REPORT

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

Lab 7
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Topic: "Quantization and Dithering"
Variant 2

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stacjonarne,
1 semestr,
Gr.2

1. Problem statement: The objective is to investigate dithering technique for different signals

2. Input data:
$f_{sin} = 400$
$f_s = 3000$

3. Commands used (or GUI):

a) source code

Input parameters definition

```
fs = 3000
N = 2 * fs
k = np.arange(0, N)
fsin = 400

# case 2
B = 16
Q = 2 ** B
deltaQ = 1 / (Q//2)
x = deltaQ * np.sin(2 * np.pi * fsin / fs * k) # smallest amplitude
```

Quantizer check function definition

```
def check_my_quant(k, x, Q):
    xq = my_quant(x, Q)
    e = xq - x

    plt.xlim(0, 100)
    plt.plot(k, x, color='C2', lw=3, label=r'$x[k]$')
    plt.plot(k, xq, color='C3', label=r'$x_q[k]$')
    plt.plot(k, e, color='C0', label=r'$e[k] = x_q[k] - x[k]$')
    plt.xlabel('input amplitude')
    plt.ylabel('output amplitude')
    if np.mod(Q, 2) == 0:
```

```
        s = ' saturated '
    else:
        s = ' '
    plt.title('uniform'+s+'midtread quantization with Q=%d steps, $\Delta
Q$=%4.3e'% (Q, 1/(Q//2)))
    plt.legend(loc='upper left')
    plt.grid(True)
```

Dithering check function definition

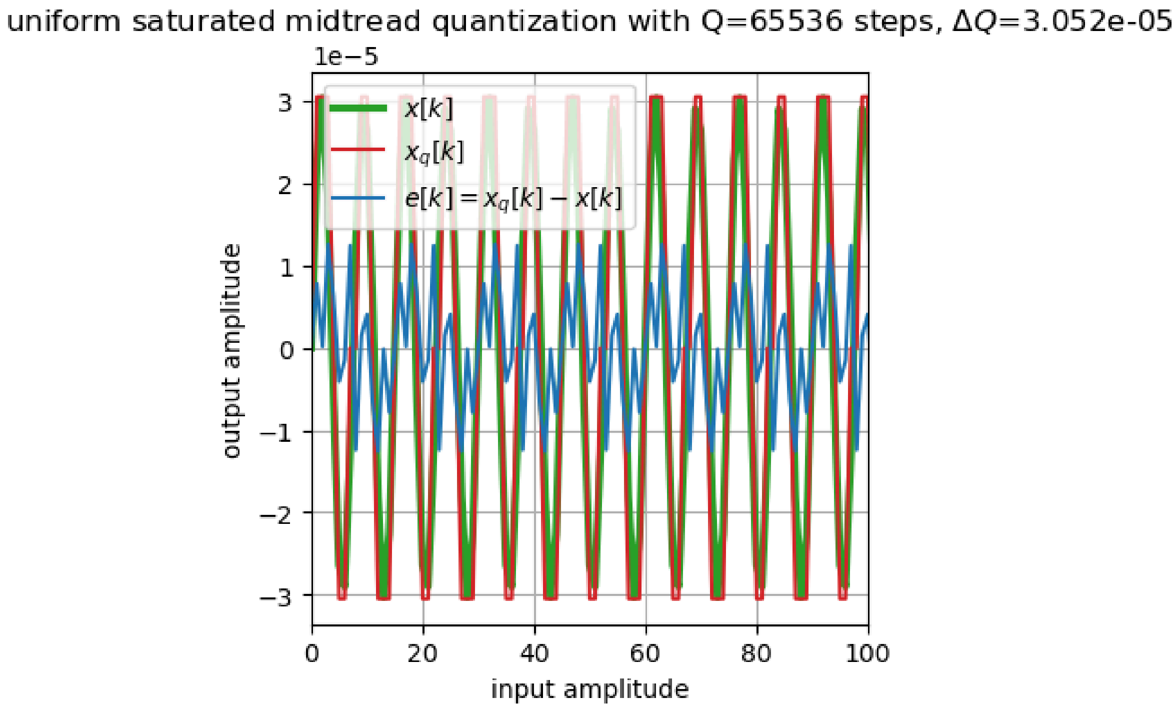
```
def check_dithering(x, dither, Q, case):
    deltaQ = 1 / (Q // 2)  # general rule

    # dither noise
    pdf_dither, edges_dither = np.histogram(dither, bins='auto', density=True)
    xd = x + dither

    # quantization
    xq = my_quant(xd, Q)
    e = xq - x
    pdf_error, edges_error = np.histogram(e, bins='auto', density=True)

    # write wavs
    sf.write(file='x_' + case + '.wav', data=x, samplerate=fs, subtype='PCM_24')
    sf.write(file='xd_' + case + '.wav', data=xd, samplerate=fs,
subtype='PCM_24')
    sf.write(file='xq_' + case + '.wav', data=xq, samplerate=fs,
subtype='PCM_24')
    sf.write(file='e_' + case + '.wav', data=e, samplerate=fs, subtype='PCM_24')

    # CCF
    kappa, ccf = my_xcorr2(xq, e, scaleopt='biased')

    plt.figure(figsize=(12, 3))
    if case == 'no_dither':
        plt.subplot(1, 2, 1)
        # nothing to plot for the zero signal
```

