

Report

The measured output voltages for a 9b digital-to-analog converter are given in the .csv file.

Question 1a:

Find the effective LSB size.

The graph below shows the digital input code represented in decimal format versus the analog output:

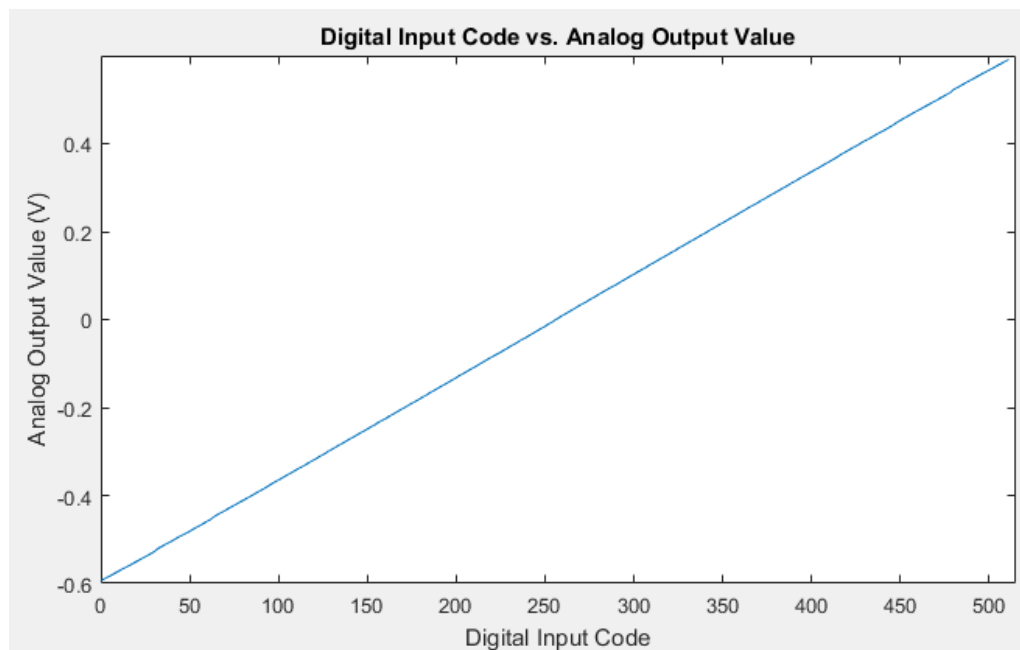


Figure 1. Digital Input Code versus Analog Output Voltage

The effective LSB size can be calculated as follows:

$$V_{LSB,actual} = \frac{V_{max} - V_{min}}{2^N - 1} = \frac{(0.59149) - (-0.59404)}{2^9 - 1} = 2.32002 * 10^{-3} \approx \boxed{2.32002 \text{ mV}}$$

Command Window results for the LSB size:

```
Command Window
Effective LSB = 2.32002 mV
```

Figure 2. Effective LSB Size Results in MATLAB

Based on the lecture slides, the offset error for the given DAC can be calculated in the following way:

$$E_{off} = \frac{V_{out}}{V_{LSB}} (at\ code = 0 \dots 0) = \frac{-0.59404}{2.34375 * 10^{-3}} \approx -253.45707\ LSBs$$

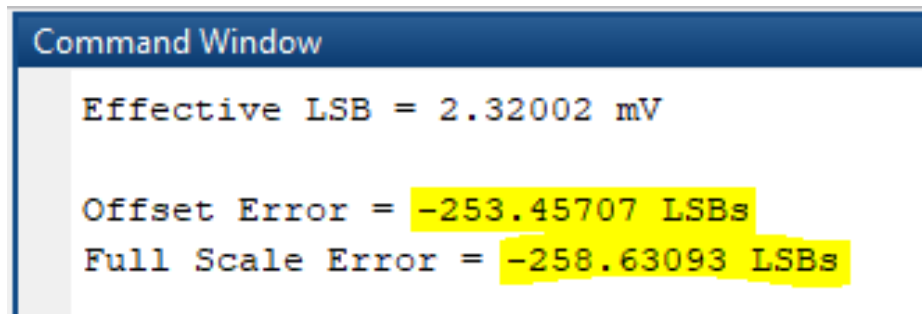
Moreover, the full-scale error for the DAC can be calculated as follows:

