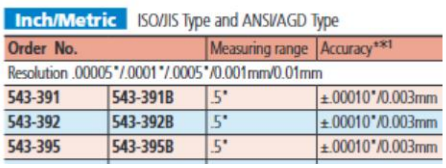
MECH 420 – Lab Report 2

Kyle Ah Von #57862609

Part A

1) Calculate the average and standard deviation for the values of each data set and provide these in a table for each sensor. The accuracy of your position readings should correspond to the accuracy of the digimatic indicator.

All values have been fixed to 3 decimal places as indicated by the accuracy of the digimatic indicator in the datasheet:



Inch/Metric ISO/JIS Type and ANSI/AGD Type

Order No.		Measuring range	Accuracy*1
Resolution .00005"/.0001"/.0005"/0.001mm/0.01mm			
543-391	543-391B	.5"	±.00010"/0.003mm
543-392	543-392B	.5"	±.00010"/0.003mm
543-395	543-395B	.5"	±.00010"/0.003mm

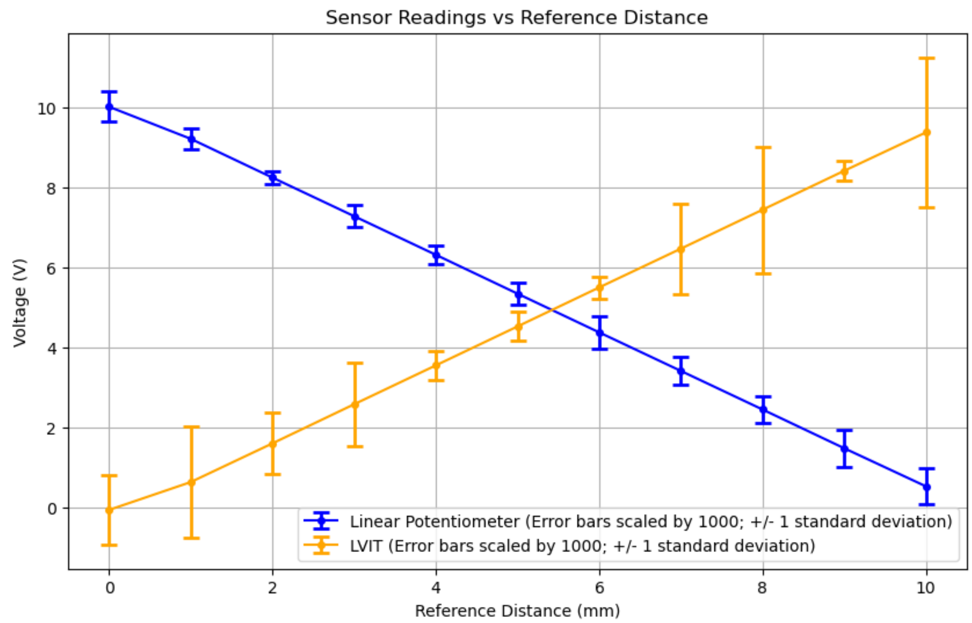
Mean Values:

Reference Distance (mm)	Linear Potentiometer (V)	LVIT (V)
0.00	10.019	-0.067
5.00	9.217	0.629
10.00	8.247	1.597
15.00	7.281	2.576
20.00	6.315	3.549
25.00	5.343	4.523
30.00	3.474	5.500
35.00	3.409	6.469
40.00	2.444	7.444
45.00	1.474	8.419
49.88	0.521	9.379

Standard Deviation Values were extremely small, hence I added an additional decimal place to see the relative sizes:

Reference Distance (mm)	Linear Potentiometer (V)	LVIT (V)
0.00	0.0004	0.0009
5.00	0.0003	0.0014
10.00	0.0002	0.0008
15.00	0.0003	0.0010
20.00	0.0002	0.0004
25.00	0.0003	0.0004
30.00	0.0004	0.0003
35.00	0.0004	0.0011
40.00	0.0003	0.0016
45.00	0.0005	0.0002
49.88	0.0004	0.0019

2) Plot the sensor signals as a function of the linear position. Include error bars indicating a measure of data uncertainty; choose +/- 1 standard deviation for the sensor signals and the estimated accuracy of your position reading for the position values.



Error bars have been scaled by 1000 so that they can give a visual representation of where the standard deviation is more significant.

3) Determine the equation for the end-points-based linear calibration curve of each sensor signal as a function of position (do not forget to include the correct units). Identify the offset V0 and the sensitivity B0.

