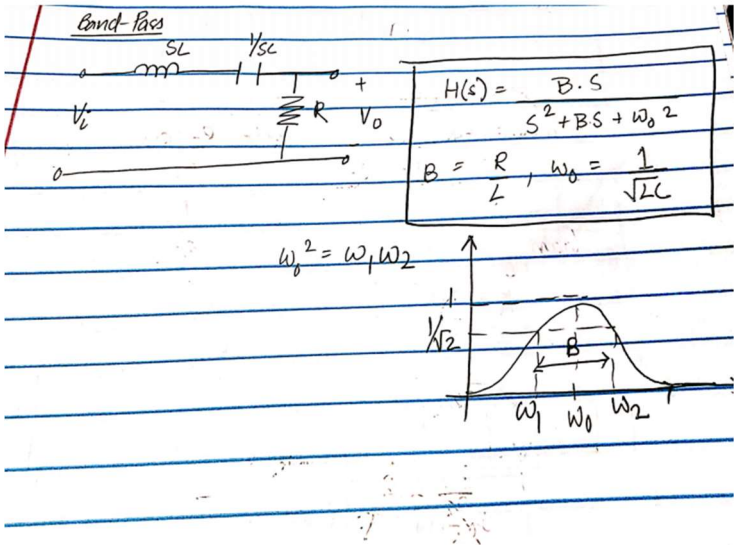
The problem we are trying to solve is how to accurately guess the frequency response from R, L or C value. Therefore, building a simulator to emulate different filter types is the best choice of action. In engineering sometimes, it is necessary to check a pre-built circuit's frequency response as well as to know what value of resistors, capacitors and inductors to use to build the filter. Therefore, I decided to design C# WPF application that shows the user the Bode magnitude plot and Bode phase plot, if the user enters the filter type then, R, L or C value, or center/cut-off frequency and any one of R, L or C value. The application also shows the transfer function and a sample circuit diagram.

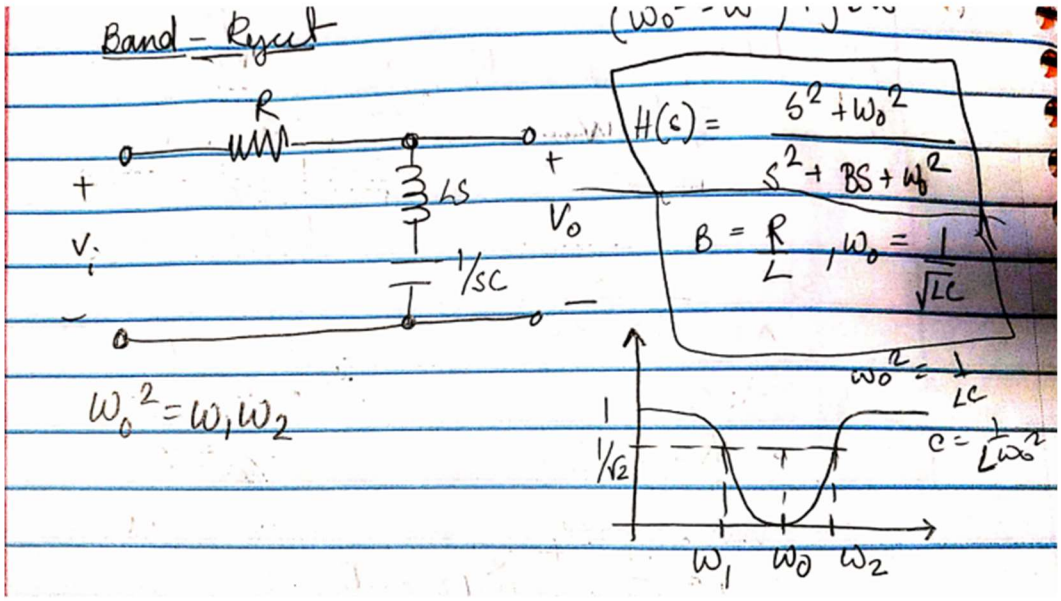
Design

There were two major design hurdles. The first design hurdle was to get all the transfer functions for RC low/high pass, RL low/high pass, RLC bandpass or RLC band stop filters. The second hurdle was to find the appropriate frequency increment value, so that all the necessary information of the bode plot is preserved but does not need a huge dataset.

The transfer function was calculated using the following equations:







The second design issue was solved by using a multiplicative increment. For example, let say, we want to graph for a frequency of 10-1000 Hz, I will use the following frequency values e.g. 1,2,3...10,20,30…100,200,300…1000. In that way, we don't need all the points in between 10-20, as the log scale of the frequency axis will not care, and this increment captures all the necessary information to plot the frequency response.