$$V_{1\dots 1,actual} = 0.59149\ V$$

$$V_{1\dots 1,ideal} = (2^N - 1) * V_{LSB} = 511 * 2.34375 * 10^{-3} \approx 1.197656\ V$$

$$E_{FS} = \frac{V_{1\dots 1,actual} - V_{1\dots 1,ideal}}{V_{LSB}} = \frac{0.59149\ V - 1.197656\ V}{2.34375 * 10^{-3}} \approx -258.63093\ LSBs$$

Command Window results for the offset and full-scale error:

A screenshot of a MATLAB Command Window. The title bar is dark blue with the text "Command Window" in white. The window contains three lines of text: "Effective LSB = 2.32002 mV", "Offset Error = -253.45707 LSBs", and "Full Scale Error = -258.63093 LSBs". The values "-253.45707 LSBs" and "-258.63093 LSBs" are highlighted in yellow.

```
Command Window  
  
Effective LSB = 2.32002 mV  
  
Offset Error = -253.45707 LSBs  
Full Scale Error = -258.63093 LSBs
```

Figure 3. Offset and Full-Scale Error Results in MATLAB

Question 1b:

Plot the DNL versus DAC code. What are the minimum and maximum DNL, and what is the standard deviation of the DNL? Is the DAC monotonic?

The following plot shows the DNL versus the DAC Code represented in decimal format.

