

LEVEL 4 ASSESSMENT SPECIFICATION

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Module:	Engineering Applications & Study Skills		
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Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one-week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Engineering Applications & Study Skills

Designing and simulating pneumatic circuits for process control.

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Introduction

In this task, I will be designing and simulating a pneumatic circuit. I will use what I have learned about pneumatic systems to come up with a working solution and test it using FluidSim software. The aim is to make sure the cylinder works correctly and at the right time. I will also include circuit diagrams, state diagrams, and calculations to support my design.

Task 1

Design Solution Required

In a production environment, a double-acting cylinder with a stroke length of 250 mm is required to lift a 100 kg load up an inclined surface at an angle of 30 degrees. Tests conducted at the production site have determined that the coefficient of static friction is 0.19 and the coefficient of sliding friction is 0.13. The compressed air supply in the facility operates at a maximum pressure of 0.7 MPa.

The system is controlled by an operator using a normally closed 3/2 push-button valve. When pressed, the button activates the cylinder to raise the load. The operator holds the button until the load is released or dispatched, after which the button is released, allowing the cylinder to retract automatically.

Step 1 static friction

$$\begin{aligned} F_B &= \mu_B \times m_m \times g \times \cos(30) \\ &= 0.19 \times 100 \times 9.81 \times \cos(30) = 161N \end{aligned}$$

Step 2 sliding friction

$$F_C = \mu_C \times m_m \times g \times \cos(30) = 0.13 \times 100 \times 9.81 \times \cos(30) N = 110N$$

Step 3 Compute the Weight of the Load

$$F_g = m \times g = 100 \times 9.81 = 981N$$

Step 4 Compute the Force Required to Overcome Gravity

$$\begin{aligned} F_g &= F \times \sin(30) \\ &= 981 \times 0.5 = 490.5N \end{aligned}$$

Step 5 Compute the Frictional Force

$$\begin{aligned} F_N &= F \times \cos(30) \\ &= 981 \times 0.866 = 849.3 N \end{aligned}$$

Step 6 Compute Total Required Force

$$\begin{aligned} F_F &= F_g + F_B \\ &= 490.5 + 161 = 651.5 N \end{aligned}$$

Cylinder Selection

The force exerted by a pneumatic cylinder is given by:

$$F = P \times A$$

Where:

A = cylinder piston area (m^2)

P = Operating pressure ($0.7MP_a = 700,000pa$)

$$A = \frac{F}{p}$$

$$A = \frac{651.5}{700000} = 0.000931m^2$$

Solving for d

$$A = \frac{\pi d^2}{4}$$

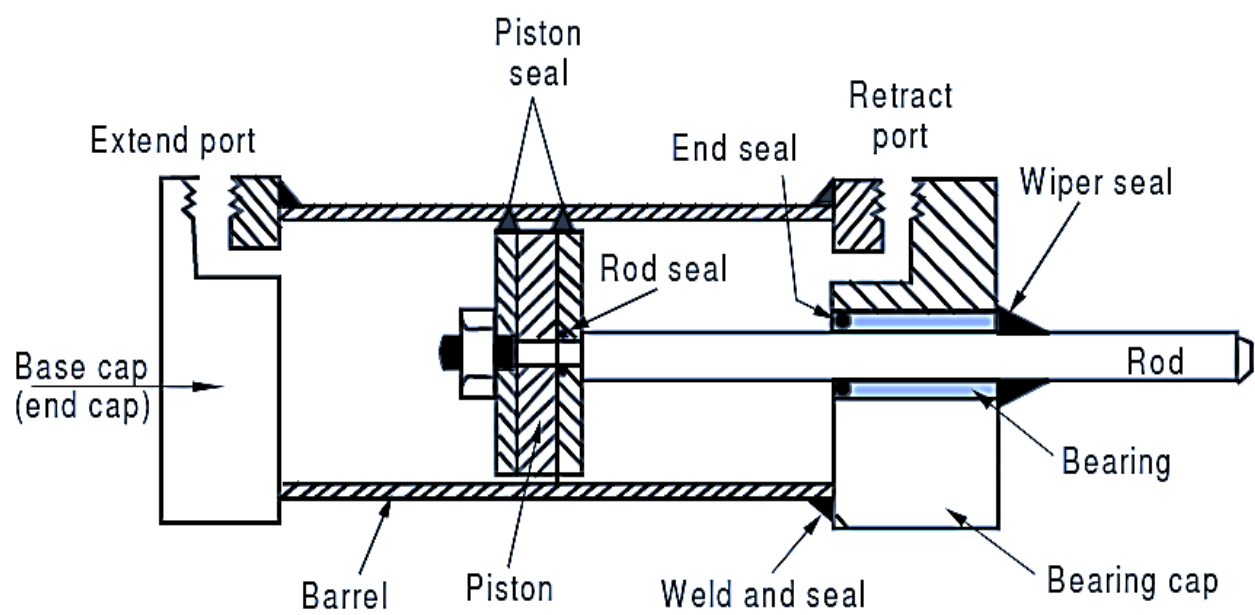
$$d = \sqrt{\frac{4 \times 0.000931}{\pi}}$$