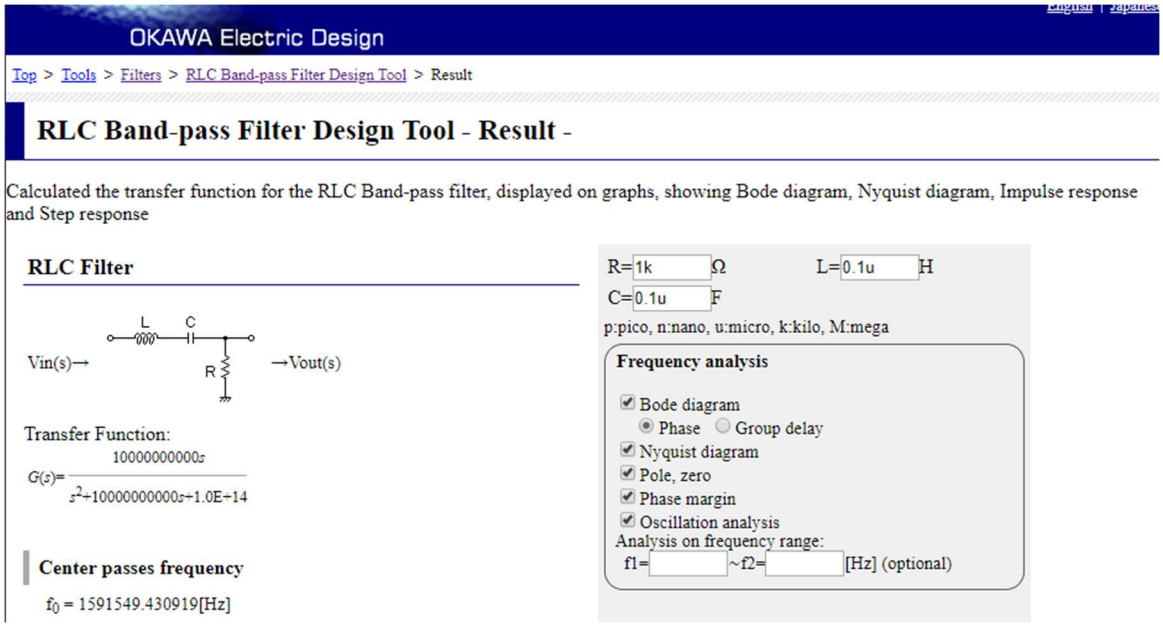
As extra feature, I have added, that you can put u-micro, p-pico, n-nano, f-femto, m-mili, k or K-kilo and M-mega along with numbers for R, L and C values. I have also added a zoom feature that will zoom in the center or the cut-off frequency depending on the filter type.

