

LEVEL 4 ASSESSMENT SPECIFICATION			
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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.	

Pneumatic Design

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Task 1:

A double acting cylinder with stroke length of 250mm must raise a load of 100kg up an inclined surface of 30 degrees. 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 0.7Mpa. An operator uses a normally closed 3/2 push button switch to raise the load which is held until the load is dispatched. The button is then released allowing the cylinder to retract.

Fluid Sim Design

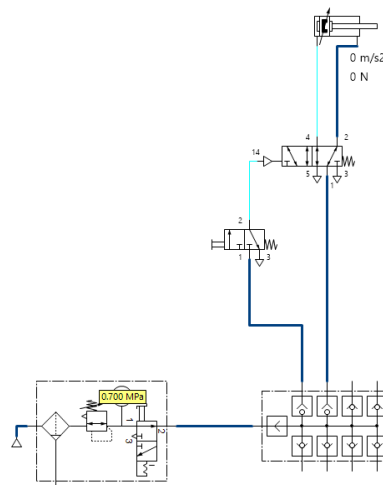


Figure 1: Design of Basic Double Acting Cylinder While Retracted

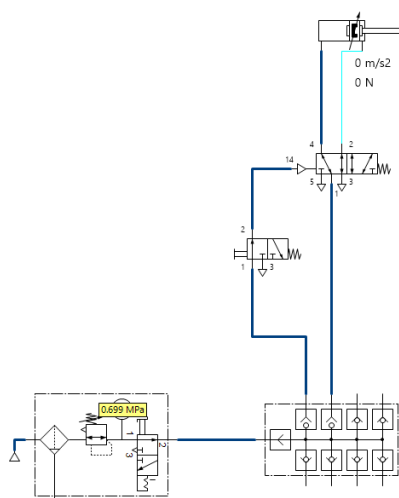


Figure 2: Design of Basic Double Acting Cylinder While Extended

Figures 1 and 2 show a simple pneumatic setup using a 3/2 way normally closed pushbutton valve to control a double acting cylinder. In Figure 1, the cylinder is retracted because the pushbutton valve blocks airflow to the pneumatically operated valve, which stops the valve from turning to the “on” position, thus not allowing any airflow to the piston. When the pushbutton is pressed (Figure 2), it shifts to send pressurised air to the pneumatically operated valve, pushing the valve into the “on” position, thus allowing air flow to the piston, extending the piston while the rod end air exhausts. This basic circuit shows how directional airflow can be controlled to move the cylinder in and out using minimal components, with the pushbutton providing the signal to switch airflow paths.

Components Used

Double Acting Cylinder:

- A double acting cylinder is a pneumatic actuator that uses compressed air to move a piston in both directions. It has two ports for air supply, one for extension and one for retraction. This makes it suitable for lifting, pushing or pulling applications where both push and pull forces are required.

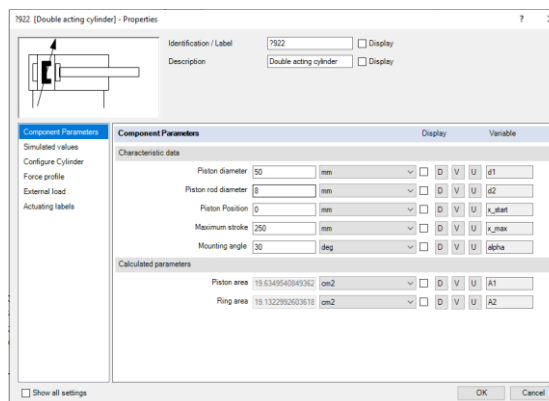


Figure 3: Chosen Double Acting Cylinder Specifications

The figure above shows the double acting cylinder specifications, namely the 250mm stroke length, external mass of 100kg, mounting surface of 30 degrees, sliding coefficient of 0.13, and a static coefficient of 0.19 for the design in figure 2 and 3.