$$d = \sqrt{0.001186} = 0.0345 \text{ m} = 34.5mm$$

Double-Acting Cylinder

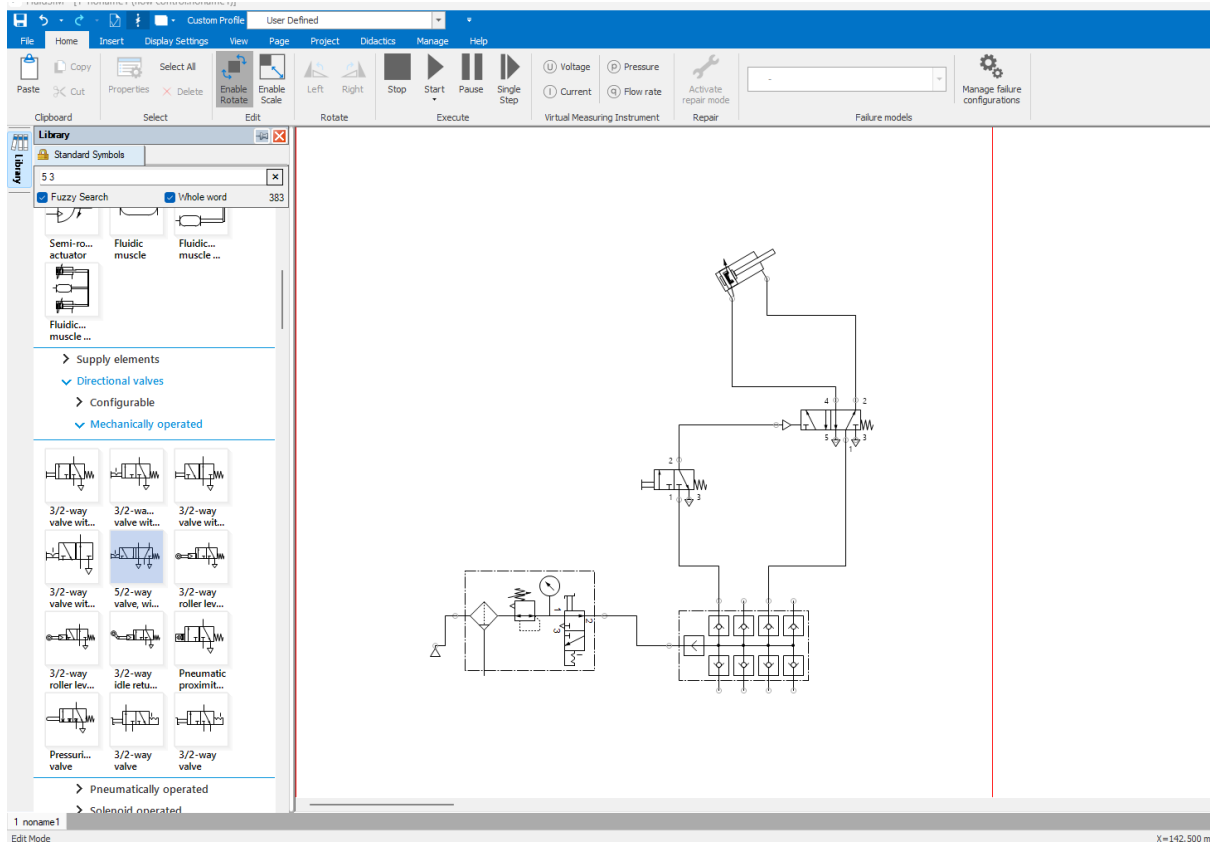
A double-acting cylinder includes two ports. One for the hydraulic fluid to enter and extend the plunger, and the other for retracting the cylinder (ENERPAC , 2021).