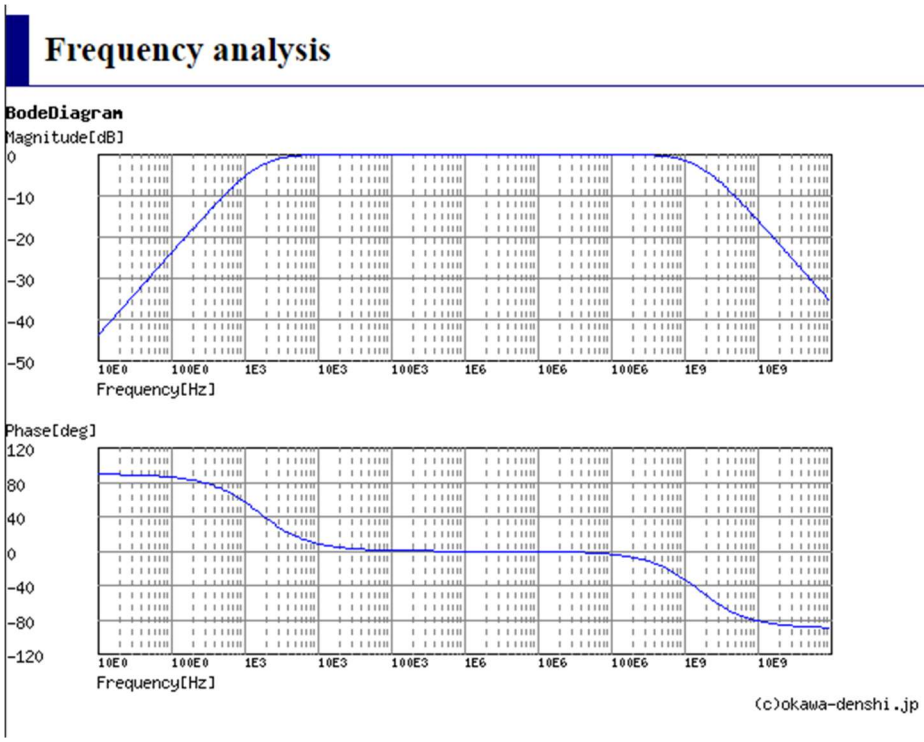
Theoretical Results

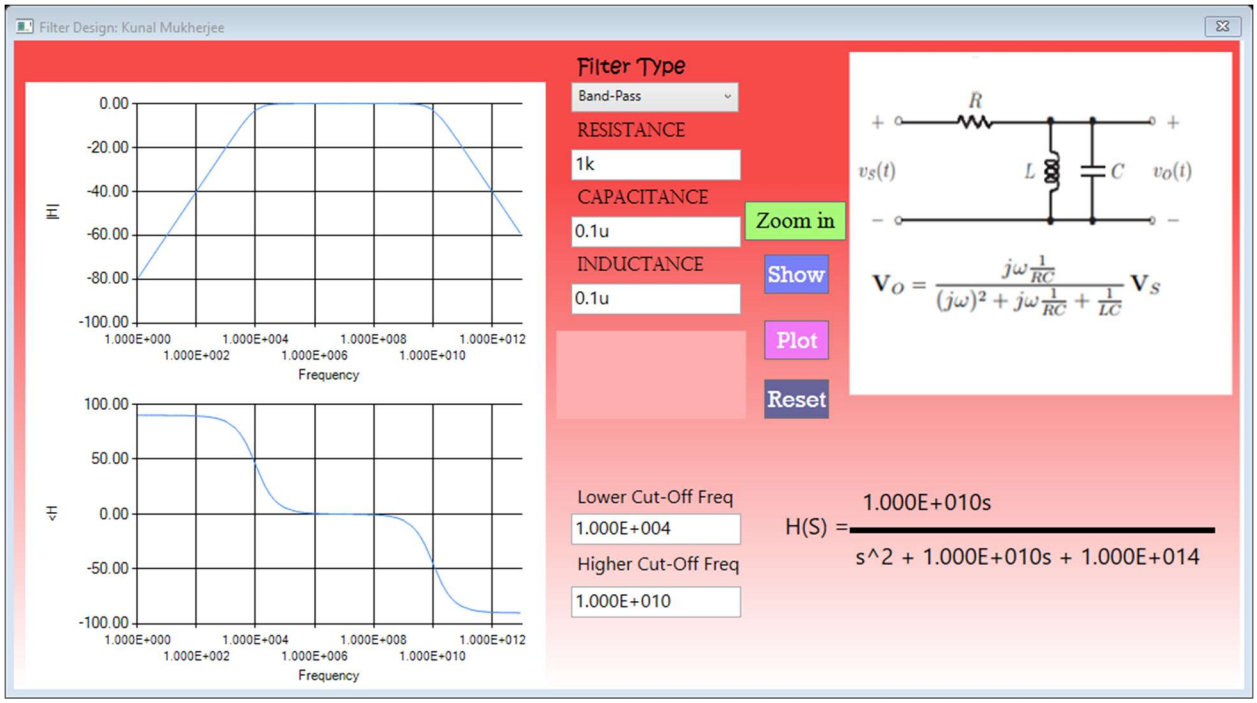
The project should be working as per the following specifications mentioned above as the calculated transfer function matches with the transfer function in the book.

Simulation Results

I used OKAWA Electric Design simulator software to test my design. The simulation result matched with the application results. The following illustration is showing the band pass filter for 1k, 0.1u C and 0.1u for I, from OKAWA electric and my application.







Experimental Design

The project did not need much experimentation, except for finding how much of a frequency range to show the relative trend of the graph.

Measure Results

The project did not need much measurement, but I checked all my simulation results e.g. frequency response, cut-off/center frequency and transfer function with OKAWA electric's simulation.

Conclusion

The project met the specifications of WPF C# application that shows the user the Bode magnitude plot and Bode phase plot, when the user enters the filter type then, R, L or C value, or center/cut-off frequency and any one of R, L or C value. The project also shows the sample circuit as well as the transfer function.

