

Designing and Simulating Pneumatic Circuits for Process Control.

Designing and Simulating a Pneumatic Circuit

LEVEL 4 ASSESSMENT SPECIFICATION

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Module:	Engineering Applications & Study Skills		
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Lecturer:	C. Williams	Internal Verifier:	R. Kadhim
Assignment Title:	Designing and simulating pneumatic circuits for process control.	Word count (or equivalent):	1000
Submission deadline:	8/05/2025	Return date of provisional marks & written feedback:	22/05/2025
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.
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Objectives
1) To calculate the loading on an actuator in a given industrial scenario and determine circuit pressure requirements to operate safely and within given parameters. 2) To design a three cylinder non repeat pattern sequence that complies with given process requirements.

Module Learning Outcomes (from module syllabus)
1. Demonstrate knowledge and understanding of specific engineering concepts and how their theoretical characteristics are used in discipline specific engineering applications. 2. Apply practical engineering skills and demonstrate know-how of practices, skills, safety and standards with respect to laboratory and workshops.

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Task 1

In a production setting, a double acting cylinder with stroke length of 250mm must raise a load of 100kg up an inclined surface of 30 degrees. Tests at the production centre have measured that the coefficient of static friction is 0.19 and the coefficient of sliding friction is 0.13. The operating pressure of the production compressed air supply is a maximum of 0.7 Mpa. An operator uses a normally closed 3/2 push button switch to raise the load which they hold until the load is dispatched. The button is then released allowing the cylinder to retract.

calculate the force required to move the load

We need to determine the force required to move the load up the incline by considering:

- Gravitational force
- Normal force
- Frictional forces

1. Static Friction

$$F_s = \mu_s \times g \times \sin(30) \approx 0.19 \times 100 \times 9.81 \times \cos(30) \approx 161N$$

2. Sliding Friction

$$F_s = \mu_s \times g \times \sin(30) \approx 0.13 \times 100 \times 9.81 \times \cos(30) \approx 110.4N$$

3. Gravitational Force

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

4. Force Parallel to Incline

$$F_{\parallel} = F_g \times \sin(30) \approx 981 \times \sin(30) \approx 490.5N$$

5. Normal Force

$$F_n = F_g \times \cos(30) \approx 981 \times \cos(30) \approx 849.5N$$

$$\therefore F_{\text{total}} = F_{\parallel} + F_s \approx 490.5 + 161 \approx 651.5N$$

select a suitable cylinder that will meet the requirements

The force generated by the **pneumatic cylinder** is given by:

$$F = P \times A$$

Where:

A= Cylinder piston area (m²)

P= Operating pressure (0.7 MPa = 700,000 Pa)

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

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

Solving for **d**

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

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

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

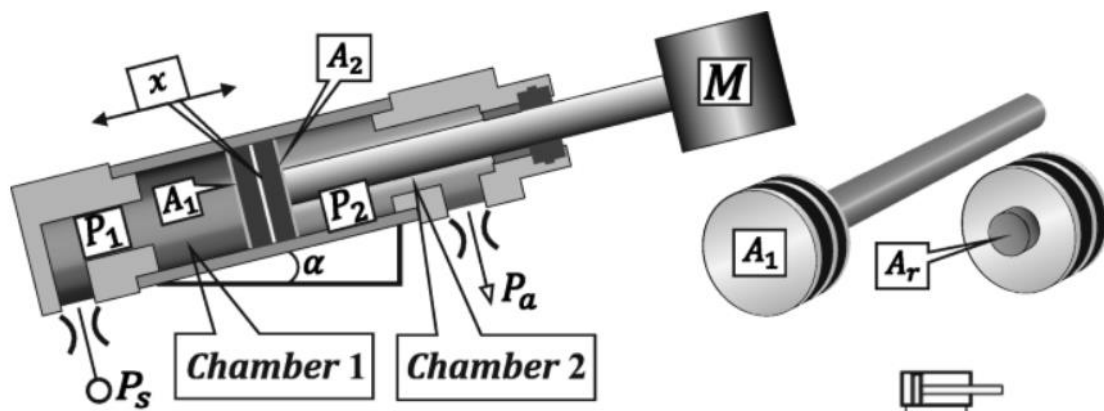
Based on the force required to move the load (651.9 N) and the available maximum operating pressure of 0.7 MPa, the calculated minimum bore diameter for the pneumatic cylinder is approximately 34.5 mm. To meet this requirement with a standard component, a cylinder with a 35 mm bore diameter is selected. The application requires controlled extension and retraction of the cylinder, making a double-acting type appropriate. Additionally, the specified stroke length for the operation is 250 mm. Therefore, the final selected cylinder is a double-acting pneumatic cylinder with a 35 mm bore diameter and a 250 mm stroke, operating at a maximum pressure of 0.7 MPa. This configuration ensures the system can generate sufficient force to move the load safely and effectively.