It has two ports, one on each side of the piston; when pressure is applied to one port, it pushes the piston in one direction, and when applied to the opposite port, it moves the piston back. This setup allows for controlled force and motion in both directions, providing more power and precise control. Double-acting cylinders are commonly used in applications that require push-and-pull or extend-and-retract motion, such as automation systems, robotics, machinery, and material handling. (Wikipedia, 2024)



(Aisoar, 2024)

Double-acting cylinder system



Component Selection Explanation

I have chosen each component in the circuit based on the task requirements and to make sure the system works properly.

1. Double Acting Cylinder:

I used a double acting cylinder because it can extend and retract using air pressure. This is important for lifting the load and then returning the cylinder back to its starting position. The stroke length is 250 mm, which matches what the task asked for.

2. 3/2 Push Button Valve (Normally Closed):

This valve is used for manual control. It is normally closed, which means air only passes through when the button is pressed. This is useful because the operator can control when the load is lifted and stop it at any time by releasing the button.

3. 5/2 Directional Control Valve (Pneumatically Operated, Spring Return):

This valve sends air to both sides of the double acting cylinder depending on the signal it gets. When the push button is pressed, this valve shifts to extend the cylinder. When the button is released, the spring return brings it back to its original position, allowing the cylinder to retract.

4. Flow Control Valve with Check Valve:

I added a flow control valve to control how fast the cylinder extends. The check valve lets air flow freely in the other direction when retracting. This helps to make the movement smoother and more controlled.

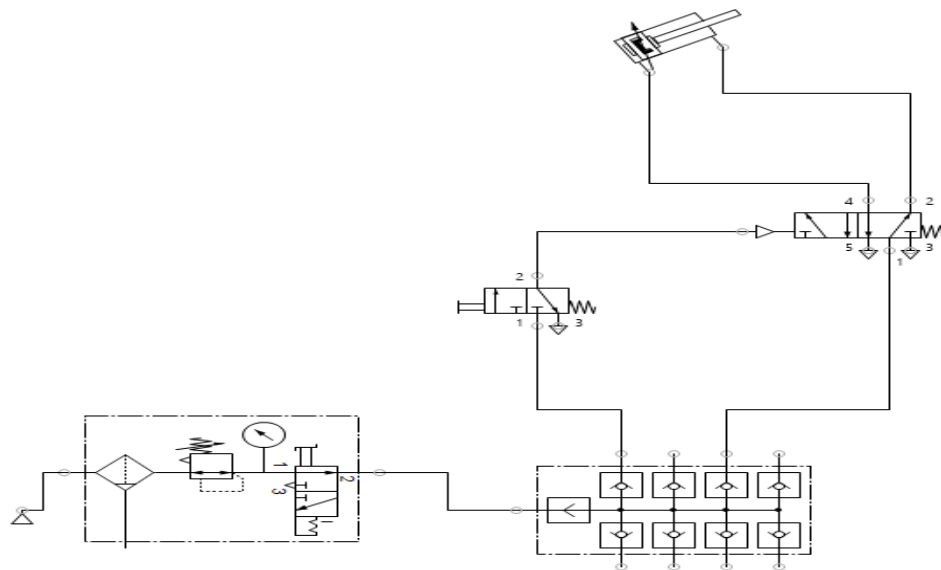
5. FRL Unit (Filter, Regulator, Lubricator):

This unit makes sure the air going into the system is clean, at the correct pressure, and

lubricated. This helps the system run properly and protects the components from damage. I set the pressure to 0.7 MPa as given in the task.

6. **Air Supply (Compressor):**

The air supply is the source of compressed air that powers the whole system. I used the standard symbol for a compressor in the diagram to show where the air is coming from.



