

# 1

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a

Because compared to a full scale input, the input signal power is only  $2 \cdot 0.2^2 / 0.6^2 = 2/9$ , so there is a  $-10\log 2/9 = 6.53\text{dB}$  drop to ideal SQDR.  $\text{SNR} = 6.02N + 1.76 - 6.53 = 67.47\text{dB}$

b

The noise's power is its variance,  $0.25 V^2$ . While the signal power is  $0.6^2/2 = 0.18V^2$ . So the input SNR is:  $\text{SNR} = P_{\text{sig,dB}} - P_{\text{noise,dB}} = -1.42\text{dB}$  After passing quantization, a  $\Delta^2/12 = 7.15 \cdot 10^{-9}$  noise is additive added:

$$\text{SNR} = 10\lg \frac{P_{\text{sig}}}{P_{\text{inputnoise}} + P_{\text{qnoise}}} \approx -1.42\text{dB}$$

Dominated by input noise.

c

The uniformly distributed noise power is  $1/12 V^2$ , then input SNR:  $\text{SNR} = 10\lg \frac{P_{\text{sig}}}{P_{\text{inputnoise}}} = 0.334\text{dB}$  Still output SNR is dominated by the input noise:  $\text{SNR} = 10\lg \frac{P_{\text{sig}}}{P_{\text{inputnoise}} + P_{\text{qnoise}}} \approx 0.334\text{dB}$

# 2

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Because total quantization noise is uniformly distributed in a wider frequency, and the noise is shaped (rejected) by the filter. Consider only the in-band noise, it is dropped  $K$  times. Then SNR is :  $\text{SNR} = 6.02N + 1.76 + 10\lg K$

# 3

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a

Offset is  $-0.01 / 0.1 = -0.1 \text{ LSB}$ . Full-scale error is  $(0.75 - 0.7)/0.1 = 0.5\text{LSB}$ .

b

Ideal gain is  $1\text{LSB/code}$  Actual gain is  $0.76/7/0.1 = 1.086\text{LSB/code}$  So gain error is  $0.086 \text{ LSB/code}$

c

End-point corrected ideal values:

Step size =  $(0.75V - (-0.01V))/7 = 0.1086V$  Code 000:  $-0.01V$  Code 001:  $-0.01V + 0.1086V = 0.0986V$  Code 010:  $-0.01V + 2 \times 0.1086V = 0.2071V$  Code 011:  $-0.01V + 3 \times 0.1086V = 0.3157V$  Code 100:  $-0.01V + 4 \times 0.1086V = 0.4243V$  Code 101:  $-0.01V + 5 \times 0.1086V = 0.5329V$  Code 110:  $-0.01V + 6 \times 0.1086V = 0.6414V$  Code 111:  $0.75V$

DNL calculation (in LSB):

$$\begin{aligned} \text{DNL}[000-001] &= (0.105 - (-0.01)) / 0.1086 - 1 = 0.064 \text{ LSB} \\ \text{DNL}[001-010] &= (0.195 - 0.105) / 0.1086 - 1 = -0.174 \text{ LSB} \\ \text{DNL}[010-011] &= (0.28 - 0.195) / 0.1086 - 1 = -0.217 \text{ LSB} \\ \text{DNL}[011-100] &= (0.37 - 0.28) / 0.1086 - 1 = -0.171 \text{ LSB} \\ \text{DNL}[100-101] &= (0.48 - 0.37) / 0.1086 - 1 = 0.018 \text{ LSB} \\ \text{DNL}[101-110] &= (0.6 - 0.48) / 0.1086 - 1 = 0.105 \text{ LSB} \\ \text{DNL}[110-111] &= (0.75 - 0.6) / 0.1086 - 1 = 0.38 \text{ LSB} \end{aligned}$$

