<u>**Lab 9**</u>

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Lab Time: 9-12pm Wednesday
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Station 13

4.1 Was the V0,1 transition voltage what you expected? Was the V126,127 transition voltage what you expected?

<u>ANSWER1 Expect from LSB</u>
LSB is the average spacing of the neighboring transition ΔV, which is calculated by my partner Dennis to be 0.01988V. I would expected $V_{0,1}$ and $V_{126,127}$ to be 0.01988V and 0.01988V*127=2.52V respectively. However, the actual measurements differ. The actual measured $V_{0,1}$ and $V_{126,127}$ are shown in Table 4.1.

Table 4.1 Measured V0,1 and V126,127 Transition Voltages

$V_{0,1}$	0.011
$V_{126,127}$	2.483

<u>ANSWER2 Expect from Division</u>
Also, I would have expected the voltage steps were linear, and I could have calculated the $V_{0,1}$ and $V_{126,127}$ directly from the end point measurements. Since the $V_{0,1}$ voltage is 0.011, so I would expect the $V_{126,127}$ to be 0.011*127= 1.397V, but the $V_{126,127}$ was 2.483 instead. Similarly, I would have assumed the steps are uniform, so $V_{0,1}$ should be $V_{126,127}$/127=0.0195V, but the $V_{0,1}$ was 0.011V instead.

This tells me than the A/D converter does not converter analog input to digital values with uniform steps. That means the conversion is not perfectly linear. Since the voltage steps are not uniform, measurements are needed to characterize the non-linearity of the D/A converter.

4.2 What was the largest millivolt deviation between your transition data and the linear model?

Table 4.2 D/A Converter Analog Input to Digital Values

n, transition step from n-1 to n	Vn,n+1, measured transition voltage (V)	V_lin(n, n+1), linear model (V)	Difference in V Vn,n+1 – V_lin(n,n+1)	Difference in mV Vn,n+1 - V_lin(n, n+1)	Difference (Vn,n+1 - V_lin(n, n+1))/delta_V
0	0.011	0.011	0	0	0
1	0.028	0.030619048	-0.002619048	-2.619047619	-0.133495146
2	0.048	0.050238095	-0.002238095	-2.238095238	-0.11407767
3	0.067	0.069857143	-0.002857143	-2.857142857	-0.145631068

24	0.479	0.481857143	-0.002857143	-2.857142857	-0.145631068
25	0.498	0.50147619	-0.00347619	-3.476190476	-0.177184466
49	0.973	0.972333333	0.000666667	0.666666667	0.033980583
50	0.994	0.991952381	0.002047619	2.047619048	0.104368932
74	1.464	1.462809524	0.001190476	1.19047619	0.060679612
75	1.483	1.482428571	0.000571429	0.571428571	0.029126214
99	1.955	1.953285714	0.001714286	1.714285714	0.087378641
100	1.976	1.972904762	0.003095238	3.095238095	0.15776699
125	2.46	2.463380952	-0.003380952	-3.380952381	-0.172330097
126	2.483	2.483	0	0	0

According to Table 2.1, the largest millivolt deviation happens when n=25 (a transition between 24 and 25), and the difference is
(Linear Model Voltage – Measured Voltage) = 0.50147619-0.498 = 3.476mV.

4.3 What was your sampling frequency in procedure section 4? What is the maximum frequency of a sine wave that your system can sample without aliasing?

The sampling frequency is 1 / 20us = 50000 samples/sec. The maximum frequency of a sine wave our system can sample without aliasing is half of the sampling frequency, which is 0.5*50000 = 25,000 samples/sec according to the Nyquist theorem.

4.4 In characterizing an A/D converter, why is it better to measure transition voltages rather than recording digital output values for a number of random analog input voltages?

In A/D converters, analog voltages increase by discrete voltage steps. Measuring random analog input voltages will not tell us where the edges of the discrete voltage steps are. In other words, if insufficient data points are taken, the random analog input voltage will give a linear relationship to the digital output. However, the actual outputs are discrete digital values. The random input method will not accurately characterize the A/D conversion.

On the other hand, measuring a random analog input voltage will not allow us to characterize the linearity of the A/D converter. According to Table 4.2, the voltage steps are uniform. If insufficient random analog input voltages are taken, the different widths of the voltage steps cannot be measured.

4.5 How would you use a high-resolution D/A converter and a computer with a digital I/O port to automate the measurement of A/D transition voltages?

1. Connect the computer to a D/A converter, and then connect the D/A converter to an A/D converter. Finally the A/D converter gives the digital output back to the computer. Set the reference and supply voltage of the D/A and A/D converters to be 10V.

2. Write a program to control the D/A converter, and the program record the output to the D/A converter as well as the input from the A/D converter.
3. Increase the output to D/A converter by 1, and then wait for the analog value to settle down.
4. Repeatedly increase the output to the D/A converter and wait for certain periods for the analog output to settle down. Record any change from the A/D converter until the output to the D/A converter reaches the maximum value.
5. The two columns of data are obtained, and stored in the computer. One column is the output to the D/A converter, and the other is the input from the A/D converter. This program and setup will automatically measure the A/D transition voltages.
6. The (input from A/D)/(Max input from A/D) will be multiplied by 10V to give the corresponding analog voltage.