Double- acting pneumatic cylinder

Pneumatic cylinders are elementary parts both in robotics and industrial automation; they are used in many industrial devices because of the advantages they offer, like low cost, easy maintenance, the great force they develop and easy assembling. As compressed air exists in almost any industrial installation, pneumatic cylinders and valves became competitive in many applications like motion control of materials, gripper devices, robotics, industrial processes, and food processing among others.

That is why the study of the simulation and control models of these actuators has become a subject of interest. (Jiménez, 2018)

Fig. 1



Scheme of a double-acting pneumatic cylinder

design the circuit and using Fluidsim check that it operates successfully

The circuit include:

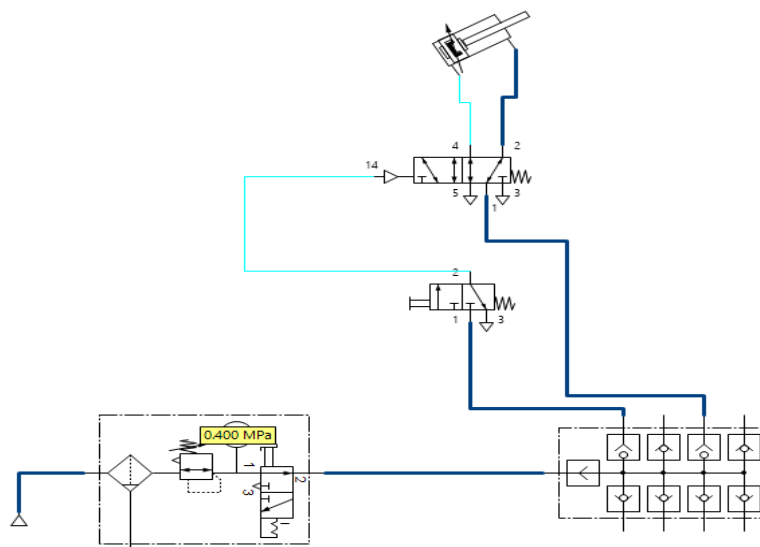
Double-acting cylinder (Bore: 35mm, Stroke: 250mm)

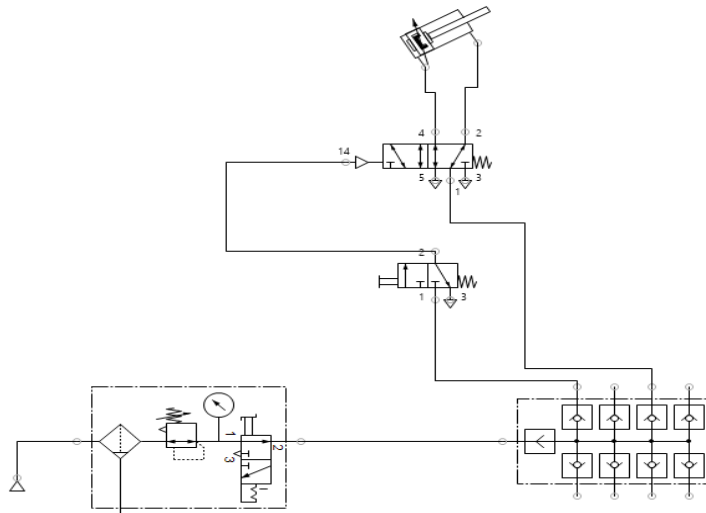
3/2 Normally Closed Push Button Valve (Operator control for extending the cylinder)

