Exercise 4

AD Converters

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1 Objective

The main objective of this laboratory exercise is to see the difference between real AD Converter and ideal AD Converter where the results would not be exactly as expected.During the realisation of the laboratory exercise we will also get in touch with concepts such as DNL , INL and how to obtain them.

2 Exercise 1: INL and DNL calculations

Figure 1 shows ideal and real 3-bit A/D converter. Fulfil the Table 1 and calculate DNL, RMS(DNL), INL and its maximum value.

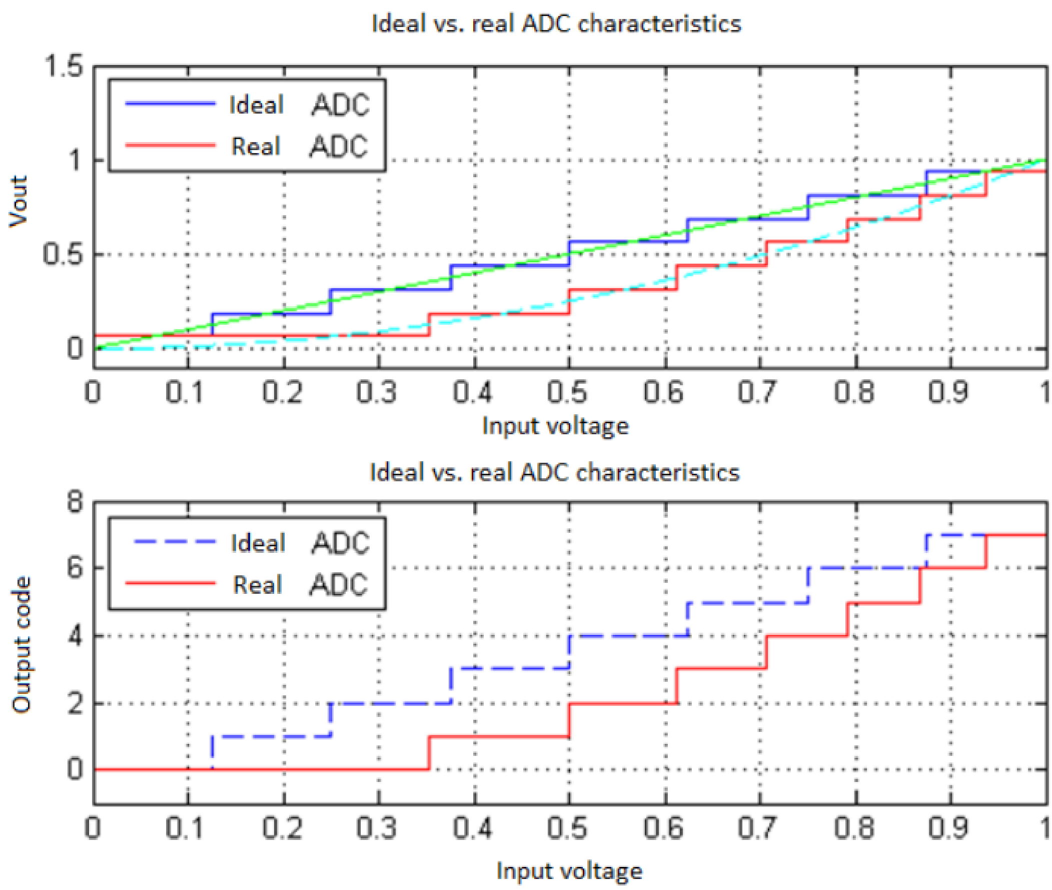

Figure 1: Comparison between ideal and real ADC

n	Transition Point (ideal)	Code (ideal)	Transition point (real)	Code (real)	DNL(n)	INL(n)
0	0	0	0	0	0	0
1	0.125	1	0.3535	0.3535	1.828	1.828
2	0.25	2	0.5	0.1465	0.172	2
3	0.375	3	0.6125	0.1125	-0.1	1.9
4	0.5	4	0.707	0.0945	-0.244	1.656
5	0.625	5	0.7905	0.0835	-0.332	1.324
6	0.75	6	0.866	0.0755	-0.396	0.928
7	0.875	7	0.9355	0.0695	-0.444	0.484

Table 1: Results of exercise 1

Looking at the table we can see that $\Delta = 0.1250$ and for G we will take G=0. The blanks have been calculated with this formulas:

$$\Delta_r(k) = X(k) - X(k-1)$$

$$DNL(k) = \frac{\Delta_r(k) - \Delta}{\Delta}$$

$$INL(k) = (1+G)\sum_{i=1}^{k} DNL(i)$$

We can see the calculations of this table in the spreadsheet: `https://docs.google.com/spreadsheets/d/1rtFr9xvIUKN1vpetLV52a_LNNet7QVA9U8BZzTiwaKg/edit?usp=sharing`

$$DNL_{rms} = \sqrt{\frac{1}{2^N-1}\sum_{i=1}^{2^N-1}[DNL(k)]^2} = 0.7468$$

$$INL_{max} = max(INL) = 2$$

We can see both in the graphic and in the table,how the transition points differ and also the difference between the function that approximate both.

