Laboratory work 2
EXAMINING THE FILTERS

A) Examining the filters with Matlab

In this work, there are questions (marked with @) you can solve in your group after the laboratory work.

Both analog and digital filters can be designed and analysed with Matlab. In this work we'll familiarize with analog Butterworth- Chebychev- and Bessel-filters.

1. ● Explain shortly to the assistant what the following program listing would do. (Use Matlab's help if needed!)

```
Wp = [1000 3000];
Ws = [100 3900];
[n,Wn] = buttord(Wp,Ws,3,20,'s')
```

Wp = _____

Ws = _____

n = _____

Wn = _____

buttord = _____

3 = _____

20 = _____

's' = _____

Start Matlab. Write on Matlab's desktop the listing above. What is filter's degree n and lower cut off frequencyWn_{low} and Wn_{high}? (Hint: Use the desktop of the Matlab to find the values.)
n = _____

Wn_{low} = _____

Wn_{high} = _____

2. Search file filter1.m to the editor from the directory assistant will tell you and save it at once to another directory told by the assistant.

3. ● Change the n-value and names of the authors and date in the title correct. Test run the listing using Matlab. Change the values of scales better, if needed. Finally print figures of the curves to your group.

● Estimate based on the results the attenuation at the frequency of 5000 Hz, the phase distortion at 1000 Hz and group delay at 2000 Hz. Remember zoom! Write answers to the next page.

Attenuation at the frequency of 5000 Hz is _____

Phase distortion at the frequency of 1000 Hz is _____

Group delay at 2000 Hz is _____

If the input signal to the filter was 1 volt cosine wave at the frequency of 7000 Hz, how big would the output voltage be? Zoom!

Answer: _____

4. ● Change the program listing so that the row

```
[n,Wn] = buttord(Wp,Ws,3,20,'s');
```

will be replaced with the row

```
[n,Wn] = cheb1ord(Wp,Ws,3,20,'s');
```

and the row

```
[b,a] = butter(n,Wn);
```

will be replaced with the row,

```
[b,a] = cheby1(n,3,Wn,'s');
```

,where 3 is the greatest ripple in decibels in the pass band

So the values set to the Butterworth filter will remain, but now we'll calculate the frequency response and other properties to the Chebychev filter.

● Save the program listing with the name filter2 to the directory used before and test run it. Check with the help of Matlab's desktop the degree of the filter and the lower cut off frequency Wn_{low} and the upper cut off frequency Wn_{high}.

n = . Wn_{low} = _____ Wn_{high} = _____

● Change the title to nth degree Chebychev band pass filter 1000-3000 Hz, where n is the degree of the filter found. Fit also the amount of the ripple to the title. Run listing and change the scales, if needed. Finally print the figures of the curves to your group.

@ Observations of the differences of Butterworth and Chebychev filters? Differences of the degrees of the filters, ripple, group delay and the slope of the attenuation on the stop band? Hint:
Put the prints on top of each other and let the light shining through show the differences.

5. Change the degree of the Chebychev filter to the same value the Butterworth filter had, that is, change the row

```
[b,a] = cheby1(n,3,Wn,'s');
```

so that in the place of n, there will be the numerical value of Butterworth filter's degree.

● Change the title to nth degree Chebychev band pass filter 1000-3000 Hz, where n is the degree of the filter. Save the listing named to filter3, run it and print the curves to your group.

@ **Observations of the ripple, group delay and the slope of the attenuation at the stop band of the same degree Butterworth and Chebychev filters.**

6. @ If the input to the Chebychev filter made last were cosine wave of 1 volt at the frequency of 600 Hz, what would be the voltage in output?
@ What would be the output from the Chebychev filter made last, if the input were rectangular wave of 2000 Hz.
@ Examine the delay time curve of the Chebychev filter last made. In which frequencies of the pass band the delay time is the minimum and maximum? What is the difference between these values? What the difference mentioned above means if the input of the filter would be these frequencies at the same time? Zoom!

7. In this version of Matlab the Bessel filter can't be designed, so we'll take the reference values from the Butterworth filter made.

● Change in the editor the row

```
[b,a] = cheby1(n,x,Wn,'s');
```

to the form

```
[b,a] = besself(n,Wp);
```

,where n is the degree of Butterworth filter calculated earlier and the Wp gives the limits of the pass band.

● Save the listing named filter4 to the already familiar directory. Test run it. Change the scales if needed and change the title of the print correct. Print the figures of the curves to your group.

@ **Observations of the properties of the Bessel filter compared to the Butterworth filter?**