

Lab 4/2003 – filter design

Useful resources

filter implements a digital filter

```
Y = filter(B, A, X);
```

$$y(n) = \sum_{k=1}^{\text{length}(B)} B_k \cdot x(n - (k - 1)) - \sum_{l=2}^{\text{length}(A)} A_l \cdot y(n - (k - 1))$$

freqz computes digital filter frequency response

```
[H,W] = freqz(B,A,N); H(e^{jW}), B,A - coefficients, N - num. points
```

Put A=[1] for FIR filters.

remez Parks-McClellan optimal equiripple FIR filter design.

```
B = remez(N,F,M); N - order, F - frequencies, M - magnitudes
```

example: F=[0 0.1 0.2 1], M=[1 1 0 0] specifies LP filter with passband of 0.1π , stopband from 0.2π to $1 \cdot \pi$ (`plot(F,M)`; plots the specified frequency response)

fir2 FIR filter design using the window method

```
B = fir2(N,F,M,win); as in remez; win – chosen window (e.g bartlett(N+1))
```

windows: blackman boxcar butter chebwin hamming hanning kaiser

******ord** compute the minimum order of a digital filter with specified constraints (use help).

Substitute butt, cheb1, cheb2, ellip for ****.

**** design a digital filter using a bilinear transformation. Substitute butter, cheby1, cheby2, ellip for ****.

Experiments

1. Prepare 2-nd order filter with poles at $0.9e^{\pm j0.2\pi}$. Plot its impulse response, frequency response (mag. and phase, use 64 points for `freqz`), group delay (approximate dy/dx with $\Delta y/\Delta x$ using `diff`). Save coefficients for future use (e.g. on paper, just in case of reboot). Test the filter with sine waves of different frequencies (check if the measured gain is consistent with the plotted frequency response).
2. Put poles at $0.9e^{\pm j0.8\pi}$. Compare impulse/frequency plots..
3. Design an easy (wide transition band) lowpass FIR filter using **remez**. Use order of 10, increase if necessary. Then put narrower transition constraint with the same order – check the change in frequency characteristics. Allow greater order.
Hint: stopband gain is better viewed in log (decibel) scale. But decibels may run to -Inf for zero input → use `max(-80,yourvalue-in-decibels)` for plotting.
4. Design FIR filters for the same specifications by window method (Standard: use **fir2**.
Extra: do it by hand, using your knowledge from lecture.)
 - (a) with boxcar window
 - (b) with hamming window

Identify the window effects. Compare results against the Parks-McClellan filter.

5. Design an IIR LP filter with passband till 0.2π , stopband from 0.3π , passband ripple 0.5 dB, stopband 80 dB down (not all the specifications are used with different filter types – see help). Compare following types:
 - (a) Butterworth
 - (b) Chebyshev type I and II
 - (c) Causer (elliptic)

Plot zeros and poles, and frequency characteristics for each filter.

6. Record (`y=getdata(Nsamples_in_row, [Krepeats, [Tsampling, [leave_bias]]])`) 1024 samples of:
 - (a) a sinusoid being in passband of the designed filters
 - (b) a sinusoid being in stopband
 - (c) a square wave with base frequency in passband and harmonics in stopband
 - (d) a noise

Use your saved 2-nd order filter to obtain coloured noise as a fifth signal.

Mix the five signals (by digital summation in matlab) to taste, then design filters to separate components. Plot spectral and time-domain plots before and after filtering.

Use `putdata(x,tsampling,Krepeats)`; to listen to the results

7. Calculate *roots*(`poly(1:20)`) and *roots*(`poly(1:22)`). Compare the biggest and smallest coefficient of a polynomial. Try to guess how the experiment corresponds to the lecture on filter design.