Exercise 7

Linear Position Sensing

EXERCISE OBJECTIVE

When you have completed this exercise, you will be familiar with the relationship between the outputs of the Digital Servo two incremental encoders and the linear positioning of the servo load.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Position sensing
- Simplified incremental shaft encoder
- The Digital Servo incremental encoders

DISCUSSION

Position sensing

The incremental encoders, sometimes called quadrature encoders, generate pulses as the encoders internal shaft-mounted disc rotates. The encoder can be coupled to a servo motor or to a pulley that is part of a belt-driven conveyor. Two signals in quadrature (90 degrees out of phase) from the encoder, generate four transition signals that are totalled to determine the position as the motor shaft or the pulley rotates. In addition, velocity can be determined by comparing the generated pulses to a fixed time base.

The movement direction is determined using the phase relationship generated by the 90-degrees (in quadrature) out-of-phase signal pairs. If the first signal pulse leads in relation to the second, then movement is determined to be in a given direction. If the first signals pulse lags behind the second, movement occurs in the opposite direction.

When the direction is determined, a software can calculate the platform position by decoding the quadrature pulses to either add to or subtract (depending on the direction) from the pulse total. To calculate the position in this way, however, a reference point must first be set. This can be done by means of a third reference (also called index pulse) that is generated once per encoder revolution. In the Digital Servo system, a command button from the computer interface resets the incremental encoder to 0. Because of this need for a reference point, robots that make use of incremental encoders for sensing joint position need to be set with an initial reference point for each joint. This process is called homing the robot.

The simplified incremental encoder described in the next section will provide a clearer understanding of incremental encoder operation.

Simplified incremental shaft encoder

The incremental encoder described below is a simplification of actual incremental encoders. This simplification is useful to understand the basic concept underlying the operation of any incremental encoders.

Imagine a disc with 16 holes penetrating the circumference as shown in Figure 38. Located at the outside edge of the disc is an assembly with a pair of photo transmitting devices such as leds, and photo receiving devices such as photo transistors. The device pairs will be labelled A and B.