Code

```
1  //Kunal Mukherjee
2  //3/2/2019
3  //EE 380: Filter design
4
5  using System;
6  using System.Windows;
7  using System.Windows.Media.Imaging;
8  using System.Windows.Forms.DataVisualization.Charting;
9
10 namespace Project2_Filters
11 {
12     /// <summary>
13     /// Interaction logic for MainWindow.xaml
14     /// </summary>
15     public partial class MainWindow : Window
16     {
17         public MainWindow()
18         {
19             InitializeComponent();
20             txtbxR.Text = "0";
21             txtbxC.Text = "0";
22             txtbxL.Text = "0";
23
24         }
25
26         //initializing variables
27         private double r = 0;
28         private double c = 0;
29         private double l = 0;
30         private double wc = 0;
31         private double filter = 0;
32         private double Mh = 0; //magnitude of H
33         private double Ah = 0; //angle of H
34         private double w0 = 0; //undamped natural frequency
35         private double wl = 0; //lower cut-off frequency
36         private double wu = 0; //upper cut-off frequency
37         private double B = 0; //bandwidth
38         private double Q = 0; //quality factor
39         private double w = 0;
40         private double tempVal = 0;
41         private int nI = 0;
42         private int nMax = 0;
43         private System.Windows.Controls.Image img = new
             System.Windows.Controls.Image();
44         public BitmapImage bmi;
45         public WriteableBitmap wbm;
46         public Series wASeries = new Series();
47         public Series wPSeries = new Series();
48         private Chart chtAmp = new Chart();
```

```
49          private Chart chtPha = new Chart();
50
51          //The function loads the |H| chart
52          private void cnvChartAmp_Loaded(object sender, RoutedEventArgs e)
53          {
54              System.Windows.Forms.Integration.WindowsFormsHost host =
55                      new System.Windows.Forms.Integration.WindowsFormsHost();
56              host.Child = chtAmp;
57              // Add the chart to the canvas so it can be displayed.
58              this.cnvChartAmp.Children.Add(host);
59          }
60
61          //The function loads the <H chart
62          private void cnvChartPha_Loaded(object sender, RoutedEventArgs e)
63          {
64              System.Windows.Forms.Integration.WindowsFormsHost host =
65                      new System.Windows.Forms.Integration.WindowsFormsHost();
66              host.Child = chtPha;
67              // Add the chart to the canvas so it can be displayed.
68              this.cnvChartPha.Children.Add(host);
69          }
70
71          //The function displays the appriopiate transfer function and the
              circut
72          private void btnShow_Click(object sender, RoutedEventArgs e)
73          {
74              imgDrawing.Source = wbm;
75
76              if (filter == 0)
77              {
78                  lblHN.Content = wc.ToString("E3");
79                  lblHD.Content = "s + " + wc.ToString("E3");
80              }
81              if (filter == 1)
82              {
83                  lblHN.Content = "s";
84                  lblHD.Content = "s + " + wc.ToString("E3");
85              }
86              if (filter == 2)
87              {
88                  lblHN.Content = " " + B.ToString("E3") + "s";
89                  lblHD.Content = "s^2 + " + B.ToString("E3") + "s + " +
                      (Math.Pow(w0, 2)).ToString("E3");
90              }
91              if (filter == 3)
92              {
93                  lblHN.Content = "s^2 + " + (Math.Pow(w0, 2)).ToString("E2");
94                  lblHD.Content = "s^2 + " + B.ToString("E3") + "s + " +
                      (Math.Pow(w0, 2)).ToString("E2");
```

```
95              }
96          }
97
98          //The function resets the R,L,C value to zero as well as the filter
              values
99          private void btnReset_Click(object sender, RoutedEventArgs e)
100         {
101             txtbxR.Text = "0";
102             txtbxC.Text = "0";
103             txtbxL.Text = "0";
104             txtbxCF.Text = "0";
105             txtbxHCF.Text = "0";
106             txtbxLCF.Text = "0";
107
108             lblHD.Content = "D(s)";
109             lblHN.Content = "H(s)";
110         }
111
112         //The function selects which canvas to display the necessary options
113         private void CmbFilterType_DropDownClosed(object sender, EventArgs e)
114         {
115             if ((cmbFilterType.Text.Equals("Low-Pass")) ||
116                (cmbFilterType.Text.Equals("High-Pass")))
117             {
118                 cnvBP.Width = 164;
119                 cnvLP.Width = 0;
120             }
121             else
122             {
123                 cnvBP.Width = 0;
124                 cnvLP.Width = 164;
125             }
126
127         }
128
129         //The function recalculates the series acording to the zooming option
130         //so that the x-axis can be zoomed in accordingly
131         private void btnZoomIn_Click(object sender, RoutedEventArgs e)
132         {
133             double centFreq = 0;
134
135             if (filter == 1 || filter == 2)
136             {
137                 centFreq = wc;
138             }
139             else
140             {
141                 centFreq = w0;
142             }
```

```
143
144             chtAmp.ChartAreas[0].AxisX.Maximum = centFreq + (0.95 *
                  (chtAmp.ChartAreas[0].AxisX.Maximum - centFreq));
145             chtAmp.ChartAreas[0].AxisX.Minimum = centFreq - (0.95 * (centFreq -
                   chtAmp.ChartAreas[0].AxisX.Minimum));
146
147             chtPha.ChartAreas[0].AxisX.Maximum = centFreq + (0.95 *
                  (chtAmp.ChartAreas[0].AxisX.Maximum - centFreq));
148             chtPha.ChartAreas[0].AxisX.Minimum = centFreq - (0.95 * (centFreq -
                   chtAmp.ChartAreas[0].AxisX.Minimum));
149
150             chtAmp.Series.Clear();
151             chtAmp.Series.Add(wASeries);
152             chtAmp.ChartAreas[0].AxisX.IsLogarithmic = true;
153             chtAmp.ChartAreas[0].AxisX.LogarithmBase = 10;
154             chtAmp.ChartAreas[0].AxisX.Title = "Frequency";
155             chtAmp.ChartAreas[0].AxisX.LabelStyle.Format = "E3";
156             chtAmp.ChartAreas[0].AxisY.Title = "|H|";