Now we will use MatLab in order to validate and confirm the data.The code will just implement the formulas from above and instead of generating a table we will generate arrays.

We are getting almost the exact same result,we are just getting slightly different decimals number due to calculations approximations.The code can be seen in the appendix

3 Exercise 2: Real A/D - INL and DNL calculation

Prepare .m file where you realise model of $real/ideal$ 3-bit A/D converter using prepared function $adc\_MES.m$ available on the e.fe.uni-lj.si. Input signal should be linear ramp function from 0 to 1 consisting of 2^{16} samples.Plot histogram where "x" axis represents output code and "y" frequency of its repetitions. Determine transition points of real and ideal A/D and calculate DN, INL,DNL_{RMS} in INL_{max}

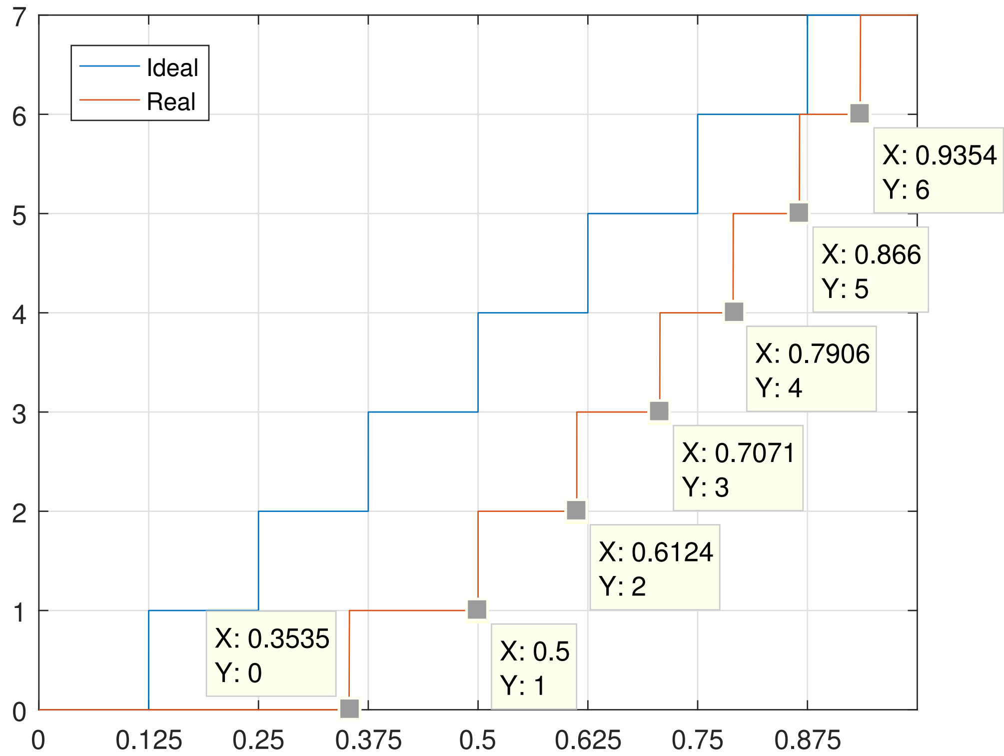

Figure 2: Comparison between ideal and real ADC

We are plotting the quatization number (Q) but we could also use values(Y),the result will be the same The difference between both is ,again, noticeable to better see the difference we will plot 2 histograms (one for the ideal and another for the real) where we will see how many times every quatization number is repeated.

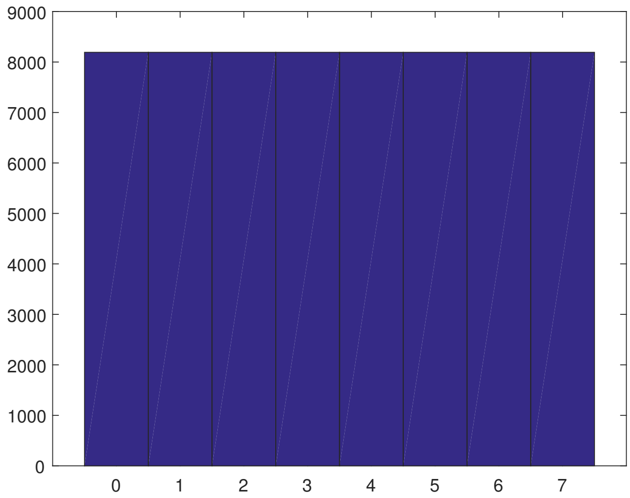

Figure 3: Histogram of the Ideal representation

The ideal histogram has the same amount of every quantization number,we can see on the graph that ideal stays the same amount on every Q(it changes every 0.125)

