Ex1

January 28, 2019

In [1]:
```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
```

1 Exercise 1: Characteristic curve of the uniform midtread quantiser (5 points)

a) Write a function xq = my_quant(x,N) that quantises a quasi amplitude-continuous signal x with a value range of 1 x 1 with an arbitrary, but odd number N of quantisation steps using the midtread uniform quantiser characteristic curve. Make use of the round function and the quantisation model that was introduced in the course. Values above 1 or below 1 shall be clipped to the highest and lowest quantisation step, respectively.

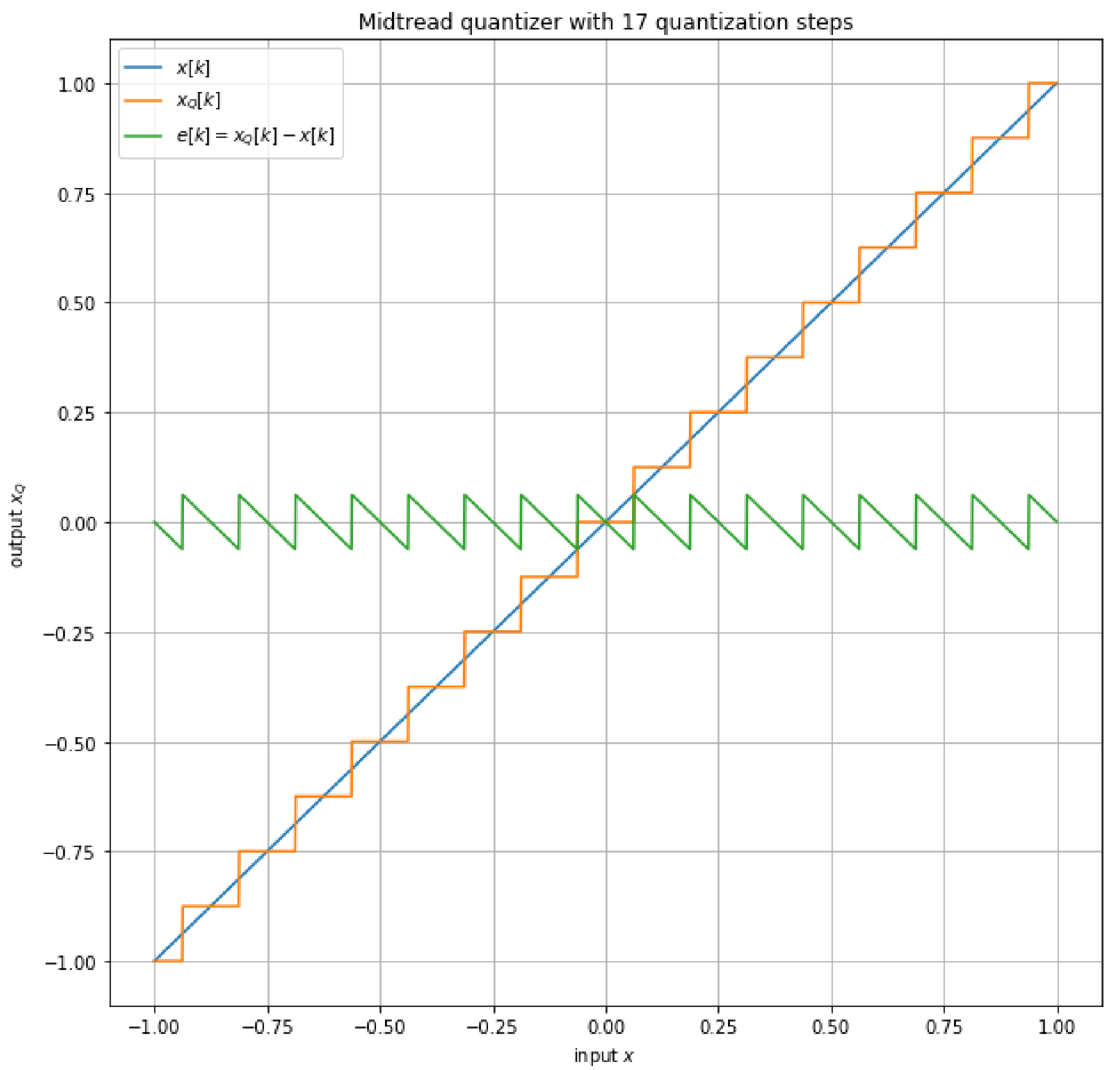
In [2]:
```
def my_quant(x,N):
    #limit
    x = np.copy(x)
    idx = np.where(np.abs(x) >= 1)
    x[idx] = np.sign(x[idx])

    #quantization
    Q = 2/(N-1) #quantization Stepsize
    xQ = Q * np.floor(x/Q + 1/2)
    return xQ
```

b) Test xq = my_quant(x,N) for a signal vector x = -1:0.001:1 and generate the left of fig. 1 using N = 17 quantisation steps.