157             chtAmp.ChartAreas[0].AxisY.LabelStyle.Format = "{0.00}";
158
159             chtPha.Series.Clear();
160             chtPha.Series.Add(wPSeries);
161             chtPha.ChartAreas[0].AxisX.IsLogarithmic = true;
162             chtPha.ChartAreas[0].AxisX.LogarithmBase = 10;
163             chtPha.ChartAreas[0].AxisX.Title = "Frequency";
164             chtPha.ChartAreas[0].AxisX.LabelStyle.Format = "E3";
165             chtPha.ChartAreas[0].AxisY.Title = "<H";
166             chtPha.ChartAreas[0].AxisY.LabelStyle.Format = "{0.00}";
167         }
168
169         //The function calls the appriopiate transfer function depending on the
                filter type
170         //the function also get the R,L,C value as well as load the correct
171         //curcit image
172         private void btnPlot_Click(object sender, RoutedEventArgs e)
173         {
174             //select the filter type
175             if (cmbFilterType.Text.Equals("Low-Pass"))
176             {
177                 filter = 0;
178             }
179             else if (cmbFilterType.Text.Equals("High-Pass"))
180             {
181                 filter = 1;
182             }
183             else if (cmbFilterType.Text.Equals("Band-Pass"))
184             {
185                 filter = 2;
186             }
```

```
187             else if (cmbFilterType.Text.Equals("Band-Reject"))
188             {
189                 filter = 3;
190             }
191 
192             //get the r,c,l value
193             if (txtbxR.Text != "")
194             {
195                 r = getRLCValue(0); // Convert.ToDouble(txtbxR.Text);
196             }
197             else
198             {
199                 r = 10;
200                 txtbxR.Text = "10";
201             }
202             if (txtbxC.Text != "")
203             {
204                 c = getRLCValue(1); //Convert.ToDouble(txtbxC.Text);
205             }
206             else
207             {
208                 c = 10;
209                 txtbxC.Text = "10";
210             }
211             if (txtbxL.Text != "")
212             {
213                 l = getRLCValue(2); //Convert.ToDouble(txtbxL.Text);
214             }
215             else
216             {
217                 l = 10;
218                 txtbxL.Text = "10";
219             }
220 
221 
222             //depending on the choice select the filter type
223             if (filter == 0)
224             {
225                 if (c == 0)
226                 {
227                     plotLowPassRLFilter();
228 
229                     bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents
                        \Kunal\UE courses\EE-380\Project2_Filters\Project2_Filters
                        \Image\LPRL.png"));
230                     wbm = new WriteableBitmap(bmi);
231 
232                 }
233                 else
```

```
234                 {
235                     plotLowPassRCFilter();
236 
237                     bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents
                        \Kunal\UE courses\EE-380\Project2_Filters\Project2_Filters
                        \Image\LPRC.png"));
238                     wbm = new WriteableBitmap(bmi);
239                 }
240             }
241             if (filter == 1)
242             {
243                 if (c == 0)
244                 {
245                     plotHighPassRLFilter();
246 
247                     bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents
                        \Kunal\UE courses\EE-380\Project2_Filters\Project2_Filters
                        \Image\HPRL.png"));
248                     wbm = new WriteableBitmap(bmi);
249 
250                 }
251                 else
252                 {
253                     plotHighPassRCFilter();
254 
255                     bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents
                        \Kunal\UE courses\EE-380\Project2_Filters\Project2_Filters
                        \Image\HPRC.png"));
256                     wbm = new WriteableBitmap(bmi);
257                 }
258             }
259             if (filter == 2)
260             {
261                 plotBandPassFilter();
262 
263                 bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents\Kunal
                    \UE courses\EE-380\Project2_Filters\Project2_Filters\Image
                    \BP.png"));
264                 wbm = new WriteableBitmap(bmi);
265 
266             }
267             if (filter == 3)
268             {
269                 plotBandRejectFilter();
270 
271                 bmi = new BitmapImage(new Uri(@"C:\Users\kunmu\Documents\Kunal
                    \UE courses\EE-380\Project2_Filters\Project2_Filters\Image
                    \BR.png"));
272                 wbm = new WriteableBitmap(bmi);
```

```
273             }
274 
275         }
276 
277         //The function allows u-micro, p-pico, n-nano, f-femto, m-mili,k,K-kilo
               and M-mega
278         //character to be used for R,L,C values
279         private double getRLCValue(int choice)
280         {
281             string num = "";
282             if (choice == 0)
283             {
284                 if (txtbxR.Text.Contains("K") || txtbxR.Text.Contains("k"))
285                 {
286                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
287                     return Convert.ToDouble(num) * Math.Pow(10, 3);
288                 }
289                 if (txtbxR.Text.Contains("M"))
290                 {
291                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
292                     return Convert.ToDouble(num) * Math.Pow(10, 6);
293                 }
294                 if (txtbxR.Text.Contains("m"))
295                 {
296                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
297                     return Convert.ToDouble(num) * Math.Pow(10, -3);
298                 }
299                 if (txtbxR.Text.Contains("u"))
300                 {
301                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
302                     return Convert.ToDouble(num) * Math.Pow(10, -6);
303                 }
304                 if (txtbxR.Text.Contains("n"))
305                 {
306                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
307                     return Convert.ToDouble(num) * Math.Pow(10, -9);
308                 }