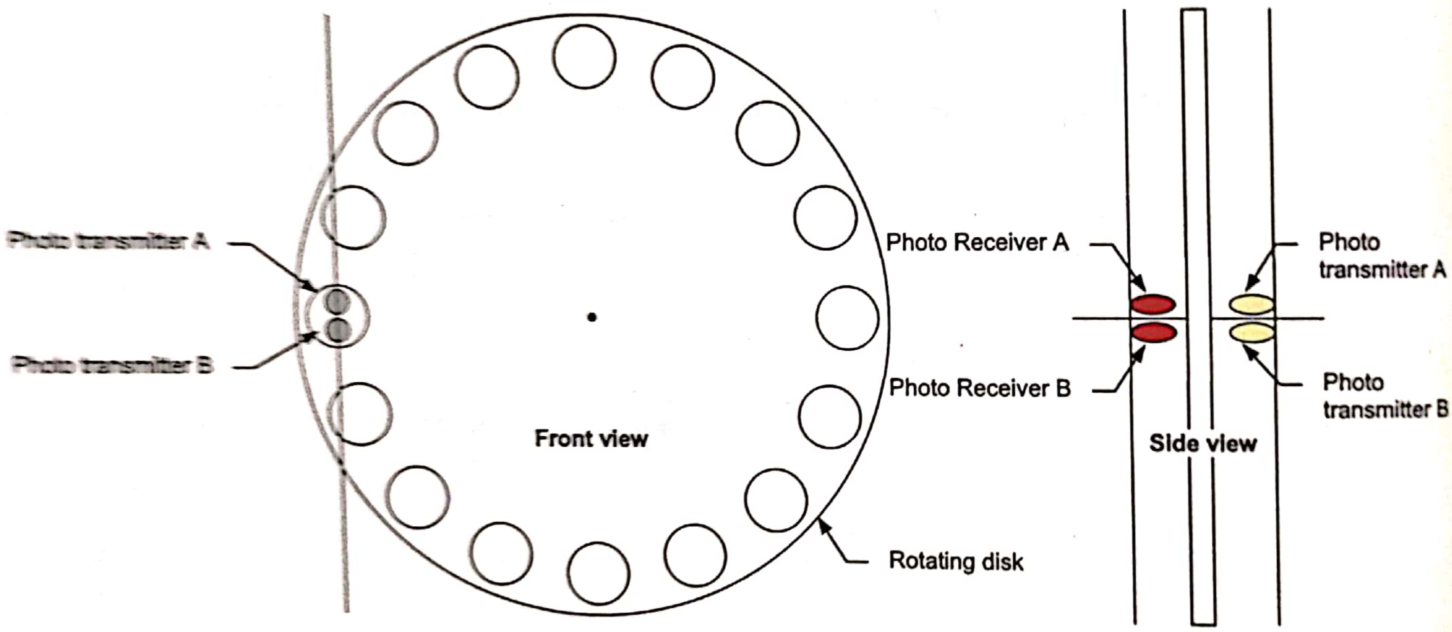

Figure 38. Simplified incremental encoder diagram.

Figure 39 shows what happens as the disc rotates. When the rotation is in a counter-clockwise direction, photo receiver A initially senses the light signal, then both A and B, followed by B only, and finally neither A nor B. In a clockwise direction, the sequence is reversed. Both signals A and B generate four-edge transitions that can be totalled to indicate the disc position. Thus, one revolution of the disc produces 64 pulses (16 × 4).

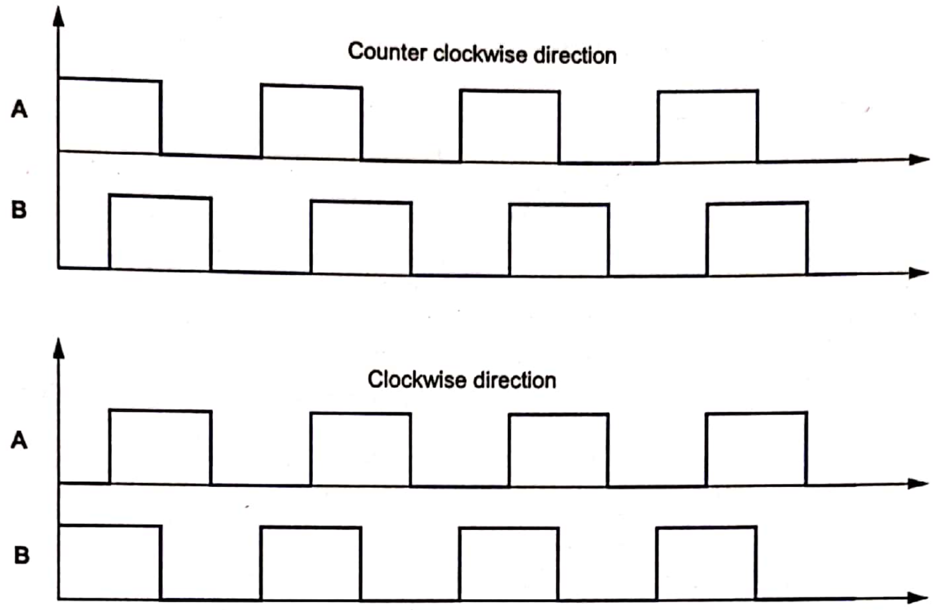

Figure 39. Quadrature signals A and B.

The Digital Servo incremental encoders

Two encoders are used in the Digital Servo system: the mother shaft incremental encoder and the rail incremental encoder. Either encoder can be used to sense the **linear position** of the platform. Each has different characteristics.

A belt pitch is the distance between each tooth. The Digital Servo system has a belt pitch of 0.526 cm.

You have already used the motor shaft encoder in the previous exercise for measuring angular positions of the flywheel coupled to the motor shaft. It contains 1000 “lines”. A “line” or slot, is similar to the hole opening shown in the simplified encoder model in Figure 38. These 1000 lines produce 4000 counts per revolution. Since the pulley used on the platform belt contains 15 notches, the motor shaft encoder counts per groove is equal to 266.67 (4000/15). This means that a belt travel distance equal to one single belt pitch (0.526 cm) corresponds to 266.67 pulses for the motor shaft encoder.

The second encoder, the rail incremental encoder, is coupled to the pulley located just below the platform belt. It contains 360 lines and produces 1440 counts per revolution. Its total counts per groove is thus 96 (1440/15), which means that a belt travel of a single belt pitch (0.526 cm) corresponds to 96 pulses for the rail encoder. Table 27 shows a summary of both incremental encoders' characteristics.

