REPORT

Zajęcia: Analog and digital electronic circuits
Teacher: prof. dr hab. Vasyl Martsenyuk

Lab 4
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Topic: "Reaction of LTI systems on random signals"
Variant 2

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Informatyka II stopień,
stacjonarne,
1 semestr,
Gr.2

1. Problem statement: The objective is to study an reaction of random signals on LTI systems with the help of numerical characteristics

2. Input data:

$\Omega_c = \pi / 3$

3. Commands used (or GUI):

a) source code

ACF definition

```
def my_xcorr2(x, y, scaleopt='none'):
    N = len(x)
    M = len(y)
    kappa = np.arange(0, N+M-1) - (M-1)
    ccf = signal.correlate(x, y, mode='full', method='auto')
    if N == M:
        if scaleopt == 'none' or scaleopt == 'raw':
            ccf /= 1
        elif scaleopt == 'biased' or scaleopt == 'bias':
            ccf /= N
        elif scaleopt == 'unbiased' or scaleopt == 'unbias':
            ccf /= (N - np.abs(kappa))
        elif scaleopt == 'coeff' or scaleopt == 'normalized':
            ccf /= np.sqrt(np.sum(x**2) * np.sum(y**2))
        else:
            print('scaleopt unknown: we leave output unnormalized')
    return kappa, ccf
```

Calculating and plotting PSD

```
N = 2**8
Omega = np.arange(N) * 2*np.pi/N
H2 = 2 / (25/8 - 3*np.cos(Omega))  # analytic
Omega, H_IIR = signal.freqz(b=(1), a=(1, -3/4), worN=Omega)  # numeric
```

```
plt.figure(figsize=(9, 3))
plt.plot(Omega/np.pi, H2, lw=3, label='analytic solution')
plt.plot(Omega/np.pi, np.abs(H_IIR)**2, label='IIR filter freqz()-solution')
plt.plot(Omega/np.pi, Omega*0+1,
        label=r'$\Phi_{xx}(\mathrm{e}^{\mathrm{j}\Omega})\,/\,\sigma_x^2$')
plt.xlabel(r'$\frac{\Omega}{\pi}$')
plt.ylabel(
    r'$\Phi_{yy}(\mathrm{e}^{\mathrm{j}\Omega})\,/\,\sigma_x^2 =
|H(\mathrm{e}^{\mathrm{j}\Omega})|^2$')
plt.title('PSD of output')
plt.xlim(0, 2)
plt.xticks(np.arange(0, 20, 2)/10)
plt.legend()
plt.grid(True)
```

Defining autocorrelation estimator function

```
def my_xcorr(x, y):
    N, M = len(x), len(y)
    kappa = np.arange(N+M-1) - (M-1)
    ccf = signal.correlate(x, y, mode='full', method='auto')
    return kappa, ccf
```

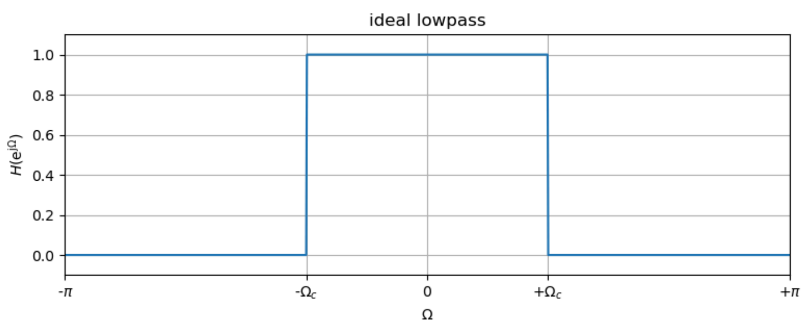
Generating and plotting signal response

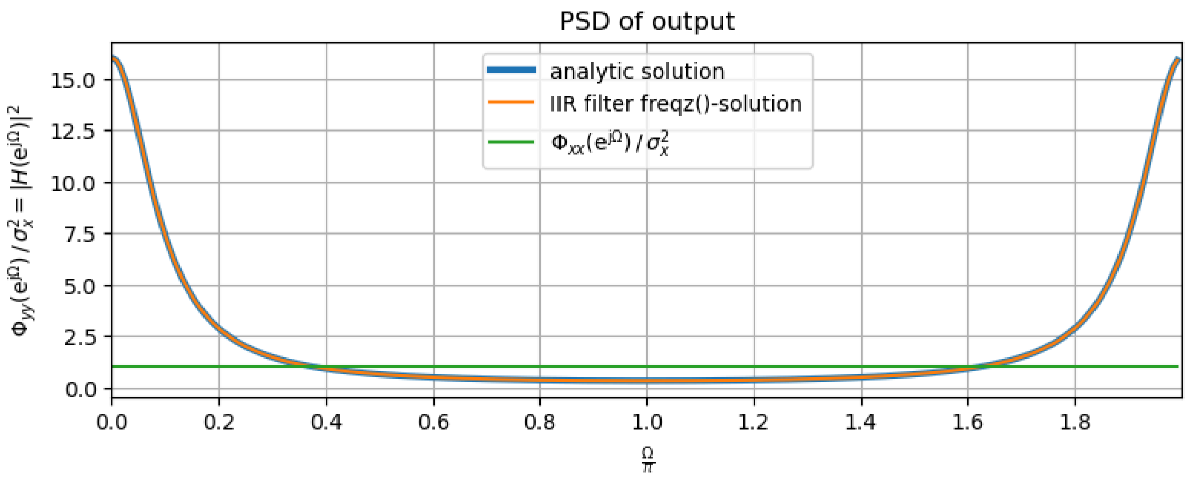
```
fs = 48000  # sampling frequency in Hz
fc = 4800  # cut frequency in Hz
number_fir_coeff = 45  # FIR taps
h = signal.firls(numtaps=number_fir_coeff,  # example for demo
                bands=(0, fc, fc+1, fs//2),
                desired=(1, 1, 0, 0),
                fs=fs)
Nh = h.size
k = np.arange(Nh)
# make the IR unsymmetric by arbitray choice for demonstration purpose
idx = 30
```