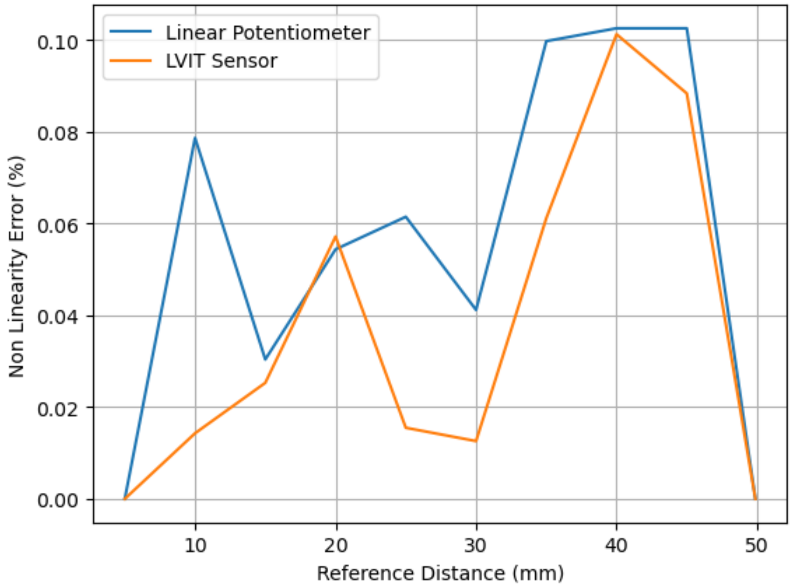
The original dataset contained a slight irregularity at the zero point. Hence, the end-points chosen are 5mm and 49.88 mm.

Equations are:

	V0 (V0)	**B0 (V/mm)**	**Equations**
Linear Potentiometer (V)	10.1853	-0.1938	10.1853-0.1938x
LVIT (V)	-0.3455	0.1949	-0.3455+01949x

4) Calculate and plot the absolute non-linearity errors as a function of position. Determine the maximum absolute non-linearity error for each sensor signal and use it to estimate a position error.

Sticking to the endpoints of 5mm and 49.88mm, here is the resulting graph of non-linearity errors:



For reference, here is the raw data used to obtain the graph above:

	Reference Distance (mm)	Linear Potentiometer (V)	LVIT (V)	Linear LinPot (V)	Linear LVIT (V)	LinPot Diff (V)	LVIT Diff (V)	LinPot NonLinearity Error (%)	LVIT NonLinearity Error (%)
0	0.00	10.019058	-0.066939	10.185287	-0.345495	0.278556	0.166229	3.2599	1.9590
1	5.00	9.216533	0.629270	9.216533	0.629270	0.000000	0.000000	0.0000	0.0000
2	10.00	8.246567	1.597315	8.247780	1.604036	0.006721	0.001213	0.0787	0.0143
3	15.00	7.281174	2.576207	7.279027	2.578801	0.002594	0.002147	0.0304	0.0253
4	20.00	6.315127	3.548920	6.310273	3.553566	0.004646	0.004854	0.0544	0.0572
5	25.00	5.342837	4.523080	5.341520	4.528332	0.005252	0.001317	0.0615	0.0155
6	30.00	4.373836	5.499576	4.372766	5.503097	0.003521	0.001070	0.0412	0.0126
7	35.00	3.409209	6.469335	3.404013	6.477863	0.008528	0.005196	0.0998	0.0612
8	40.00	2.443860	7.443864	2.435260	7.452628	0.008764	0.008600	0.1026	0.1013
9	45.00	1.474008	8.418627	1.466506	8.427393	0.008766	0.007502	0.1026	0.0884
10	49.88	0.521003	9.378764	0.521003	9.378764	0.000000	0.000000	0.0000	0.0000

The difference between the linear response and the actual response is calculated for every case, then the non-linearity error is found by dividing the difference by the range of values and multiplying it by 100.

The maximum non-linearity error in the **Linear potentiometer** is 0.103%

The maximum non-linearity error in the **LVIT** is 0.101%

The position error for both sensor is thus about **0.1% of the full measured scale**: (49.88 mm – 5 mm = 44.55 mm) which is **0.0446 mm**.

5) Compared the errors that you found to the accuracy of your position readings and to the data sheets of both sensors.