Table 27. Digital Servo incremental encoders characteristics.

Incremental encoders	Number of lines	Counts per revolution	Counts per groove
Motor shaft	1000	4000	266.67
Rail	360	1440	96

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Setup and connections
- Count totals of a complete platform travel for both incremental encoders
- Platform position reference
- Platform movement for both incremental encoders

PROCEDURE

Setup and connections

In this section, you will setup the Digital Servo for linear position sensing.

In this experiment, the platform will be engaged. To prevent equipment damage, it is extremely important to ensure that the position device controller application is used at all times.

Belt lifted off metal pins and placed on pulley, thereby engaging platform for linear position exercises.

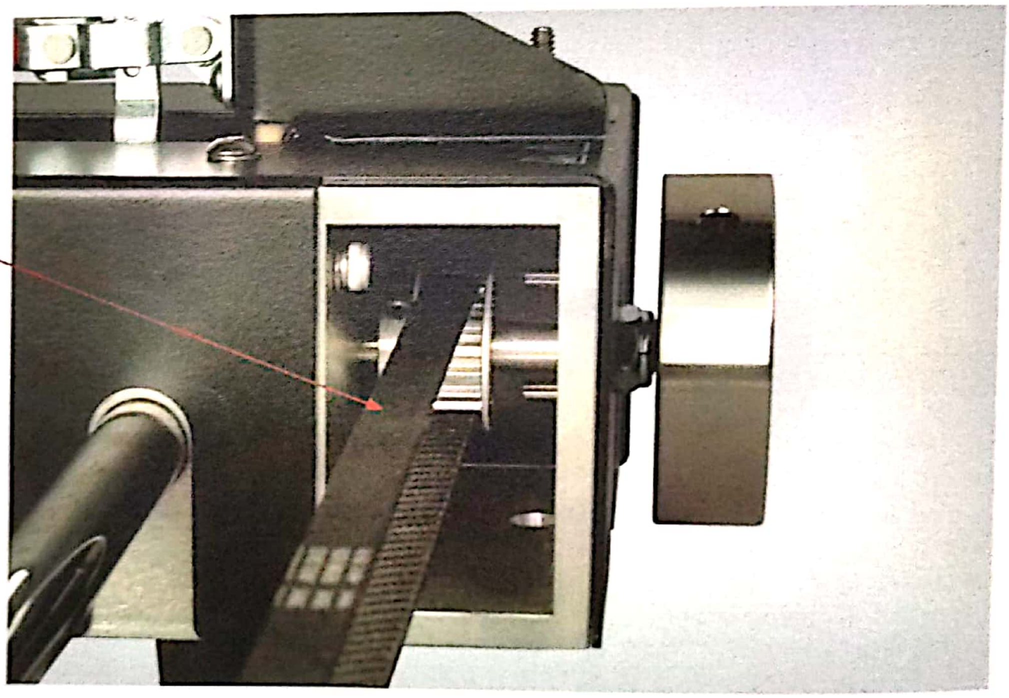

Figure 40. Belt placed on pulley to engage the platform.

1. Run LVServo, and click on the **Device Controlled** button in the **Position Loop** menu.

Count totals of a complete platform travel for both incremental encoders

In this section, you will make the count totals of a complete platform travel for both the motor shaft incremental encoder and the rail incremental encoder. You will then translate these counts into a percentage reading and an engineering unit reading of position. Finally, you will compare the ±100% travel for each incremental encoder.

2. Do not turn on the function generator **Power** switch for this part of the experiment. Leave the **Open Loop/Closed Loop** switch in the OPEN LOOP position.

3. Ensure that the **Incremental Encoder Selection** switch is set to MOTOR SHAFT ENCODER.

4. Move the platform to the extreme right hand side until it is touching the end stop.

5. Reset the count to 0 using the **Position Reset** switch.

6. Move the platform from right end stop to the left end stop and record the counts.

   Counts = 34335

7. Referring back to the discussion section, calculate the length (cm) that this travel represents.

   Travel = ______ cm

8. Set the selection switch for the incremental encoders to **Rail Encoder** and repeat steps 4 through 7. Record the counts and calculate the travel length.