5/2 Directional Control Valve (Controls cylinder movement)

Air Supply at 0. MPa

Exhaust Ports to vent air when retracting





Component Selection & Justification

Component	Justification
Double-Acting Cylinder (35 mm Bore, 250 mm Stroke)	Provides the required force and motion for lifting the load
3/2 Normally Closed Push Button Valve	Ensures the operator controls when the load is raised
5/2 Directional Control Valve	Directs compressed air to extend/retract the cylinder
Air Compressor (0.7 MPa Supply)	Provides the necessary operating pressure
Exhaust Ports	Allow air to escape during retraction

Task2/

Design the circuit and using Fluidsim and state diagrams check that it operates successfully

Sequence is correct, and well evidenced.

The required sequence is:

A+ → C+ → B+ → (2s delay) → B- → C- → A-

In my labelling:

A+ → R+ → E+ → (2s delay) → E- → R- → A-

Time delay is correct and well evidenced

From my time graph:

- E+ (B+) completes around 49s
- E- (B-) starts around 51s
- This matches the 2-second delay requirement

Cylinders extend and retract meeting customer requirements

Cylinder	Requirement	Observation from Graph
A	Extend: 3–3.5s, Retract: Rapid	Gradual rise ~3s, quick return
E	Extend: Rapid, Retract: 1.5–2s	Fast up, ~1.5s–2s retraction
R	Extend: Rapid, Retract: 1.5–2s	Fast up, controlled retraction observed

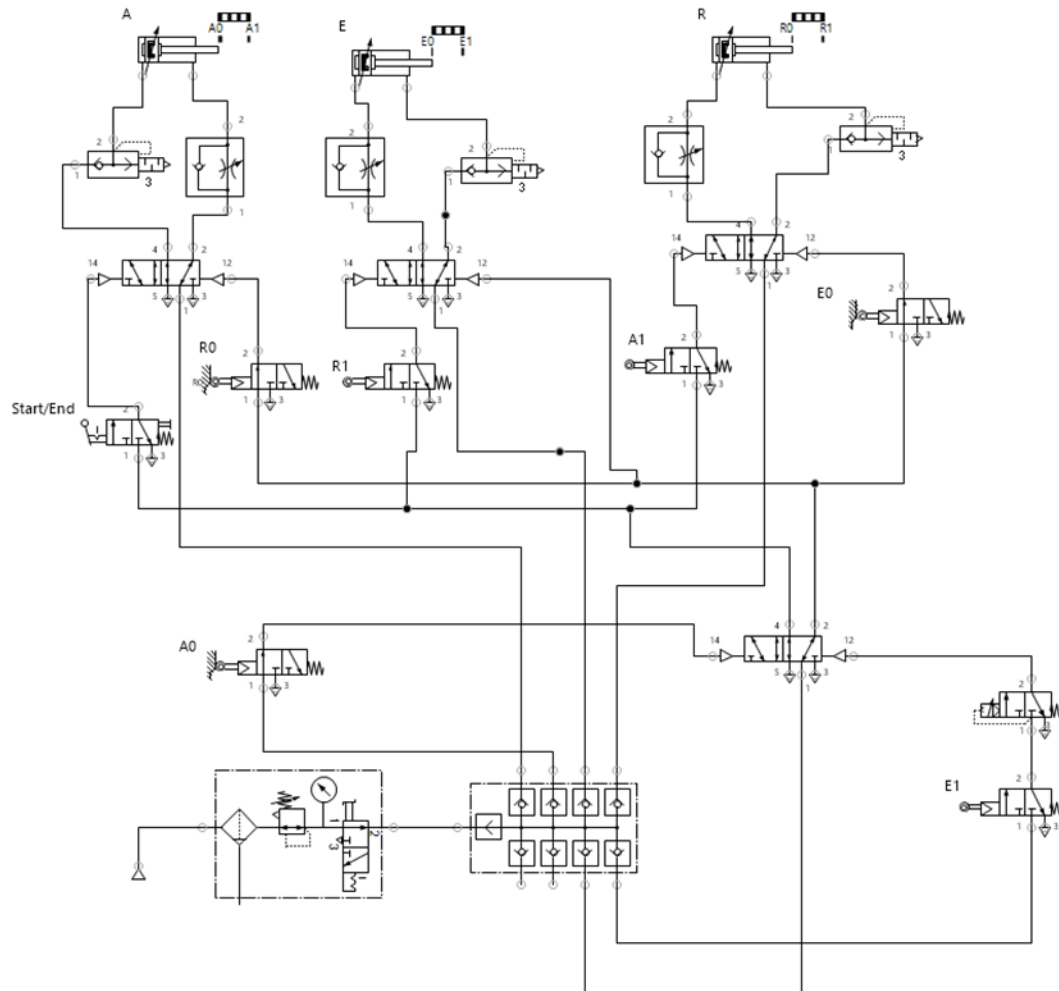
Explanation of Circuit Design & Decisions