INL calculation (in LSB):

$$\begin{aligned} \text{INL}[000] &= ((-0.01) - (-0.01)) / 0.1086 = 0 \text{ LSB} \\ \text{INL}[001] &= (0.105 - 0.0986) / 0.1086 = 0.059 \text{ LSB} \\ \text{INL}[010] &= (0.195 - 0.2071) / 0.1086 = -0.111 \text{ LSB} \\ \text{INL}[011] &= (0.28 - 0.3157) / 0.1086 = -0.329 \text{ LSB} \\ \text{INL}[100] &= (0.37 - 0.4243) / 0.1086 = -0.5 \text{ LSB} \\ \text{INL}[101] &= (0.48 - 0.5329) / 0.1086 = -0.487 \text{ LSB} \\ \text{INL}[110] &= (0.6 - 0.6414) / 0.1086 = -0.381 \text{ LSB} \\ \text{INL}[111] &= (0.75 - 0.75) / 0.1086 = 0 \text{ LSB} \end{aligned}$$

d

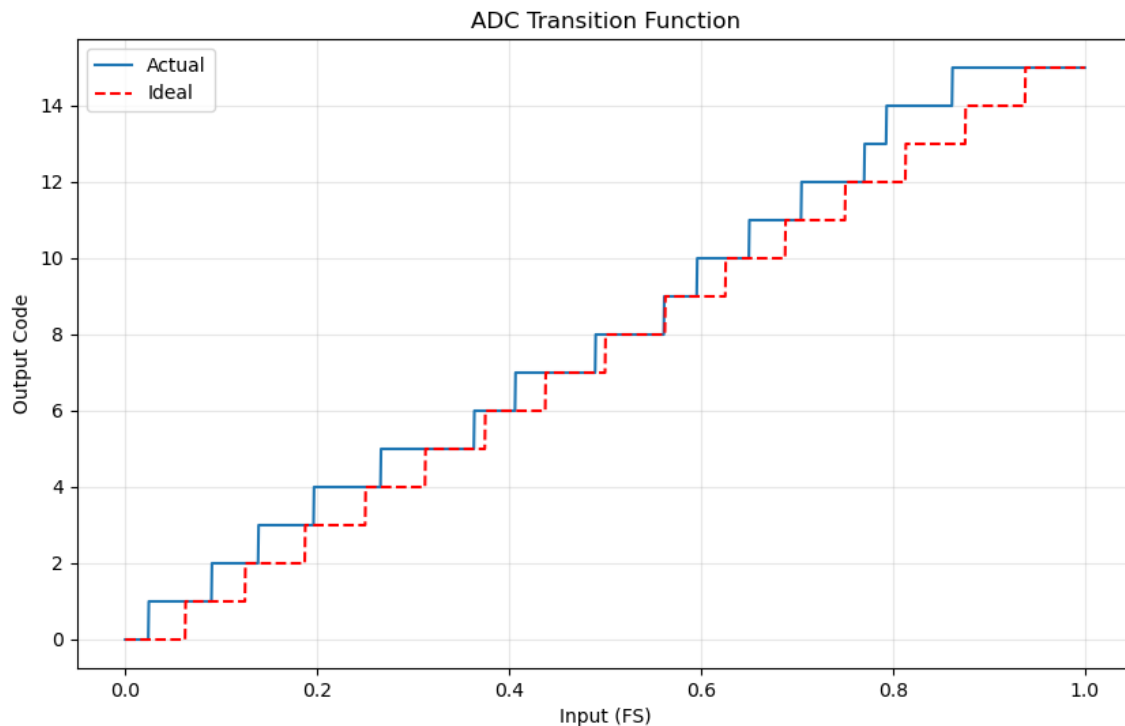
Maxium DNL = 0.38 LSB Maxium INL = 0.5 LSB