Task 2

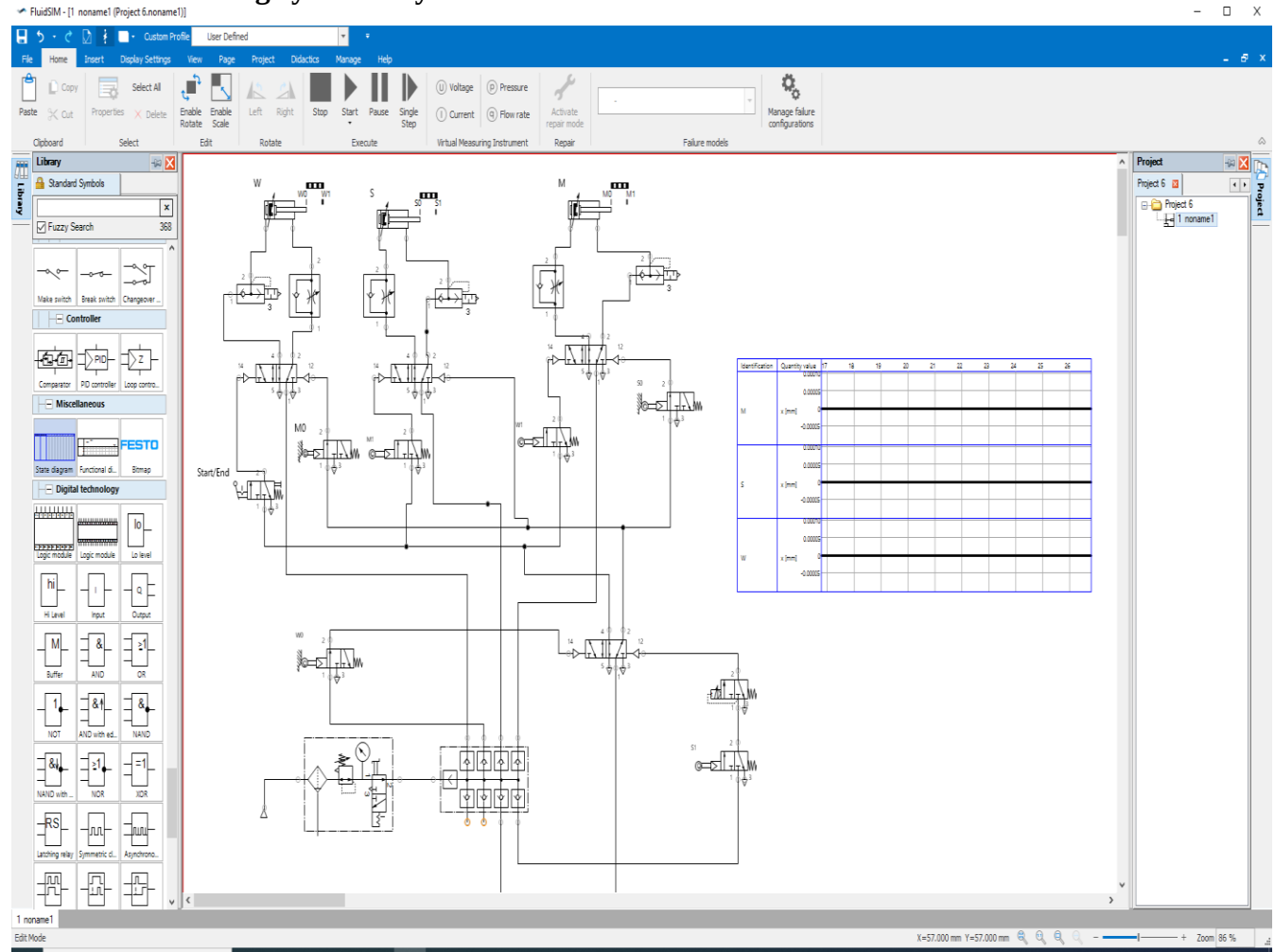
In this task, I have to design an automatic pneumatic circuit that controls three double-acting cylinders named W, S, and M. The cylinders need to follow a specific sequence: W+, M+, S+, S-, M-, W-. Each cylinder has its own timing and speed requirements that must be met for the system to work correctly.