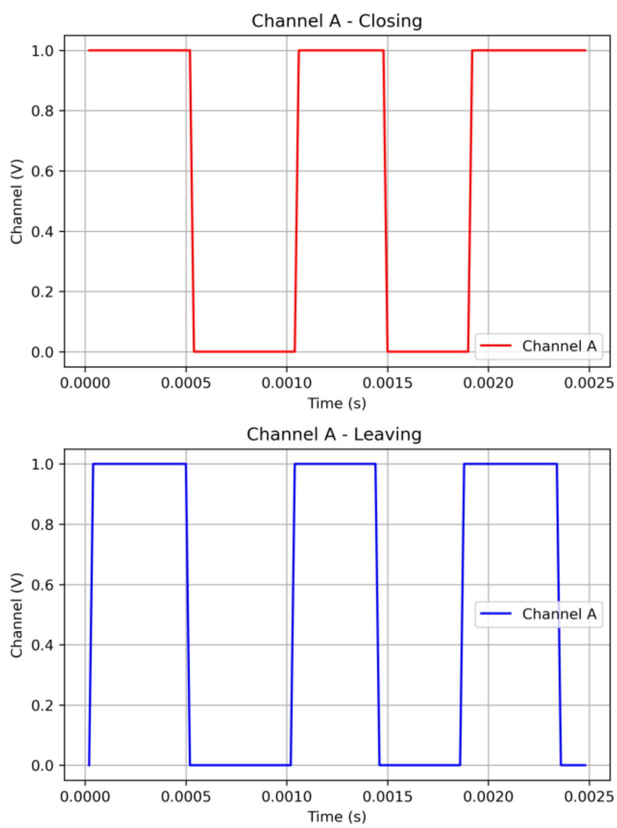
	Data Sheet Linearity Error (%)	Experimental Linearity Error (%)
Linear Potentiometer	0.1%	0.103%
LVIT	0.15%	0.101%

The experimental linearity errors are close to the theoretical errors in the datasheet. They are within acceptable experimental errors.

Part B

Displacement Direction

1. For each direction of displacement of the platform provide one plot with both encoder phases (the two pick-off signals) as a function of time for a few encoder increments.



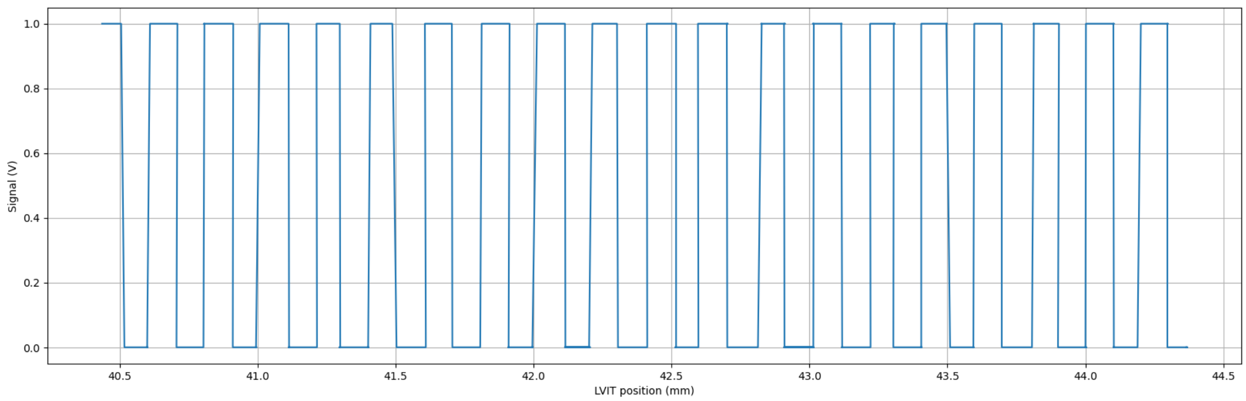
Closing refers to the platform moving towards the sensors and leaving refers to the platform moving away from the sensor.

2. Comment on the measurement of the direction of displacement.

There is a difference in the phase between the two directions. In Closing, we notice that signal of channel B is shifted by about 90 degrees to the left, which indicates that the strip platform was moving to the left relative to the encoder. In Leaving, we notice that the signal of Channel B is shifted by about 90 degrees to the right relative to Channel A, indicating that the platform was moving to the right relative to the encoder.

Characterization of the Encoder Strip

4) Convert the DVRT signal to position and plot 20 pulses of one encoder phase against position. Determine the average an standard deviation of the encoder pulses in terms of linear displacement.



Using the calibration obtained above in part A, we can map Channel A signal onto the distance.