3/2-way valve pneumatically operated:

- A 3/2-way pneumatical valve has three ports and two positions, hence the 3/2 label. It is used to control the flow of compressed air to the actuator. When activated by a pneumatic flow, it allows air to flow through, enabling the movement of the cylinder.

3/2-way valve with pushbutton normally closed:

- This valve is manually operated using a push button. In the default state, the valve stays closed, blocking the airflow. When pressed, it opens to allow airflow through the valve. Once released, the valve returns to the closed position, blocking airflow.

Manifold:

- A manifold is a component that distributes compressed air from a single source to multiple outputs (8 in this case). It simplifies the overall pneumatic system by reducing the need for multiple air supply lines.

Start-up valve with filter control valve:

- A start-up valve ensures a controlled pressurisation of the system during start-up. It prevents pressure surges that could damage system components. The filter control valve removes any foreign elements from the air supply, ensuring clean and efficient operation.

Compressed air supply:

- The compressed air supply provides the necessary air to power the pneumatic system. It operates at a maximum pressure of 0.7 MPa and is essential for the double-acting cylinder to lift and lower the load.

Calculations



1. In order to move the mass, we first have to overcome the static friction. For this, the break-away force F_B is calculated as follows (see [Cylinder model - Friction](#)):

$$F_B = \mu_B \cdot m_m \cdot g \cdot \cos(\alpha) \approx 0.15 \cdot 50 \cdot 9.81 \cdot \cos(0) \text{ N} \approx 73.6 \text{ N}$$

According to the data sheet, the theoretical piston force amounts to 188.5 N (see excursus [Calculating the theoretical and effective piston force](#) for further details) which is therefore sufficient to set the cylinder piston (and with it, the external mass) horizontally in motion.

2. The mass remains in motion, because the sliding friction is less than the static friction. The sliding friction force F_C , which counteracts the motion, is calculated as follows:

$$F_C = \mu_C \cdot m_m \cdot g \cdot \cos(\alpha) \approx 0.1 \cdot 50 \cdot 9.81 \cdot \cos(0) \text{ N} \approx 49.1 \text{ N}$$

The inertia of the mass affects the acceleration. The larger the mass to be moved, the lower the acceleration. This needs to be considered for the desired procedural speed. You can find out more about the influence of the moment of inertia in the experiment [moment of inertia](#).

Figure 4: Formula for Forces from Fluid Sim Didactics

The force required to move the mass when the mass is static:

$$F_B = \text{Static Coefficient} \cdot \text{Mass (kg)} \cdot \text{Gravity} \left(\frac{m}{s^2} \right) \cdot \cos(\phi)$$

$$F_B = 0.19 \cdot 100 \cdot 9.81 \cdot \cos(30)$$

$$F_B = 161.42 \text{ N}$$

The force required maintain motion:

$$F_C = \text{Sliding Coefficient} \cdot \text{Mass (kg)} \cdot \text{Gravity} \left(\frac{m}{s^2} \right) \cdot \cos(\phi)$$

$$F_C = 0.13 \cdot 100 \cdot 9.81 \cdot \cos(30)$$

$$F_C = 110.45 \text{ N}$$

The force due to gravity along the incline:

$$F_g = mg \cdot \sin(\phi)$$

$$F_g = (100 \cdot 9.81) \cdot \sin(30)$$

$$F_g = 490.5 \text{ N}$$

The total force with the highest friction factor:

$$F_t = F_g + F_B$$

$$F_t = 490.5 + 161.42$$

$$F_t = 651.92N$$

Minimum piston diameter:

Formulas gathered from the didactics and online show that:

$$F_{piston} = P(\text{pressure}) \cdot A(\text{piston cross – sectional area})$$