309                 if (txtbxR.Text.Contains("p"))
310                 {
311                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
312                     return Convert.ToDouble(num) * Math.Pow(10, -12);
313                 }
314                 if (txtbxR.Text.Contains("f"))
315                 {
316                     num = txtbxR.Text.Substring(0, txtbxR.Text.Length - 1);
317                     return Convert.ToDouble(num) * Math.Pow(10, -15);
318                 }
319                 else
320                 {
```

```
321                         return Convert.ToDouble(txtbxR.Text);
322                     }
323                 }
324                 if(choice == 1)
325                 {
326                     if (txtbxC.Text.Contains("M"))
327                     {
328                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
329                         return Convert.ToDouble(num) * Math.Pow(10, 6);
330                     }
331                     if (txtbxC.Text.Contains("K") || txtbxC.Text.Contains("k"))
332                     {
333                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
334                         return Convert.ToDouble(num) * Math.Pow(10, 3);
335                     }
336                     if (txtbxC.Text.Contains("m"))
337                     {
338                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
339                         return Convert.ToDouble(num) * Math.Pow(10, -3);
340                     }
341                     if (txtbxC.Text.Contains("u"))
342                     {
343                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
344                         return Convert.ToDouble(num) * Math.Pow(10, -6);
345                     }
346                     if (txtbxC.Text.Contains("n"))
347                     {
348                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
349                         return Convert.ToDouble(num) * Math.Pow(10, -9);
350                     }
351                     if (txtbxC.Text.Contains("p"))
352                     {
353                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
354                         return Convert.ToDouble(num) * Math.Pow(10, -12);
355                     }
356                     if (txtbxC.Text.Contains("n"))
357                     {
358                         num = txtbxC.Text.Substring(0, txtbxC.Text.Length - 1);
359                         return Convert.ToDouble(num) * Math.Pow(10, -15);
360                     }
361                     else
362                     {
363                         return Convert.ToDouble(txtbxC.Text);
364                     }
365                 }
366                 if(choice == 2)
367                 {
368                     if (txtbxL.Text.Contains("M"))
369                     {
```

```
370                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
371                     Console.WriteLine(num);
372                     return Convert.ToDouble(num) * Math.Pow(10, 6);
373                 }
374                 if (txtbxL.Text.Contains("K") || txtbxL.Text.Contains("k"))
375                 {
376                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
377                     Console.WriteLine(num);
378                     return Convert.ToDouble(num) * Math.Pow(10, 3);
379                 }
380                 if (txtbxL.Text.Contains("m"))
381                 {
382                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
383                     Console.WriteLine(num);
384                     return Convert.ToDouble(num) * Math.Pow(10, -3);
385                 }
386                 if (txtbxL.Text.Contains("u"))
387                 {
388                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
389                     Console.WriteLine(num);
390                     return Convert.ToDouble(num) * Math.Pow(10, -6);
391                 }
392                 if (txtbxL.Text.Contains("n"))
393                 {
394                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
395                     Console.WriteLine(num);
396                     return Convert.ToDouble(num) * Math.Pow(10, -9);
397                 }
398                 if (txtbxL.Text.Contains("p"))
399                 {
400                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
401                     Console.WriteLine(num);
402                     return Convert.ToDouble(num) * Math.Pow(10, -12);
403                 }
404                 if (txtbxL.Text.Contains("f"))
405                 {
406                     num = txtbxL.Text.Substring(0, txtbxL.Text.Length - 1);
407                     Console.WriteLine(num);
408                     return Convert.ToDouble(num) * Math.Pow(10, -15);
409                 }
410                 else
411                 {
412                     return Convert.ToDouble(txtbxL.Text);
413                 }
414             }
415 
416             return 0;
417         }
418 
```

```
419         //The function calculates the number of sig.fig for a number given
420         private int magnitudeQuantificationofValue(double number)
421         {
422             int counter = 0;
423 
424             if (number > 1)
425             {
426                 while (number > 10)
427                 {
428                     number /= 10;
429                     counter++;
430                 }
431             }
432 
433             return counter;
434         }
435 
436         //The function maximum and the minimum w value for the transfer
              function
437         //for low and high pass filter
438         private void setWCAxisMinandMax(double wTemp)
439         {
440             int x = magnitudeQuantificationofValue(wTemp);
441 
442             chtAmp.ChartAreas[0].AxisX.Minimum = Math.Pow(10, x - 2);
443             chtPha.ChartAreas[0].AxisX.Minimum = Math.Pow(10, x - 2);
444 
445             chtAmp.ChartAreas[0].AxisX.Maximum = Math.Pow(10, x + 2);
446             chtPha.ChartAreas[0].AxisX.Maximum = Math.Pow(10, x + 2);
447 
448             nI = magnitudeQuantificationofValue(chtAmp.ChartAreas
                  [0].AxisX.Minimum);
449             nMax = magnitudeQuantificationofValue(chtAmp.ChartAreas
                  [0].AxisX.Maximum);
450         }
451 