   Counts = ______ 12352

   Travel = ______ cm

9. Complete Table 28. Recall that ±100% counts for the Digital Servo system is ±5000 counts.

Table 28. Measured count totals and distances.

Incremental encoders	Distance for ±100% (cm)	Counts per total travel	Distance for a total travel (cm)
Motor Shaft Counts per revolution = 4000 Counts per belt pitch = 266.7			
Rail Counts per revolution = 1440 Counts per belt pitch = 96.0			

70cm

10. Below are two diagrams representing the platform/belt arrangement. Using the data from Table 28, complete Figure 41 and Figure 42 by filling in the blanks.

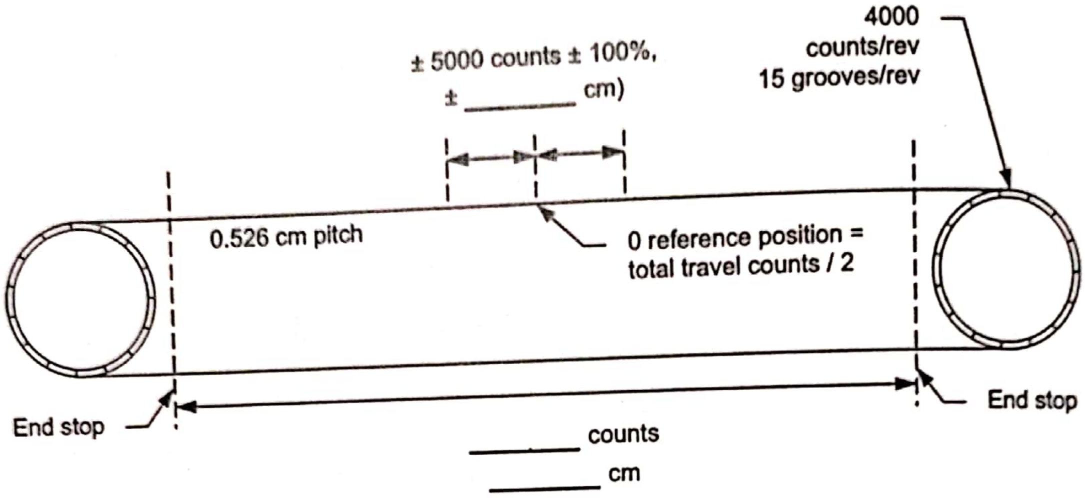

Figure 41. Motor shaft encoder diagram.

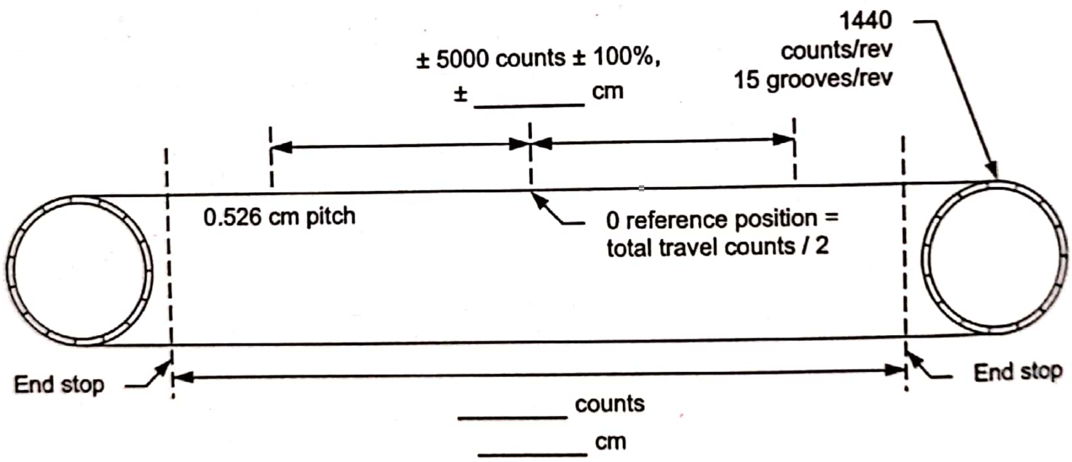

Figure 42. Rail encoder diagram.

Platform position reference

In this section, you will calculate the position reference of the platform of the Digital Servo.