If the formula is rearranged for the piston cross-sectional area (A), it becomes:

$$A = \frac{F_{piston}}{P}$$

This formula will be known as formula 1

A separate formula for the cross-sectional area of the piston is:

$$A = \frac{\pi \cdot D(\text{piston diameter})^2}{4}$$

If we rearrange the formula above for the piston diameter (D), it becomes:

$$D = \sqrt{\frac{4 \cdot A}{\pi}}$$

This formula will be known as formula 2

Subbing formula 1 into formula 2 gives:

$$D = \sqrt{\frac{4 \cdot F_{piston}}{\pi \cdot P}}$$

The F_{piston} in this case, is equivalent to F_t which is 651.92N.

$$D = \sqrt{\frac{4 \cdot 651.92}{\pi \cdot 0.7}}$$

$$D = 34.43 \text{ mm}$$

The minimum diameter required is 34.43mm, or 35mm rounded up.

The diameter of the rod chosen is 40mm, this is due to the increased diameter increasing the speed of the piston opening and closing for ease of use.

Choosing suitable pistons:

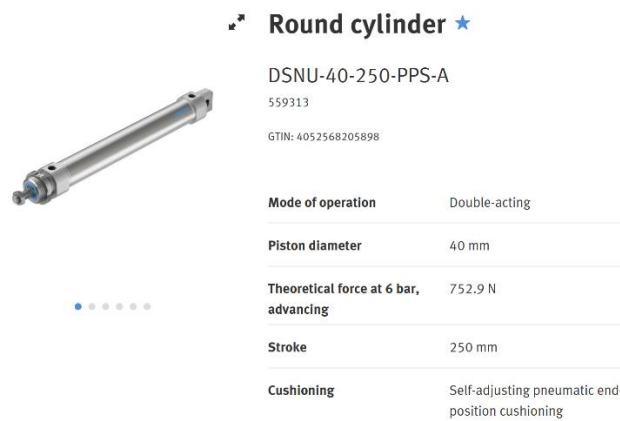


Figure 5: Possible Choice of Chosen Piston

Figure 5 shows one of the possible choices of pistons (Festo, 2025) for the real-world equivalent of the pneumatic circuit. As the minimum piston diameter required is 34mm, and there is no 34 to 39mm piston diameter to choose from, the minimum piston diameter must be rounded up to 40mm.

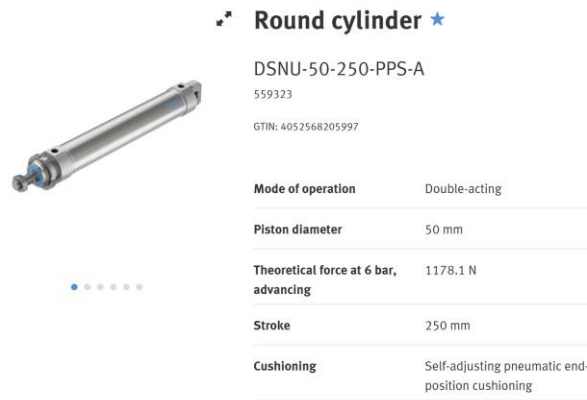


Figure 6: Possible Choice of Chosen Piston

Figure 6 also shows one of the possible choices of pistons to choose from (Festo, 2025), however this piston has a piston diameter of 50mm in comparison to the previous 40mm. Increasing the piston diameter boosts the cylinder's available force at the same supply pressure because a larger bore area produces a greater output force ($F = P \times A$). However, that larger bore also requires more air per stroke, so the system's air consumption goes up. If flow-control valves or the supply flow rate remain unchanged, the cylinder may move more slowly because more volume needs to fill and exhaust. In other words, a bigger diameter provides greater force but demands higher airflow capacity to maintain speed and can increase overall energy use and costs if the system frequently cycles.