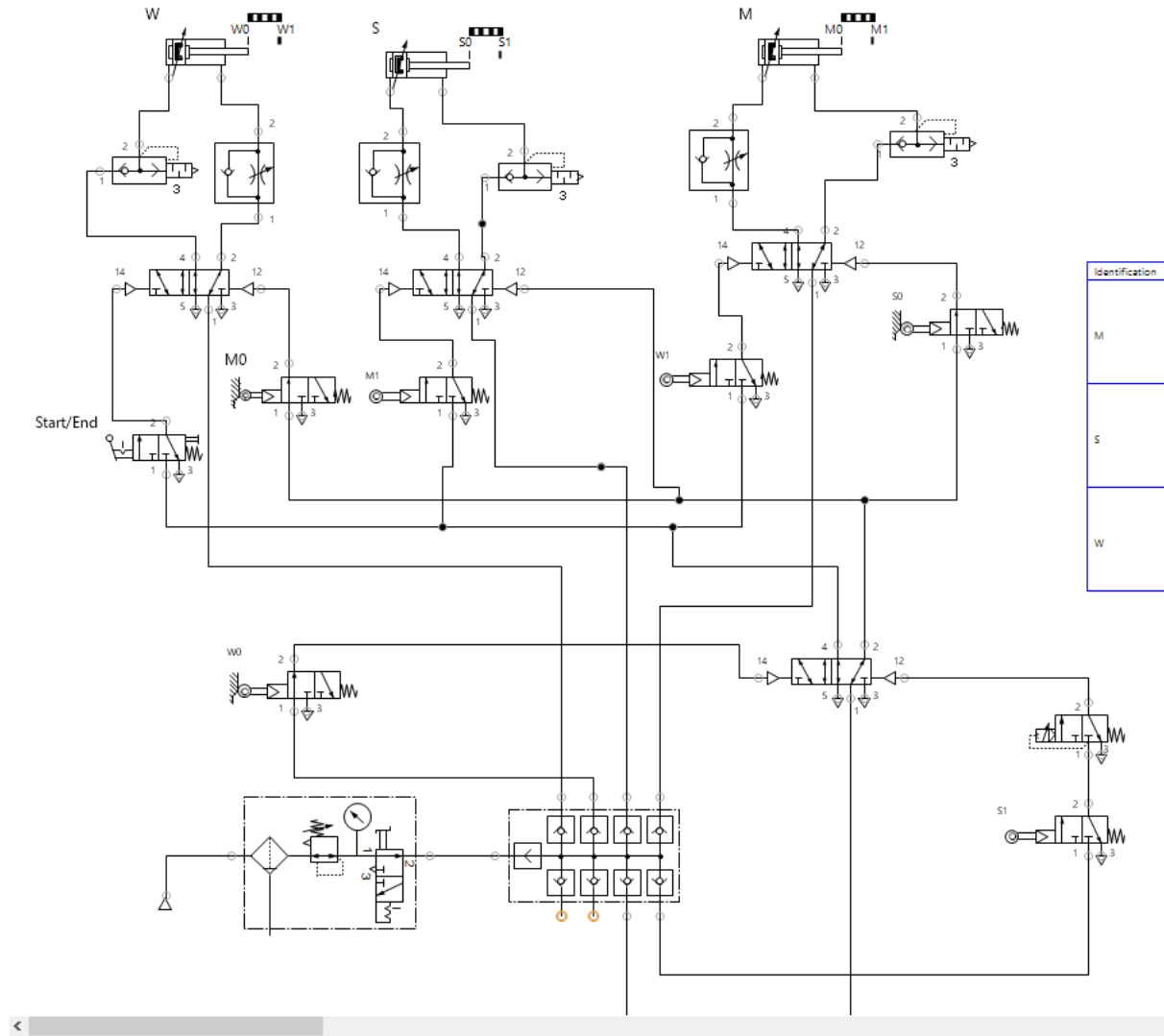
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The system will be started using a latch switch and should keep running until the switch is turned off. Even when the switch is turned off, the system needs to finish the full cycle before it stops. I will design and test the circuit using FluidSim and include a state diagram and explanation of the components I've used to make sure the sequence and timing are correct.