11. Find the center (0) position reference of the platform by moving the platform to the right hand stop position, resetting the position count to 0 and then moving the platform manually until the count read is exactly half the total count. When this point is found, reset the position count to 0. The platform has now been positioned to exactly half way. This also corresponds to the 0% position reference.

12. For both the motor shaft incremental encoder and the rail incremental encoder, calculate the position reference in percentage, considering that the platform is to be placed exactly 5.1 cm to the right of the 0 position reference.

- Motor Shaft Incremental Encoder

  Position reference = ______ %

- Rail Incremental Encoder

  Position reference = ______ %

Platform movement for both incremental encoders

In this section, you will measure the platform movement for both incremental encoders and compare their gain values.

13. Run LVServo, and click on the **Device Controlled** button in the **Position Loop** menu. Make sure the settings are initially as shown in Table 29 below:

Table 29. Settings for measuring the platform movement.

Function Generator		**Trend Recorder**	
Signal Type	*Constant*	Reference	*Checked*
Frequency	*1 Hz*	Position	*Unchecked*
Amplitude	*0%*	Speed	*Checked*
Offset	___ %	Current	*Unchecked*
Power	*Off*	Voltage	*Unchecked*
PID Controller		Error	*Unchecked*
Gain (K_p)	2	K_p x Error	*Unchecked*
Integral Time (t_i)	*0.1*	Error Sum / t_i	*Unchecked*
Derivative Time on E (t_d (E))	*0*	t_d x Delta Error	*Unchecked*
Derivative Time on PV (t_d (PV))	*0*	PID Output	*Unchecked*
Timebase	*10 ms*	Display Type	*Sweep*
Anti-Reset Windup	*On*	Show and Record Data	*On*
Upper Limit	*100%*	Measured Gain (rpm)	*3000*
Lower Limit	*-100%*	Measured Gain (A)	*7*
Open or Closed Loop	*Closed*	Measured Gain (V)	*48*
PV Speed Scaling		**Encoders**	
100% Value	*5000 cnt*	Motor or Rail	*Motor*
-100% Value	*-5000 cnt*		

14. Set the function generator **Power** switch to ON.

15. Using a ruler, measure the platform movement in cm.

    Platform movement = ______ cm

16. Set the function generator **Offset** to OFF.

17. Set the **Open Loop/Closed Loop** switch to OPEN LOOP.

18. Set the **Incremental Encoder Selection** switch to RAIL ENCODER.

19. Set the function generator **Offset** to the value calculated in Step 12) for the rail encoder.

20. Set the **Open Loop/Closed Loop** switch to CLOSED LOOP.

21. Set the function generator **Power** switch to ON.

22. Using a ruler, measure the platform movement in cm.

    Platform Movement = _______ cm

23. Set the function generator **Power** switch to OFF.

    In Exercise 6, the motor shaft incremental encoder gain value was calculated to be 40. What is the gain for the rail incremental encoder? Compare both encoder gains and their effects.

    ____

    ____

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CONCLUSION

In this exercise, you familiarized yourself with the two incremental encoders that constitute the Digital Servo system. You learned how to calculate the position reference needed for platform movement measurements. You observed how the different resolution of the two encoders affects their encoder gain and the linear movement of the platform by performing platform travel measurements.

REVIEW QUESTIONS

1. Considering the Digital Servo system using the motor shaft incremental encoder, what position reference in percentage would be required to position the platform 6 cm from the 0% reference point?

2. Considering the Digital Servo system using the rail incremental encoder, what position reference in percentage would be required to position the platform 6 cm from the 0% reference point?

3. The position reference for the Digital Servo system using the rail incremental encoder is 70%, What is the platform movement in cm?

4. Suppose the Digital Servo system original motor shaft incremental encoder was replaced with an encoder that had a resolution of 10000 counts per revolution. Calculate the resulting encoder gain.

5. The default range of the position measurement for the Digital Servo system is ± 5000 counts. This range can be changed with the HMI. Suppose that the position needs to be correlated to percent in the following way:

   100% is equivalent to a displacement of 25.4 cm or 0.3 cm/%. A position reference of 50% would thus result in a 12.7-cm displacement.

   Knowing this, calculate the rail incremental encoder modified range.