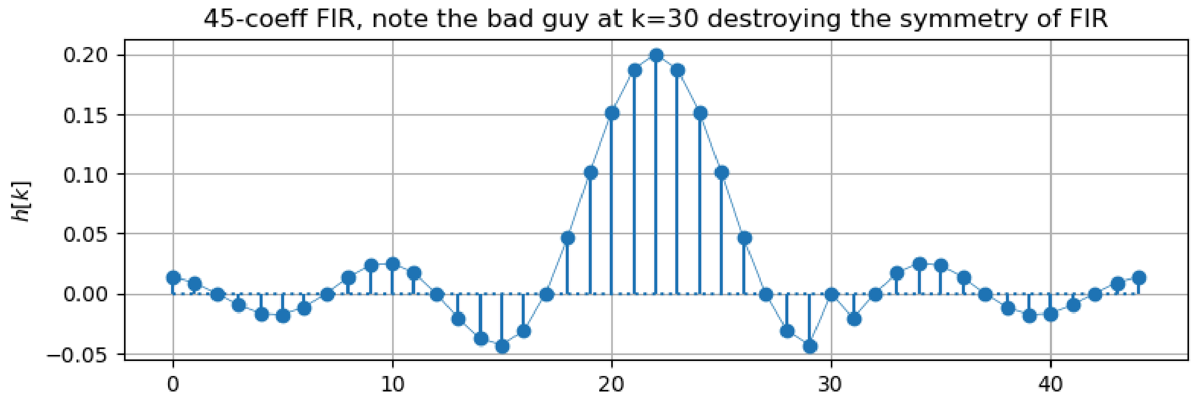
```
h[idx] = 0  # then FIR is not longer linear-phase, see the spike in the plot

print('h[0]={0:4.3f}, DC={1:4.3f} dB'.format(h[0], 20*np.log10(np.sum(h))))

N = 2**8
Omega = np.arange(0, N) * 2*np.pi/N
_, H = signal.freqz(b=h, a=1, worN=Omega)

plt.figure(figsize=(9, 6))
plt.subplot(2, 1, 1)
plt.stem(k, h, basefmt='C0:')
plt.plot(k, h, 'C0-', lw=0.5)
plt.xlabel(r'$k$')
plt.ylabel(r'$h[k]$')
plt.title(str(Nh)+'-coeff FIR, note the bad guy at k=%d destroying the symmetry
of FIR' % idx)
plt.grid(True)
plt.subplot(2, 1, 2)
plt.semilogx(Omega / (2*np.pi) * fs, 20*np.log10(np.abs(H)))
plt.xlabel(r'$f$ / Hz')
plt.ylabel(r'$|H(\mathrm{e}^{\mathrm{j}\Omega})|$ / dB')
plt.xlim(1, fs//2)
plt.ylim(-40, 10)
plt.grid(True)
```

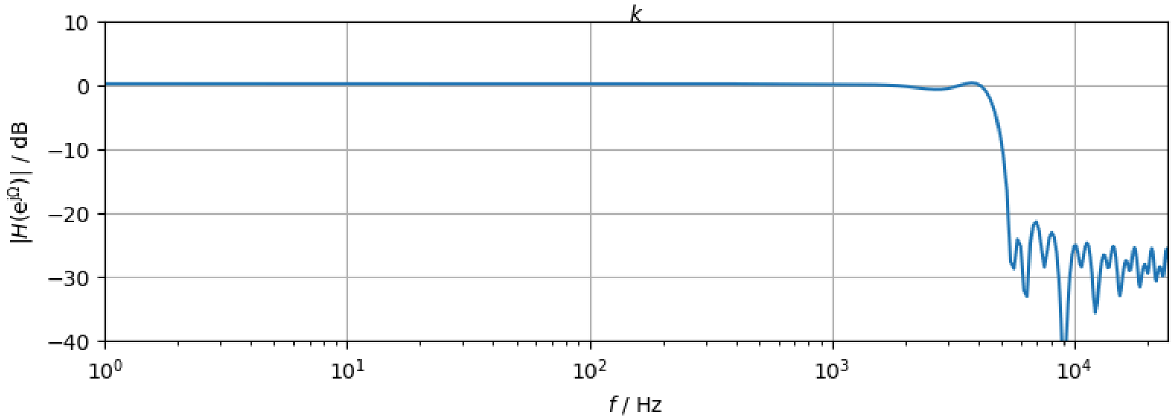
https://github.com/wm64167/AADEC

4. Outcomes:









5. Conclusions:

During this laboratory the output signal's average behavior, predictability, and spread was analyzed using its mean, variance, and autocorrelation function (ACF). The power spectral density (PSD) of the output revealed how the LTI system (a low pass filter in this case) affected different frequencies. The lab explored system identification using white noise as input and estimating the impulse response through correlation analysis.