The average encoder pulses per mm is 4.82 pulses/mm which is equivalent to 127.6 pulses/inch

The standard deviation of encoder pulses per inch is 6.48 pulses/inch

The method used to calculate the average and standard deviation revolved around, calculating the distance travelled between each rising edge, here is a code snippet:

```
# Find rising edges (transitions from 0 to 1 in Channel A)
rising_edges = partb2steady[partb2steady['Channel A'].diff() == 1]['LVIT position (mm)'].values

# 2. Calculate periods (Δx)
periods = np.diff(rising_edges)

# 3. Convert to frequency (pulses/mm)
frequencies = 1/periods
# 3.b Convert to pulses/in
frequencies = frequencies/0.0393701

# 4. Calculate mean (μ)
mean_freq = np.mean(frequencies)

# 5. Calculate standard deviation (σ)
std_freq = np.std(frequencies)
```

5) Compare this with the resolution indicated in the data sheet.

The Data sheet highlights that the Linear encoder strip is 127 Lines per inch, which is consistent with the average value experimentally calculated at 127.6 lines per inch. The small discrepancy is likely due to the inconsistency in the rotation speed of the crank as well as other approximation errors.

Characterization of Velocity Resolution

6) Calculate the average speed of the platform from one of the encoder phases using the pulse counting method as well as for the pulse timing method for both displacement speeds. Compare this with the average speed from the DVRT signal.

Slow steady:

Pulse counting: $V_c = \frac{L}{N} \cdot \frac{n}{T}$

$= \frac{1 \text{ inch}}{127 \text{ lines}} \cdot \frac{20 \text{ Lines}}{2 \text{ seconds}}$

$= 0.0787 \text{ in/sec}$

$= 1.999 \text{ mm/sec}$

Pulse timing: $V_t = \frac{L}{N} \cdot \frac{f}{m}$

$= \frac{1 \text{ inch}}{127 \text{ lines}} \cdot \frac{500 \text{ Hz}}{51.17 \text{ pts}}$

$= 0.0769 \text{ in/sec}$

$= 1.954 \text{ mm/sec}$

Average velocity from data (gradient)

$= 1.94 \text{ mm/sec}$

Fast:

Pulse counting: $V_c = \frac{L}{N} \cdot \frac{n}{T}$

$= \frac{1 \text{ inch}}{127 \text{ lines}} \cdot \frac{39 \text{ Lines}}{2 \text{ seconds}}$

$= 0.154 \text{ in/sec}$

$= 3.9116 \text{ mm/sec}$

Pulse timing: $V_t = \frac{L}{N} \cdot \frac{f}{m}$

$= \frac{1 \text{ inch}}{127 \text{ lines}} \cdot \frac{500 \text{ Hz}}{25.65 \text{ pts}}$

$= 0.153 \text{ in/sec}$

$= 3.8862 \text{ mm/sec}$

Average velocity from Data (gradient)

$= 3.92 \text{ mm/sec}$

The speeds calculated using pulse counting and pulse timing are similar in order of magnitude. They are also generally in the same range as the velocity from the LVIT data recorded through the experiment.

Note: the LVIT data was fitted with a trendline, the gradient then became the experimental average velocity.

7) Calculate the velocity resolution of the encoder signal for each measurement. For the pulse timing method, determine the exact value of the resolution and the approximate value (assuming the number of clock pulses m for one encoder increment is large). Compare the different velocity resolution values.

Velocity Resolution: (slow)

Pulse counting:

$$\Delta U_c = \frac{L}{NT} = \frac{1 \text{ inch}}{127 \text{ lines}} \cdot \frac{1}{2 \text{ seconds}} = 3.9 \times 10^{-3} \text{ in/s}$$

$$= 0.1 \text{ mm/s}$$

Pulse timing:

$$\Delta U_t = \frac{Lf}{Nm(m+1)} = \frac{1 \text{ in}}{127 \text{ lines}} \cdot \frac{500 \text{ Hz}}{51.17(52.17)} = 1.47(10^{-3}) \frac{\text{in}}{\text{s}}$$

$$= 0.0374 \text{ mm/s}$$

$$\Delta U_t = \frac{N U_t^2}{Lf} = \frac{127(1.954)^2}{1(500)} = 0.969 \text{ in/s}$$

$$= 24.63 \text{ mm/s}$$

Fast: $\Delta U_c = 3.9 \times 10^{-3}$ in/s $= 0.1$ mm/s

$\Delta U_t = 5.759 \times 10^{-3}$ in/s $= 0.146$ mm/s

Approx. $\Delta U_t = 3.836$ in/s $= 97.4$ mm/s

Above are the velocity resolutions for the slow and steady and the faster cranking (fast).

Pulse timing resolution is worse at higher speeds, this is because the timing errors than become more significant and this method is also more susceptible to quantization errors as the timing between pulses become smaller (Also affected by resolution of timer).

Pulse counting remained more consistent across speed ranges and is thus less affected by timer resolution.