452         //The function maximum and the minimum w value for the transfer
              function
453         //for band pass and stop filter
454         private void setW0AxisMinandMax()
455         {
456             if (txtbxLCF.Text == "0")
457             {
458                 w0 = 1 / Math.Sqrt(l * c);
459                 B = r / l;
460 
461                 double rTemp = Math.Sqrt(Math.Pow((B / 2), 2) + Math.Pow(w0,
                      2));
462 
```

```
463                 wl = (-(B / 2) + rTemp);
464                 wu = (+(B / 2) + rTemp);
465 
466                 txtbxLCF.Text = (wl).ToString("E3");
467                 txtbxHCF.Text = (wu).ToString("E3");
468 
469             }
470             else
471             {
472                 wl = Convert.ToDouble(txtbxLCF.Text);
473                 wu = Convert.ToDouble(txtbxHCF.Text);
474 
475                 w0 = Math.Sqrt(wl * wu);
476                 B = wu - wl;
477 
478                 if (txtbxR.Text != "0")
479                 {
480                     txtbxL.Text = (getRLCValue(0) / B).ToString( "E3");
481                     txtbxC.Text = (1 / (getRLCValue(2) * Math.Pow(w0,
                        2))).ToString("E3"); ;
482                 }
483                 else if (txtbxC.Text != "0")
484                 {
485                     txtbxL.Text = (1 / Math.Pow(w0, 2) * getRLCValue
                        (1)).ToString("E3");
486                     txtbxR.Text = (getRLCValue(2) * B).ToString( "E3");
487                 }
488                 else
489                 {
490                     txtbxC.Text = (1 / Math.Pow(w0, 2) * getRLCValue
                        (2)).ToString("E3");
491                     txtbxR.Text = (getRLCValue(2) * B).ToString( "E3");
492                 }
493 
494             }
495 
496             int xMin = magnitudeQuantificationofValue(wl);
497             int xMax = magnitudeQuantificationofValue(wu);
498 
499             chtAmp.ChartAreas[0].AxisX.Minimum = Math.Pow(10, xMin - 3);
500             chtPha.ChartAreas[0].AxisX.Minimum = Math.Pow(10, xMin - 3);
501 
502             chtAmp.ChartAreas[0].AxisX.Maximum = Math.Pow(10, xMax + 3);
503             chtPha.ChartAreas[0].AxisX.Maximum = Math.Pow(10, xMax + 3);
504 
505             nI = magnitudeQuantificationofValue(chtAmp.ChartAreas
                  [0].AxisX.Minimum);
506             nMax = magnitudeQuantificationofValue(chtAmp.ChartAreas
                  [0].AxisX.Maximum);
```

```
507
508         }
509
510         //The function clears the series up and sets it up for data population
511         private void initializeSeries()
512         {
513             //clear the chart area
514             chtAmp.ChartAreas.Clear();
515             chtAmp.ChartAreas.Add("Default");
516             chtPha.ChartAreas.Clear();
517             chtPha.ChartAreas.Add("Default");
518
519             chtAmp.Width = 450;
520             chtAmp.Height = 270;
521             chtPha.Width = 450;
522             chtPha.Height = 270;
523
524             chtAmp.Location = new System.Drawing.Point(0, 0);
525             chtPha.Location = new System.Drawing.Point(0, 0);
526
527             //w for |H|
528             wASeries = new Series();
529             //w for <H
530             wPSeries = new Series();
531
532             wASeries.ChartType = SeriesChartType.Line;
533             wPSeries.ChartType = SeriesChartType.Line;
534         }
535
536         //The function fills up the graph after series is calculated
537         //as well as formats the graph
538         private void fillSeriesGraph()
539         {
540             chtAmp.Series.Clear();
541             chtAmp.Series.Add(wASeries);
542             chtAmp.ChartAreas[0].AxisX.IsLogarithmic = true;
543             chtAmp.ChartAreas[0].AxisX.LogarithmBase = 10;
544             chtAmp.ChartAreas[0].AxisX.Title = "Frequency";
545             chtAmp.ChartAreas[0].AxisX.LabelStyle.Format = "E3";
546             chtAmp.ChartAreas[0].AxisY.Title = "|H|";
547             chtAmp.ChartAreas[0].AxisY.LabelStyle.Format = "{0.00}";
548
549
550
551             chtPha.Series.Clear();
552             chtPha.Series.Add(wPSeries);
553             chtPha.ChartAreas[0].AxisX.IsLogarithmic = true;
554             chtPha.ChartAreas[0].AxisX.LogarithmBase = 10;
555             chtPha.ChartAreas[0].AxisX.Title = "Frequency";
```

```
556             chtPha.ChartAreas[0].AxisX.LabelStyle.Format = "E3";
557             chtPha.ChartAreas[0].AxisY.Title = "<H";
558             chtPha.ChartAreas[0].AxisY.LabelStyle.Format = "{0.00}";

559         }
560
561         //The function calculates the transfer function for
562         //low pass RL filter
563         private void plotLowPassRLFilter()
564         {
565             initializeSeries();
566
567             //calculate the cutoff frequency
568             wc = r / l;
569
570             if (txtbxCF.Text == "0")
571             {
572                 txtbxCF.Text = wc.ToString("E3");
573             }
574             else
575             {
576                 wc = Convert.ToDouble(txtbxCF.Text);
577
578                 if(txtbxR.Text == "0")
579                 {
580                     txtbxR.Text = (wc * getRLCValue(2)).ToString("E3");
581                 }
582                 else
583                 {
584                     txtbxL.Text = (getRLCValue(0) / wc).ToString("E3");
585                 }
586             }
587
588             setWCAxisMinandMax(wc);
589
590             //generate the graph points |H| and <H
591             for (int n = nI; n <= nMax; n++)
592             {
593                 for (int m = 1; m < 10; m++)
594                 {
595                     w = m * Math.Pow(10, n);
596
597                     Mh = 20 * Math.Log10(1 / Math.Sqrt(1 + Math.Pow((w / wc),
                        2)));
598                     Ah = (-Math.Atan2(w, wc)) * (180 / Math.PI);
599
600                     wASeries.Points.AddXY(w, Mh);
601                     wPSeries.Points.AddXY(w, Ah);
602
```

```
603                 }
604
605             }
606
607             fillSeriesGraph();
608         }
609
610         //The function calculates the transfer function for
611         //low pass RC filter
612         private void plotLowPassRCFilter()
613         {
614             initializeSeries();
615
616             wc = 1 / (r * c);
617