- **W** represents Cylinder A
- **M** represents Cylinder C
- **S** represents Cylinder B

Three double acting cylinders system





State Transitions

The system starts in an idle state, waiting until the Start/End latch switch is turned ON. Once the switch is pressed, the automatic sequence begins. First, Cylinder W extends. When it reaches the end of its stroke, sensor W1 is triggered, which moves the system to the next step. Then, Cylinder M extends, and when sensor M1 detects it has reached its full extension, the process continues. After that, Cylinder S extends. Once sensor S1 is activated, the system waits for a 2-second delay before moving on. Following the delay, Cylinder S retracts. When the sensor confirms that it has returned to its starting position, the circuit goes to the next step. Cylinder M then retracts, and the system waits until it is fully back in place. Lastly, Cylinder W retracts. When sensor W0 confirms the retraction, the full cycle is complete. If the latch switch is still ON, the system repeats the sequence from the beginning. If it has been turned OFF, the system will finish the current cycle and then stop.

Circuit Operation Explanation

The pneumatic circuit is designed to run automatically once the Start/End latch switch is turned ON. The switch activates the logic and allows the first cylinder (W) to extend. Each cylinder movement is controlled by 5/2 directional control valves and is monitored by sensors at the end positions. These sensors send signals to the next part of the circuit to continue the sequence. The system follows the order W+, M+, S+, S-, M-, W-. A time delay valve is used after S+ to create a 2-second pause before it retracts, which is one of the requirements. Flow control valves are added to control the speed of extension and retraction where needed. Once the full cycle is completed, the circuit checks the latch switch. If it is still ON, the cycle restarts. If it has been turned OFF during operation, the circuit finishes the current sequence and then stops safely. The operation is fully automated and runs in the correct order with accurate timing using the combination of sensors, logic, and delay components.