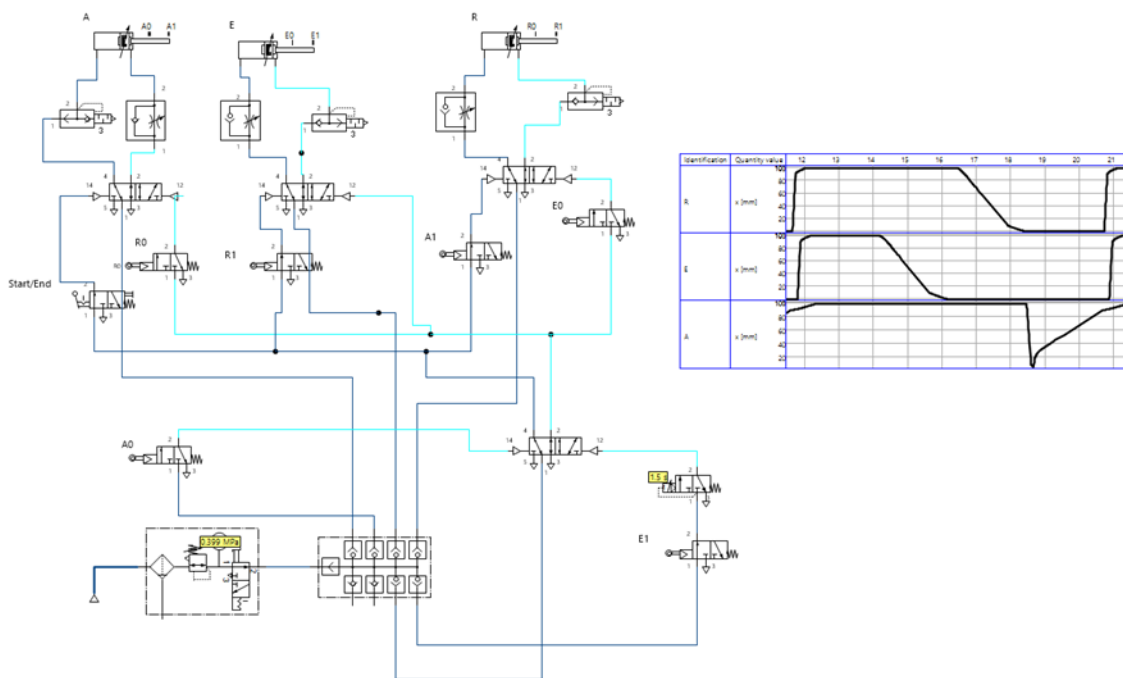
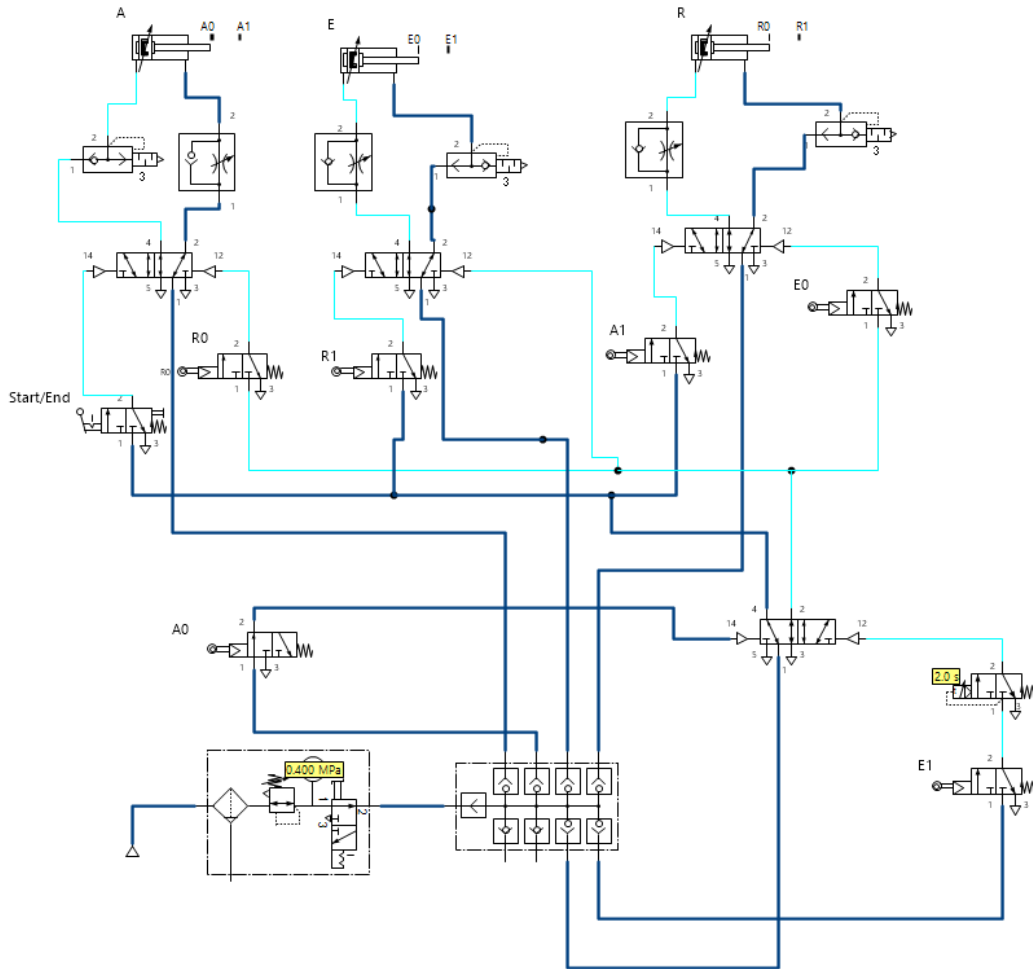
The pneumatic system was instructed to execute a six-step sequence using three double-acting cylinders A, R, and E. The sequence is $A^+ \rightarrow R^+ \rightarrow E^+ \rightarrow (2s \text{ delay}) \rightarrow E^- \rightarrow R^- \rightarrow A^-$. Latching start/stop button controls continuous cycle operation. Once the latch is turned off, the system completes the ongoing sequence and will shut down.

The cylinders are driven using 5/2 solenoid valves with extension and retract controlled by one-way flow control valves to shift speeds. A slowly retracts through a flow restrictor (3–3.5s extension) while retracting fast. Cylinders R and E extend and retract fast at 1.5–2 seconds using adjustable restrictors. A timer relay provides the needed 2-second delay between E^+ and E^- .

The state sequence is implemented through relay logic and limit switches in a way that activities progress on only after completion of the prior operation. FluidSim was

used to simulate the system, and the timing diagram ensures that every need of operation—sequence order, timing constraint, and automated cycle control—is successfully fulfilled.







References

Jiménez, M. K. (2018). *Experimental Study of Double-Acting Pneumatic Cylinder*. springer.