618             if (txtbxCF.Text == "0")
619             {
620                 txtbxCF.Text = wc.ToString("E3");
621             }
622             else
623             {
624                 wc = Convert.ToDouble(txtbxCF.Text);
625
626                 if (txtbxR.Text == "0")
627                 {
628                     txtbxR.Text = (1 / wc * getRLCValue(1)).ToString("E3");
629                 }
630                 else
631                 {
632                     txtbxC.Text = (1 / wc * getRLCValue(0)).ToString("E3");
633                 }
634             }
635
636             setWCAxisMinandMax(wc);
637
638             //generate the graph points |H| and <H
639             for (int n = nI; n <= nMax; n++)
640             {
641                 for (int m = 1; m < 10; m++)
642                 {
643                     w = m * Math.Pow(10, n);
644
645                     Mh = 20 * Math.Log10(1 / Math.Sqrt(1 + Math.Pow((w / wc),
                        2)));
646                     Ah = (-Math.Atan2(w, wc)) * (180 / Math.PI);
647
648                     wASeries.Points.AddXY(w, Mh);
649                     wPSeries.Points.AddXY(w, Ah);
```

```
650                 }
651             }
652
653             fillSeriesGraph();
654         }
655
656         //The function calculates the transfer function for
657         //high pass RL filter
658         private void plotHighPassRLFilter()
659         {
660             initializeSeries();
661
662             wc = r / l;
663
664             if (txtbxCF.Text == "0")
665             {
666                 txtbxCF.Text = wc.ToString("E3");
667             }
668             else
669             {
670                 wc = Convert.ToDouble(txtbxCF.Text);
671
672                 if (txtbxR.Text == "0")
673                 {
674                     txtbxR.Text = (wc * getRLCValue(2)).ToString("E3");
675                 }
676                 else
677                 {
678                     txtbxL.Text = (getRLCValue(0) / wc).ToString("E3");
679                 }
680             }
681
682             setWCAxisMinandMax(wc);
683
684             //generate the graph points |H| and <H
685             for (int n = nI; n <= nMax; n++)
686             {
687                 for (int m = 1; m < 10; m++)
688                 {
689                     w = m * Math.Pow(10, n);
690
691                     Mh = 20 * Math.Log10(1 / Math.Sqrt(1 + Math.Pow((wc / w),
                        2)));
692                     Ah = (Math.Atan2(wc, w)) * (180 / Math.PI);

693
694                     wASeries.Points.AddXY(w, Mh);
695                     wPSeries.Points.AddXY(w, Ah);
696                 }
```

```
697             }
698
699             fillSeriesGraph();
700         }
701
702         //The function calculates the transfer function for
703         //high pass RC filter
704         private void plotHighPassRCFilter()
705         {
706             initializeSeries();
707
708             wc = 1 / (r * c);
709
710             if (txtbxCF.Text == "0")
711             {
712                 txtbxCF.Text = wc.ToString( "E3");
713             }
714             else
715             {
716                 wc = Convert.ToDouble(txtbxCF.Text);
717
718                 if (txtbxR.Text == "0")
719                 {
720                     txtbxR.Text = (1 / wc * getRLCValue(1)).ToString( "E3");
721                 }
722                 else
723                 {
724                     txtbxC.Text = (1 / wc * getRLCValue(0)).ToString( "E3");
725                 }
726             }
727
728             setWCAxisMinandMax(wc);
729
730             //generate the graph points |H| and <H
731             for (int n = nI; n <= nMax; n++)
732             {
733                 for (int m = 1; m < 10; m++)
734                 {
735                     w = m * Math.Pow(10, n);
736
737                     Mh = 20 * Math.Log10(1 / Math.Sqrt(1 + Math.Pow((wc / w),
                        2)));
738                     Ah = (Math.Atan2(wc, w)) * (180 / Math.PI);
739
740                     wASeries.Points.AddXY(w, Mh);
741                     wPSeries.Points.AddXY(w, Ah);
742                 }
743
```

```
744             }
745
746             fillSeriesGraph();
747         }
748
749         //The function calculates the transfer function for
750         //band pass filter
751         private void plotBandPassFilter()
752         {
753             initializeSeries();
754
755             setW0AxisMinandMax();
756
757             for (int n = nI; n <= nMax; n++)
758             {
759                 for (int m = 1; m < 10; m++)
760                 {
761                     w = m * Math.Pow(10, n);
762
763                     tempVal = (Math.Pow(w0, 2)) - (Math.Pow(w, 2));
764
765                     Mh = 20 * Math.Log10(Math.Sqrt(Math.Pow(B * w, 2)) /
                    Math.Sqrt(Math.Pow(tempVal, 2) + Math.Pow(B * w, 2)));
766                     Ah = (Math.Atan2(B * w, 0) - Math.Atan2(B * w, tempVal)) *
                    (180 / Math.PI);
767
768                     wASeries.Points.AddXY(w, Mh);
769                     wPSeries.Points.AddXY(w, Ah);
770                 }
771
772             }
773
774             fillSeriesGraph();
775         }
776
777         //The function calculates the transfer function for
778         //band stop filter
779         private void plotBandRejectFilter()
780         {
781             initializeSeries();
782
783             setW0AxisMinandMax();
784
785             for (int n = nI; n <= nMax; n++)
786             {
787                 for (int m = 1; m < 10; m++)
788                 {
789                     w = m * Math.Pow(10, n);
790
```

```
791                     tempVal = (Math.Pow(w0, 2)) - (Math.Pow(w, 2));
792
793                     if (Math.Sqrt(Math.Pow(tempVal, 2))  != 0)
794                     {
795                         Mh = 20 * Math.Log10(Math.Sqrt(Math.Pow(tempVal, 2)) /
                        Math.Sqrt(Math.Pow(tempVal, 2) + Math.Pow(B * w, 2)));
796                     }
797
798                     Ah = (Math.Atan2(0, tempVal) - Math.Atan2(B * w, tempVal))
                        * (180 / Math.PI);
799
800                     wASeries.Points.AddXY(w, Mh);
801                     wPSeries.Points.AddXY(w, Ah);
802                 }
803
804             }
805
806             fillSeriesGraph();
807         }
808
809     }
810 }
811
```