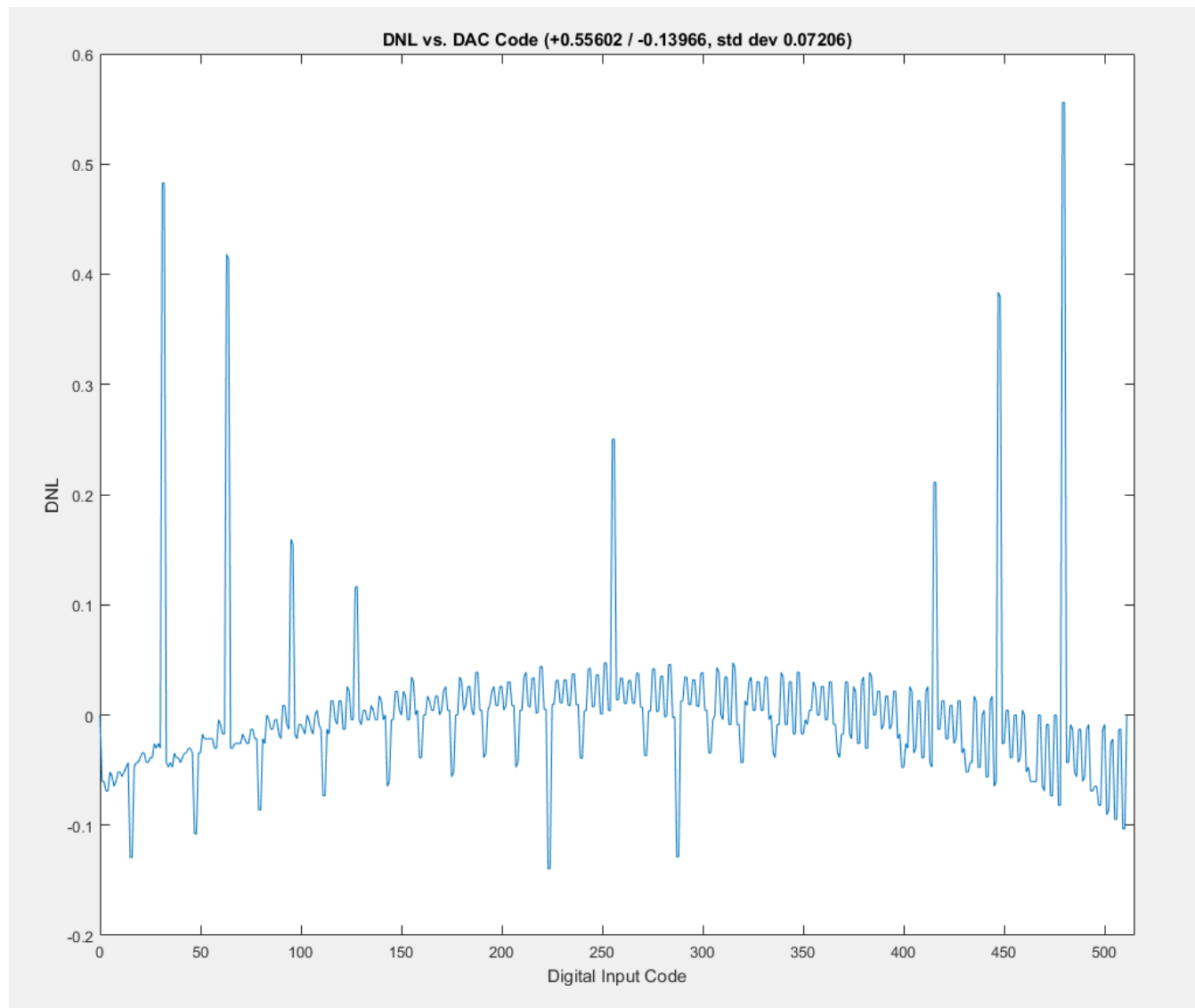


Figure 4. DNL versus the DAC Code

The minimum and maximum values for the DNL are:

$$\text{minimum (DNL)} = \boxed{-0.13966 \text{ LSBs}}$$

$$\text{maximum (DNL)} = \boxed{0.55602 \text{ LSBs}}$$

The standard deviation of the DNL was also found to be:

$$\sigma(DNL) = \boxed{0.07206}$$

Since the minimum value of the DNL is greater than -1 LSB it can be said that the DAC is monotonic.

$$\text{minimum}(DNL) = -0.13966 \text{ LSBs} > -1 \text{ LSB}$$

$$\boxed{\text{DAC is monotonic.}}$$

Command Window results for the mathematical analysis of the DNL:

```
Command Window

Effective LSB = 2.32002 mV

Offset Error = -253.45707 LSBs
Full Scale Error = -258.63093 LSBs

Standard Deviation (DNL) = 0.07206
Minimum DNL = -0.13966 LSBs
Maximum DNL = 0.55602 LSBs
The DAC is monotonic. Minimum DNL > -1 LSB.
```

Figure 5. DNL Analysis Results in MATLAB

Question 1c:

Plot the INL versus DAC code, and find the minimum and maximum values of INL.

The following plot shows the INL versus the DAC Code represented in decimal format.