In [3]:
```
def plot_signal(x, XQ, titel):
    e = xQ - x
    plt.figure(figsize=(10,10))
    plt.plot(x, x, label=r'$x[k]$')
    plt.plot(x, xQ, label=r'$x_Q[k]$')
    plt.plot(x, e, label=r'$e[k] = x_Q[k] - x[k]$')
    plt.xlabel(r'input $x$')
    plt.ylabel(r'output $x_Q$')
    plt.legend()
    plt.grid()
```

```
        plt.title(titel)
```

In [4]:
```
x = np.arange(-1, 1, 0.001)
xQ = my_quant(x, 17)

plot_signal(x,xQ, r'Midtread quantizer with 17 quantization steps')
```



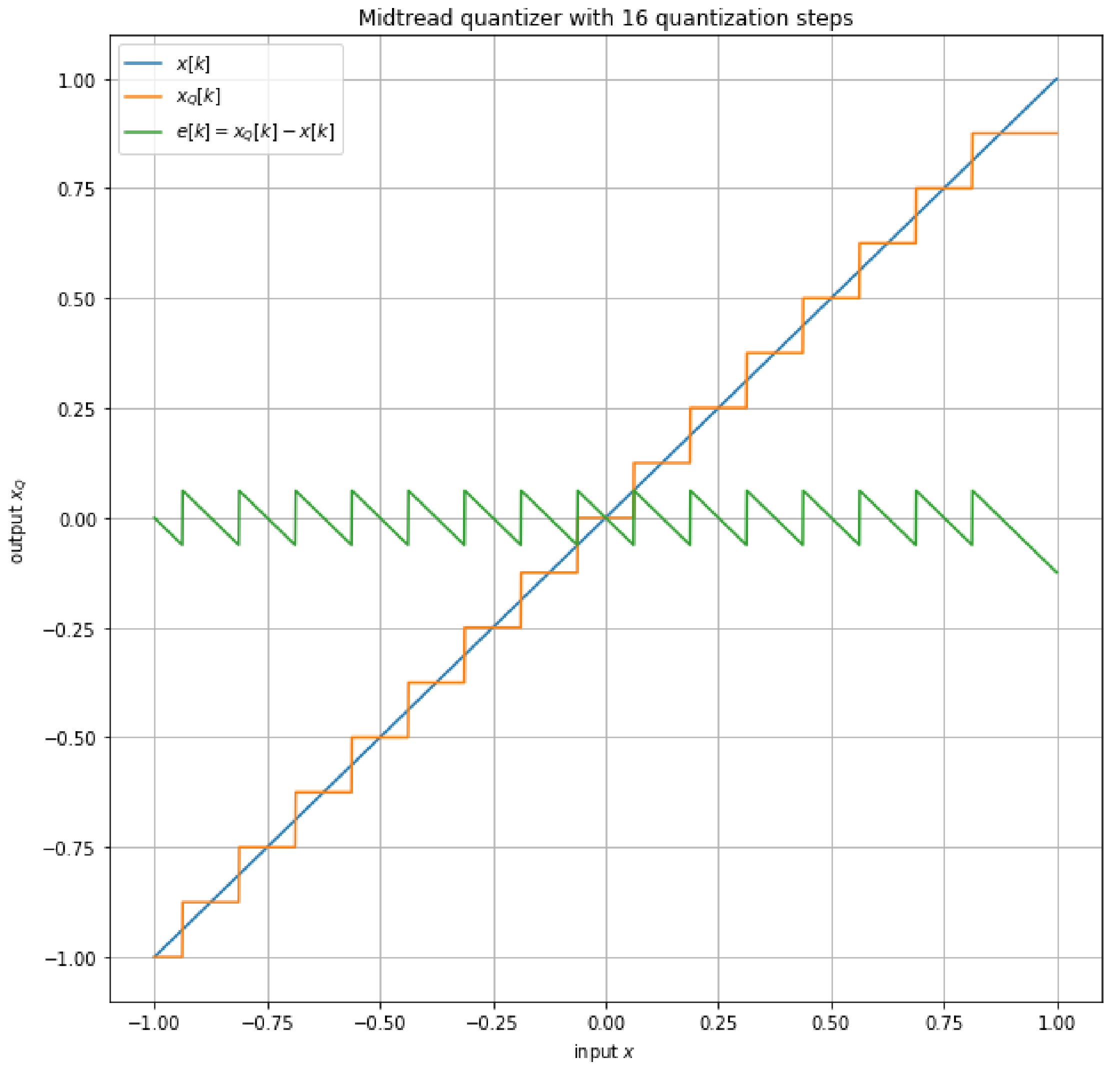
c) Modify xq = my_quant(x,N) so that it also works for even N. To this end, the last quantisation step for positive amplitudes is increased, cf. fig. 1 on the right. This models typical analogue-to-digital (ADC) / digital-to-analogue (DAC) converters that use N = 2^w quantisation steps with number of bits w N. In video applications, typically 8 to 16 bit can be found, in audio typically 16 to 24 bit.

In [5]:
```
def my_quant_even(x,N):
    #limit
```

```
    x = np.copy(x)
    idx = np.where(np.abs(x) >= 1)
    x[idx] = np.sign(x[idx])


    #quantization
    Q = 2/N #quantization Stepsize
    xQ = Q * np.floor(x/Q + 1/2)
    #increase last quantisation step
    iqdx = np.where(x > (1-Q))
    xQ[iqdx] = 1-Q

    return xQ
```

d) Test the modifed xq = my_quant(x,N) for a signal vector x = -1:0.001:1 and generate the right of fig. 1 using N = 16 quantisation steps, i.e. resolution of 4 bit.

```
In [6]: x = np.arange(-1, 1, 0.001)
        xQ = my_quant_even(x, 16)

        plot_signal(x,xQ, r'Midtread quantizer with 16 quantization steps')
```


Midtread quantizer with 16 quantization steps
$x[k]$
$x_Q[k]$
$e[k] = x_Q[k] - x[k]$
output x_Q
input x
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00