# 4

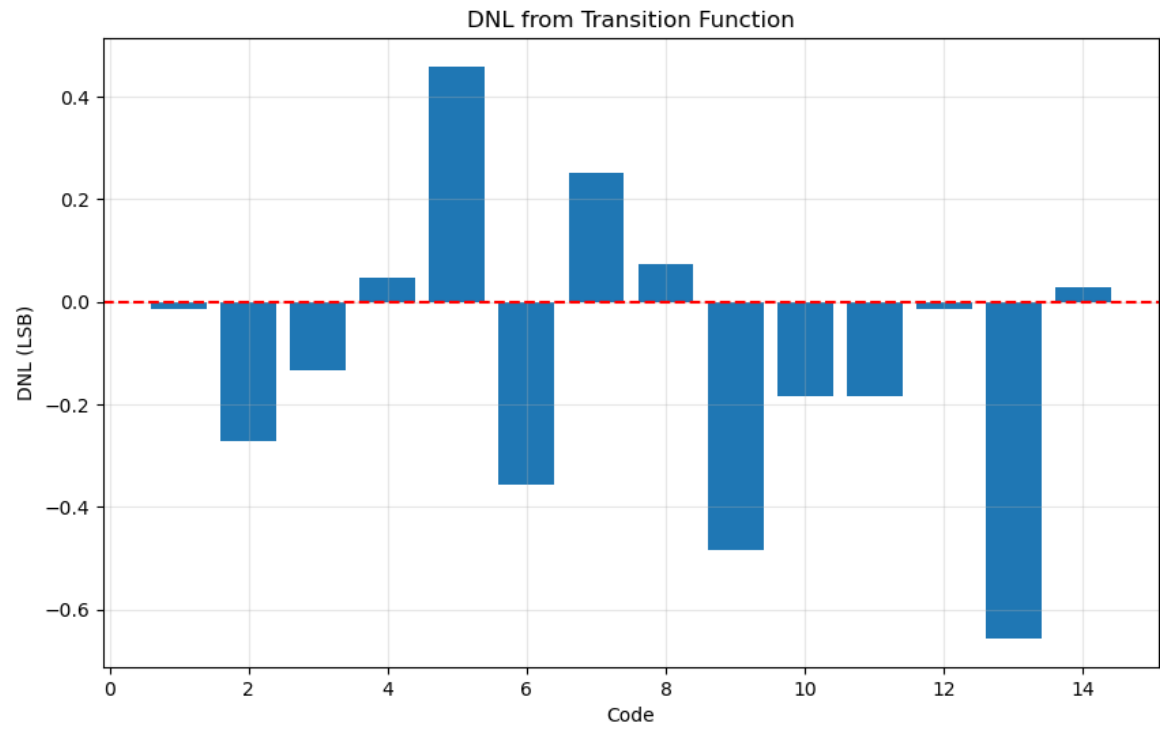
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a

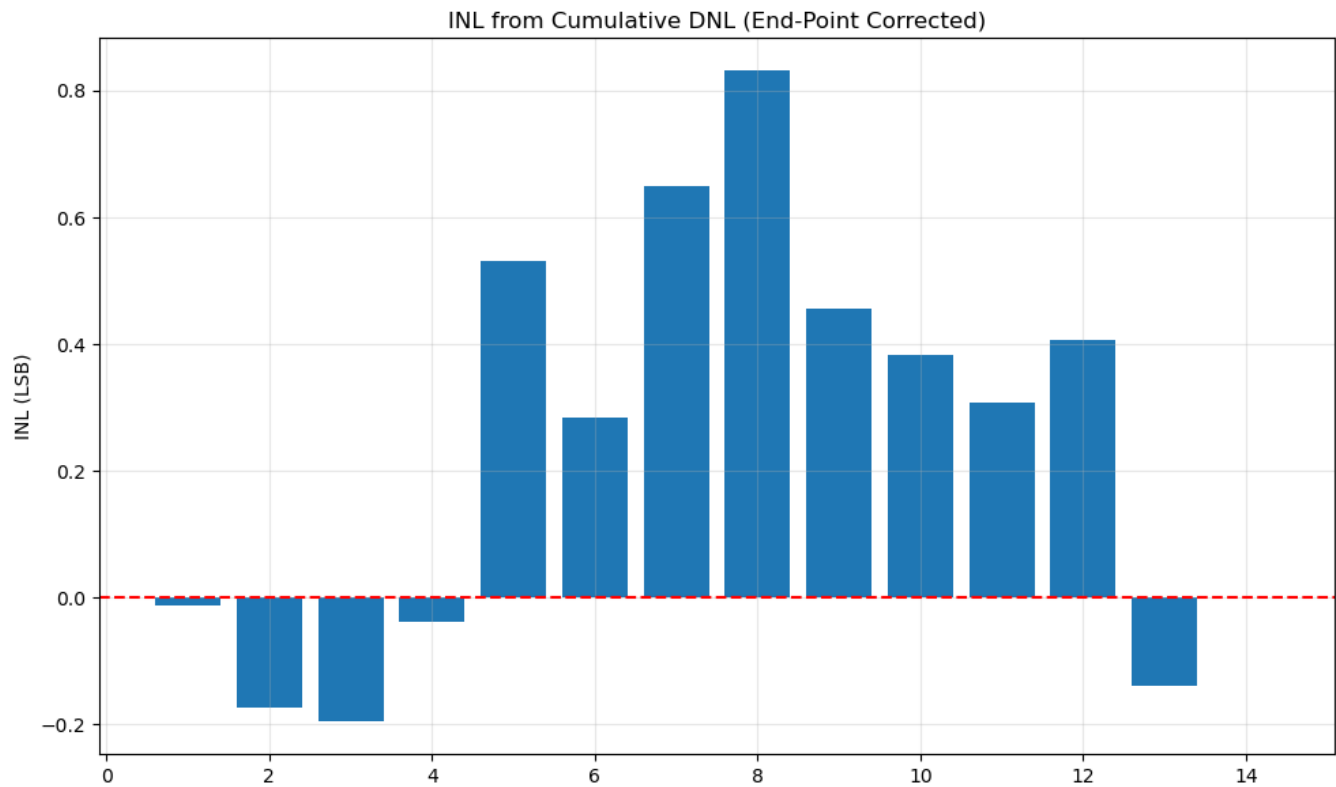
Based on the histogram code result, the transition function of ideal and real are:



Then DNL can be calculated:



INL can be accumulated by DNL, is:



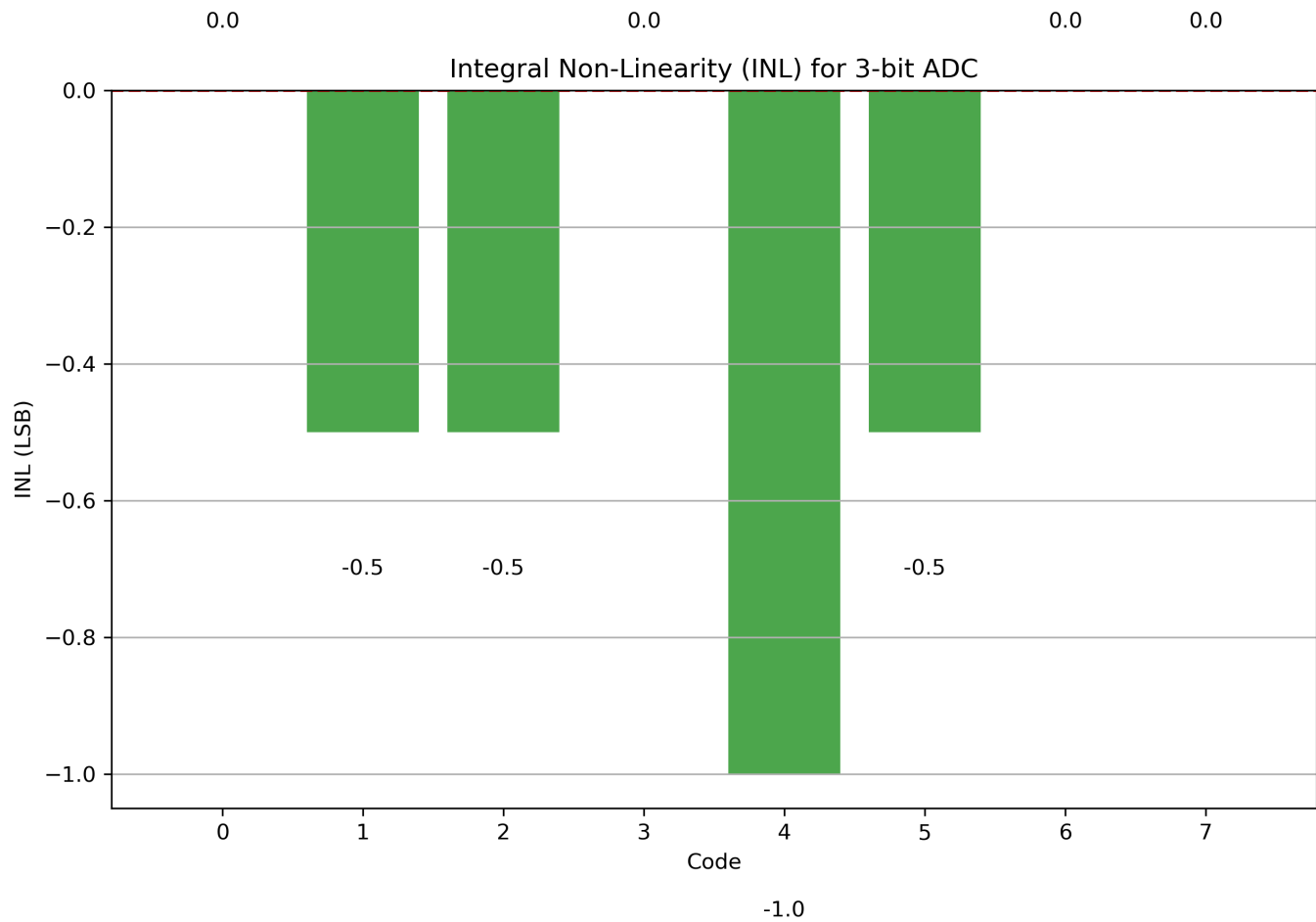