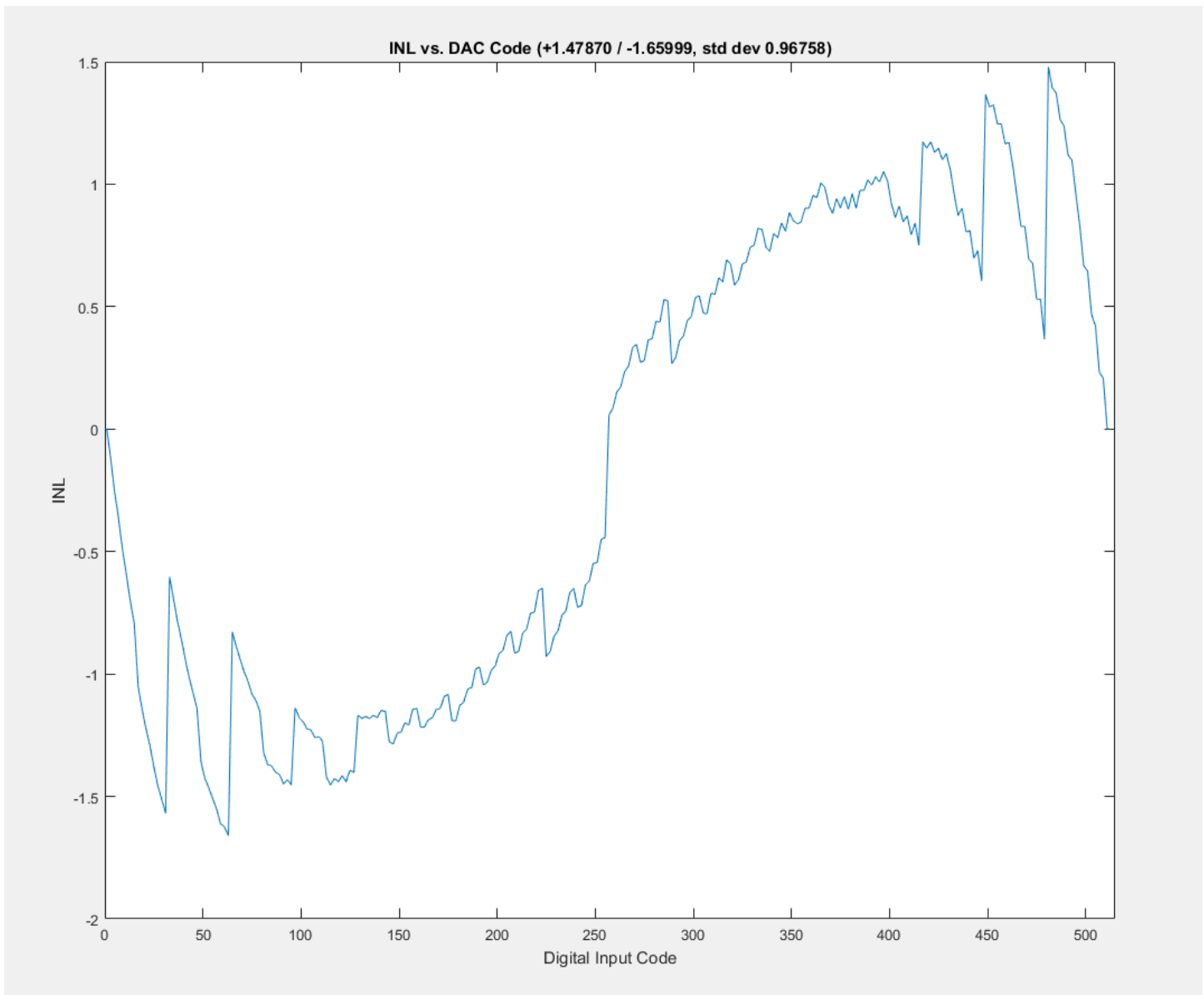


Figure 6. INL versus the DAC Code

The minimum and maximum values for the INL are:

$$\text{minimum (INL)} = \boxed{-1.65999 \text{ LSBs}}$$

$$\text{maximum (INL)} = \boxed{1.47870 \text{ LSBs}}$$

The standard deviation of the INL was also found to be:

$$\sigma(INL) = \boxed{0.96758}$$

Command Window results for the mathematical analysis of the INL:

```
Command Window

Effective LSB = 2.32002 mV

Offset Error = -253.45707 LSBs
Full Scale Error = -258.63093 LSBs

Standard Deviation (DNL) = 0.07206
Minimum DNL = -0.13966 LSBs
Maximum DNL = 0.55602 LSBs
The DAC is monotonic. Minimum DNL > -1 LSB.

Standard Deviation (INL) = 0.96758
Minimum INL = -1.65999 LSBs
Maximum INL = 1.47870 LSBs
```

Figure 7. INL Analysis Results in MATLAB

As part of the report, the following are included for the submission:

- “DAC_9b_levels.csv”
 - Original CSV file given as part of the assignment.
- “problem_set_6_code.m”
 - MATLAB code where the DAC output voltages are analyzed.
- “analysis_output_DNL.csv”
 - CSV output file from the code showing the values for the DNL against the DAC levels.
- “analysis_output_INL.csv”
 - CSV output file from the code showing the final values for the INL.