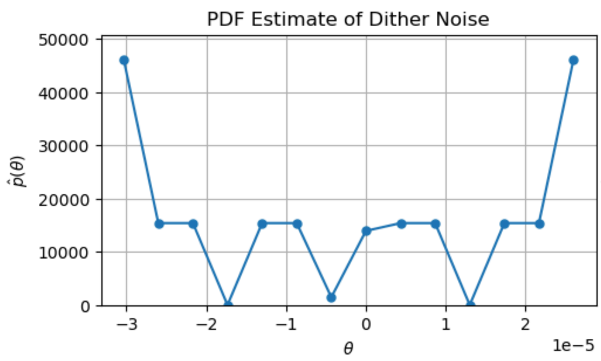
```
    # the PDF would be a weighted Dirac delta at amplitude zero
else:
    # plot dither noise PDF estimate as histogram
    plt.subplot(1, 2, 1)
    plt.plot(edges_dither[:-1], pdf_dither, 'o-', ms=5)
    plt.ylim(-0.1, np.max(pdf_dither) * 1.1)
    plt.grid(True)
    plt.xlabel(r'$\theta$')
    plt.ylabel(r'$\hat{p}(\theta)$')
    plt.title('PDF Estimate of Dither Noise')

# plot error noise PDF estimate as histogram
plt.subplot(1, 2, 2)
plt.plot(edges_error[:-1], pdf_error, 'o-', ms=5)
plt.ylim(-0.1, np.max(pdf_error) * 1.1)
plt.grid(True)
plt.xlabel(r'$\theta$')
plt.ylabel(r'$\hat{p}(\theta)$')
plt.title('PDF Estimate of Error Noise')

# plot signals
plt.figure(figsize=(12, 3))
plt.subplot(1, 2, 1)
plt.plot(k, x, color='C2', label=r'$x[k]$')
plt.plot(k, xd, color='C1', label=r'$x_d[k] = x[k] + dither[k]$')
plt.plot(k, xq, color='C3', label=r'$x_q[k]$')
plt.plot(k, e, color='C0', label=r'$e[k] = x_q[k] - x[k]$')
plt.plot(k, k * 0 + deltaQ, ':k', label=r'$\Delta Q$')
plt.xlabel('k')
plt.title('Signals')
plt.xticks(np.arange(0, 175, 25))
plt.xlim(0, 150)
plt.legend(loc='lower left')
plt.grid(True)

# plot CCF
plt.subplot(1, 2, 2)
```

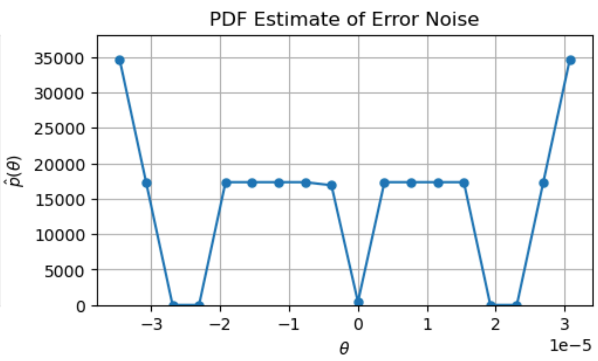
```
plt.plot(kappa, ccf)
plt.xlabel(r"$\kappa$")
plt.ylabel(r"$\varphi_{xq,e}[\kappa]$")
plt.title('CCF between xq and e=xq-x')
plt.xticks(np.arange(-100, 125, 25))
plt.xlim(-100, 100)
plt.grid(True)
```

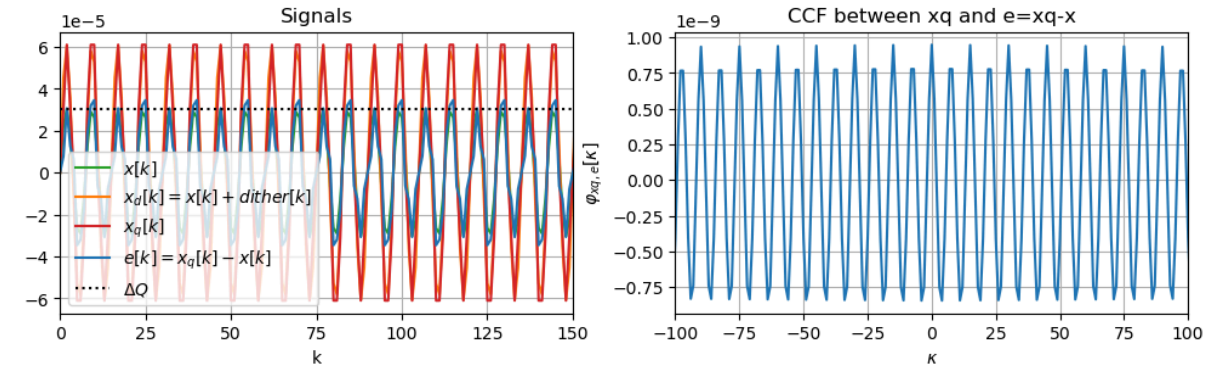
https://github.com/wm64167/AADEC

4. Outcomes:









5. Conclusions:

The lab investigated dithering techniques for signals. By adding dither noise, the quantization error was less correlated with the signal. The experiment showed that even for signals with amplitude below the quantization step size, dithering can help preserve signal clearness. The lab also analyzed the statistical properties of dither noise and quantization error.