b

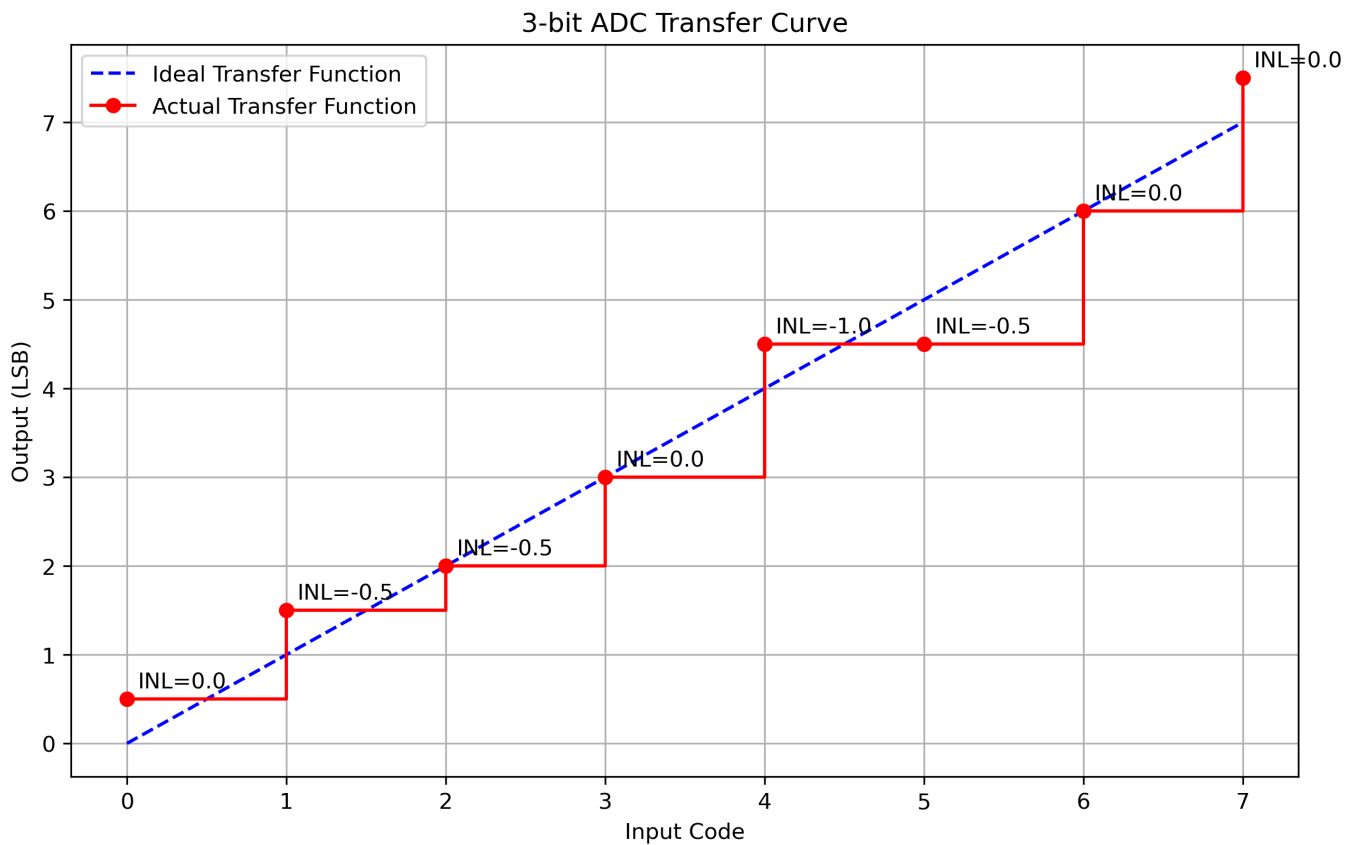
Based on the result, DNL max = -0.6568LSB, INI max = 0.8316LSB