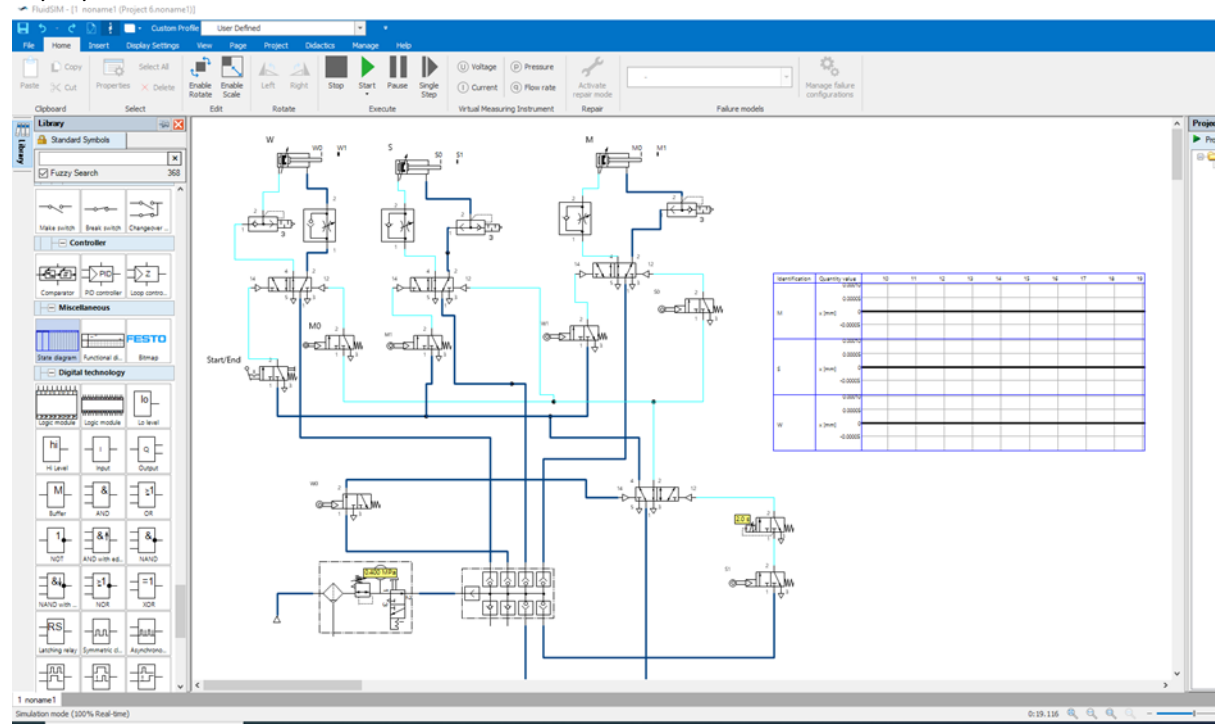
Timing Chart Explanation

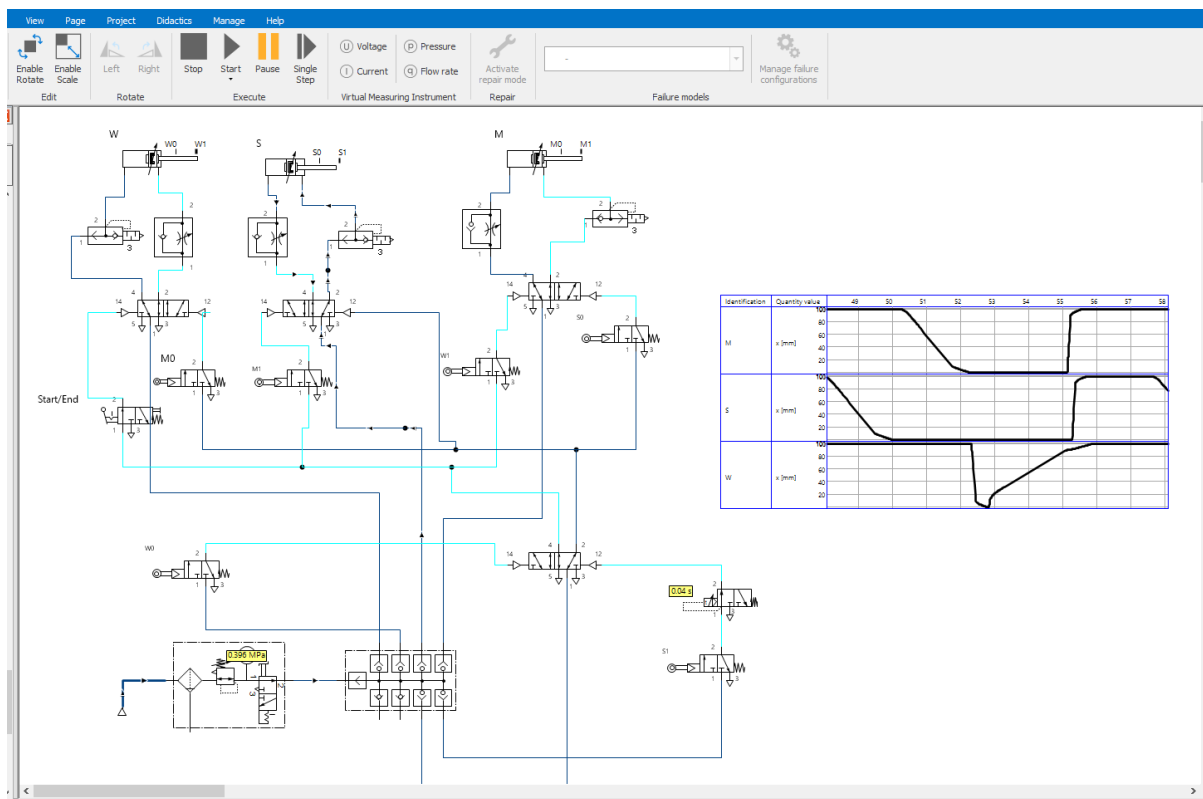
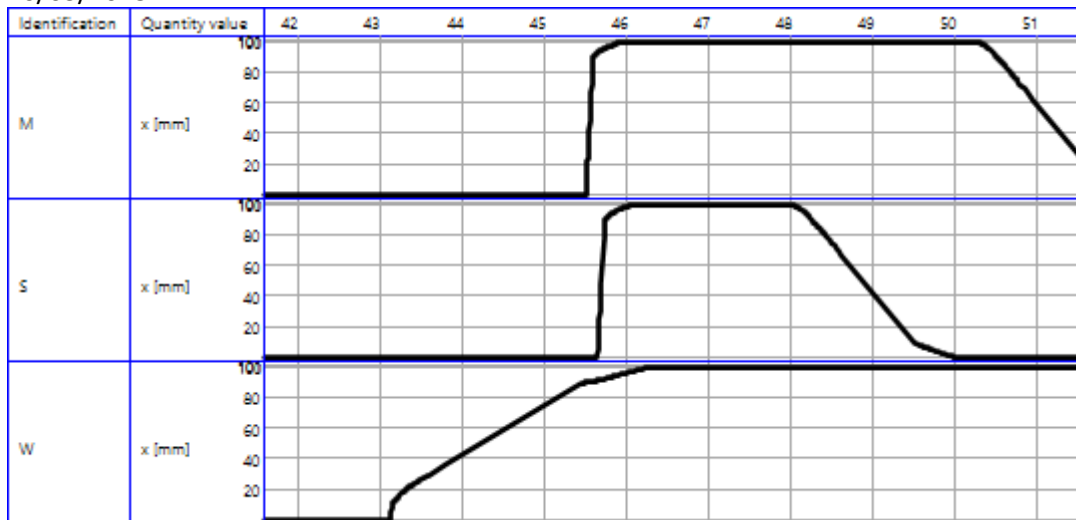
The timing chart shows the movement and timing of each cylinder throughout the automatic sequence. It visually represents when each cylinder extends and retracts, and how long each action takes. The chart follows the required sequence: A+, C+, B+, B-, C-, A-. From the chart, we can see that Cylinder A (W) extends first and stays extended while Cylinder C (M) and Cylinder B (S) complete their actions. The chart includes a delay of around 2 seconds after B+ before B- begins, as specified in the task. Cylinder C then retracts after B- is complete, and Cylinder A retracts last. The timing chart also shows that Cylinder A moves slower than the others, which was done using flow control valves to match the requirement of 3 to 3.5 seconds. The full cycle is shown clearly from start to end, and the timing of each action lines up correctly with the intended operation of the system.