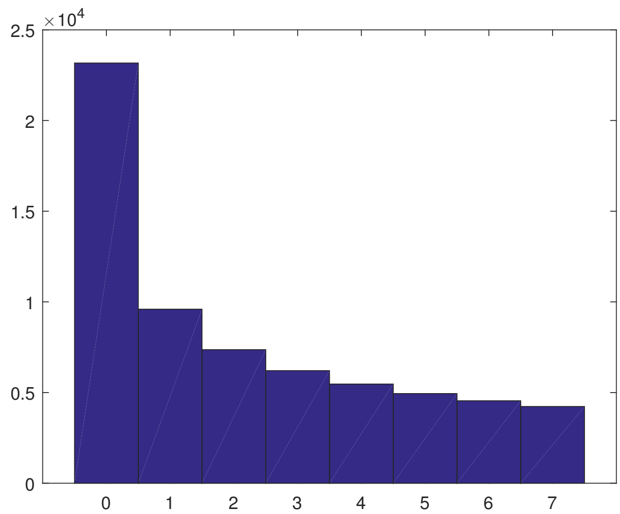

Figure 4: Histogram of the Real representation

For the real one we can see that 0 appears the most,that can be seen on the graphic, ideal changes to Q=1 on 0.125 and real on 0.3535, and for the other values happens the same but the difference is a bit lower.

The table of this exercise will be exactly the same as Exercise 1,since both exercises are using the ramp function as input.And for the DNL_{RMS} and INL_{max} we also get the same result:

n	Transition Point (ideal)	Code (ideal)	Transition point (real)	Code (real)	DNL(n)	INL(n)
0	0	0	0	0	0	0
1	0.125	1	0.3535	0.3535	1.828	1.828
2	0.25	2	0.5	0.1465	0.172	2
3	0.375	3	0.6125	0.1125	-0.1	1.9
4	0.5	4	0.707	0.0945	-0.244	1.656
5	0.625	5	0.7905	0.0835	-0.332	1.324
6	0.75	6	0.866	0.0755	-0.396	0.928
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Table 2: Results of exercise 1

$$DNL_{rms} = \sqrt{\frac{1}{2^N-1}\sum_{i=1}^{2^N-1}[DNL(k)]^2} = 0.7468$$

$$INL_{max} = max(INL) = 2$$

4 Appendix

4.1 Exercise 1

```
close all;
clear all;

Delta=0.125;
TransitionPointReal=[0 0.3535 0.5 0.6215 0.7070 0.7905 0.8660
    0.9335];

samples= length(TransitionPointReal);
for i=1:samples
    TransitionPointIdeal(i)=Delta*(i);
end

for i=2:samples
    CodeReal(i)=TransitionPointReal(i)-TransitionPointReal(i-1);
    DeltaR(i)=(CodeReal(i)-Delta)/Delta; % DNL(n)
    DeltaRi=DeltaR(1:i);
    INL(i)=sum(DeltaRi);
end
% We calculate the DNL rms and INL max
DeltaR2=DeltaR.^2; % We get the square for the DNL_rms formula
DLNrms=sqrt((1/(8-1))*sum(DeltaR2)); % Formula pdf
INLmax=max(INL);

% We print the results
disp('DNLrms:')
disp(DLNrms)
disp('INLmax:')
disp(INLmax)
```

4.2 Exercise 2

```
clear all;
close all;
% We define the number of samples ,the number of bits,amplitude of Vin,
% we create the function ramp and finally we define the step
N=2^16;
B=3;
V=1;
ramp=(0:(N-1))./N;
step=V/2^B;
% We use the provided function to get Q and Y
% Q contains the code and Y the value between 0 and 1 equivalent
[Qideal,Yideal]=adc_MES(ramp,B,'ideal');
[Qreal,Yreal]=adc_MES(ramp,B,'real');
% In order to calculate the real one,it makes ramp square in line 9 of the
% function adc_MES.m

% We plot the results
figure(1)
plot(ramp,Qideal)
hold on
plot(ramp,Qreal)
set(gca,'xTick',(0:2^B-1)*step)
grid on
legend('Ideal','Real')
% We get the histogram from both ideal and real
figure(2)
hist(Qideal,(0:(2^B)-1))
figure(3)
hist(Qreal,(0:(2^B)-1))
```