c

Because minimum DNL=-0.6568 > -1.0, it is monotonic. Otherwise the result from histogram is useless.

5





## 6

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a

FS SQDR is:  $SQDR = 6.02N + 1.76$

b

Now the noise power is distributed uniformly to  $L/2$  bins (up to Nyquist Freq) as the noise floor, while the signal power remains the same at a specific bin. Consider the power in dB  $\text{Signal to Noise Floor} = 6.02N + 1.76 + 10\lg(L/2)$

c

The input signal frequency should fall on a specific signal bin with no leakage to all other noise bins, and input signal should be uncorrelated to the quantization noise.  $f_s/f_{in} = L/C$  Where  $\gcd(N,C)=1$  These are necessary but still not enough to create a totally flat noise floor, with some small spurs on the noise floor.

d

Now the noise floor is also shaped by the digital filter. By calculating the integration (area) of the rejected 2 triangles, the total eliminated noise power is:  $P_{\text{noise,dropped}} = \frac{B^2}{(A-B)A} * F_s/4$  Then SNR is improved by this value in dB

## 7

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## a

When  $\Phi_1$  is HIGH and  $\Phi_1$  is LOW:

Transistors M1 and M2 operate in saturation region, forming a differential input pair M3 and M4 act as MOS resistor loads in triode region M5 and M6 are OFF (since  $\Phi_1$  is LOW) The circuit operates as a preamplifier with open-loop gain The differential input ( $V_1^+ - V_1^-$ ) is amplified at the outputs ( $V_o^+ - V_o^-$ )

When  $\Phi_1$  is LOW and  $\Phi_1$  is HIGH:

M1 and M2 are turned OFF, disconnecting the input from the circuit M5 and M6 turn ON and operate in saturation region M3 and M4 continue to operate in triode region The circuit enters regenerative mode with positive feedback through the cross-coupled pair M5 and M6 The small voltage difference at the outputs gets amplified until it reaches the rails (VDD and GND)

## b

In differential mode, consider the 2 phases together:  $V_o = G_1 V_i + G_2 V_o$  SO  $V_o = \frac{G_1}{1 - G_2} V_i$  Where:

$G_1$  is the open-loop gain of the differential pair (M1-M4)  $G_2$  is the positive feedback gain from the cross-coupled pair (M5-M6)

## c

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Static Latches:

Advantages:

Can hold data indefinitely without refreshing More robust against noise and clock glitches Less sensitive to charge leakage

Disadvantages:

Higher power consumption Larger area (more transistors) Typically slower due to higher capacitive load

Dynamic Latches:

Advantages:

Lower power consumption Smaller area (fewer transistors) Often faster due to lower capacitive load

Disadvantages:

Cannot hold data indefinitely (requires periodic refreshing) More sensitive to noise and leakage Less reliable at low clock frequencies

## d

This is a semi-dynamic latch because it dynamically amplifies input voltage, and regenerate statically.