Explanation of Circuit Function and Design Decisions

The circuit was designed to operate fully automatically based on the given sequence: W+, M+, S+, S-, M-, W-. To achieve this, I used 5/2 directional control valves for each double-acting cylinder to control their movement in both directions. Sensors (W1, M1, S1) were used to detect when each cylinder reached the end of its stroke, triggering the next step in the sequence. A Start/End latch switch was included so that the operator can start or stop the process safely. I added a time delay valve after S+ to introduce a 2-second delay before S-, as required. Flow control valves were also added to control the speed of extension and retraction especially for Cylinder W, which needed to move slower (3 to 3.5 seconds), and Cylinder S, which needed to retract within 1.5 to 2 seconds. These choices ensured that each cylinder moved at the correct time and speed. The design ensures that the system continues running as long as the latch is ON, and if it's turned OFF, the circuit still finishes the full cycle before stopping. These decisions made the system safe, efficient, and fully in line with the task requirements.

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Conclusion

In Task 1, I designed and simulated a pneumatic circuit to lift a 100 kg load up a 30° inclined plane using a double-acting cylinder with a 250 mm stroke. I calculated the required force based on the weight, friction, and angle of the slope, then selected a suitable cylinder that could provide enough force at 0.7 MPa. The circuit was created in FluidSim and tested using a 3/2 push button to extend the cylinder and automatically retract it when the button was released. The circuit performed as expected, and all component selections were based on calculations and practical requirements. This task helped me understand how to apply pneumatic principles to real-world load handling.

In Task 2, I developed an automatic pneumatic system to control three double-acting cylinders (W, S, and M) in a specific sequence: W+, M+, S+, S-, M-, W-. The system used a latch switch to start and stop the cycle and included sensors, time delay valves, and flow controls to meet timing and speed requirements. The full sequence was simulated in FluidSim, and the system was designed to complete the cycle even if the latch was turned off mid-operation. A timing chart and state diagram confirmed that the sequence and timing were accurate. This task allowed me to apply automation and logic control concepts to a multi-cylinder pneumatic system.

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References

(ENERPAC , 2021)

(Wikipedia, 2024)

(Aisoar, 2024)