Property	Round cylinder	Round cylinder
Comparison	DSNU-50-250-PPS-A	DSNU-40-250-PPS-A
Price	\$0.00	\$0.00
Expected to deliver on		03/12/2025
Operating pressure	0.1 MPa ... 1 MPa	0.1 MPa ... 1 MPa
Mode of operation	Double-acting	Double-acting
Seals material	NBR TPE-U(PU)	NBR TPE-U(PU)
LABS (PWS) conformity	VDMA24364-B1/B2-L	VDMA24364-B1/B2-L
Theoretical force at 6 bar, retracting	989.6 N	633.3 N
Type of mounting	With accessories	With accessories
Corrosion resistance class (CRC)	2 - Moderate corrosion stress	2 - Moderate corrosion stress
Theoretical force at 6 bar, advancing	1178.1 N	752.9 N
Information on operating and pilot media	Operation with oil lubrication possible (required for further use)	Operation with oil lubrication possible (required for further use)
Piston rod thread	M18x1.5	M12x1.25
Cushioning length	20 mm	18 mm
Cushioning	Self-adjusting pneumatic end-position cushioning	Self-adjusting pneumatic end-position cushioning
Position sensing	For proximity sensor	For proximity sensor
Note on materials	RoHS-compliant	RoHS-compliant
Operating medium	Compressed air as per ISO 8573-1:2010 [7:4:4]	Compressed air as per ISO 8573-1:2010 [7:4:4]
Pneumatic connection	G1/4	G1/4
Ambient temperature	-20 °C ... 80 °C	-20 °C ... 80 °C
Moving mass	1038 g	630 g
Stroke	250 mm	250 mm
Product weight	2087 g	1261 g
Piston diameter	50 mm	40 mm
Structural design	Piston Piston rod Cylinder barrel	Piston Piston rod Cylinder barrel
Material of cylinder barrel	High-alloy stainless steel	High-alloy stainless steel
Operating pressure	1 bar ... 10 bar	1 bar ... 10 bar
Cover material	Wrought aluminum alloy	Wrought aluminum alloy
Mounting position	Any	Any
Piston rod material	High-alloy steel	High-alloy steel
Symbol		992970

Figure 7: Comparison of the 2 Chosen Pistons

Figure 7 (Festo, 2025) shows the comparison of the 2 selected piston datasheets; the notable points of difference is theoretical force at 6 bar (retracting), which is 989.6N for the 50mm piston and 633.3N for the 40mm piston. The theoretical force at 6 bar (retracting) value is the value to be used when calculating the operating pressure of the chosen pistons.

Operating Pressure Calculations:

The operating pressure can be calculated using the formula.

$$F_{Piston} = P(\text{pressure}) \cdot A(\text{piston cross-sectional area})$$

The formula above is then rearranged for P (pressure)

$$A = \frac{F_{Piston}}{P}$$

With this, we can then sub the formula above into the formula below:

$$A = \frac{\pi \cdot D(\text{piston diameter})^2}{4}$$

Subbing in and rearranging for (P) gives us:

$$P = \frac{4 \cdot F_{Piston}}{\pi \cdot D(\text{piston diameter})^2}$$

For the 40mm piston:

Introducing the values gives

$$\frac{4 \cdot 633.3}{\pi \cdot 40^2} = 0.5 \text{ MPa}$$

For the 50mm piston:

Introducing the values gives

$$\frac{4 \cdot 989.6}{\pi \cdot 50^2} = 0.5 \text{ MPa}$$

The calculations show that both the 40mm and 50mm have an operating pressure of 0.5Mpa, which is as expected, as both of their standard operating pressures according to their datasheets, is between 0.1MPa and 1MPa.

Task 2:

Methodology/ Introduction

A pneumatic circuit is to be created with three double acting cylinders and is to have the following actuating sequence and operating requirements.

The control system must have a pneumatic solution to meet production requirements.

- The Sequence is to be: A+ C+ B+ B- C- A-
- A time delay of 2 seconds after B+
- C & B are to extend rapidly and take between 1.5 to 2 seconds to retract
- A is to take between 3 to 3.5 seconds to extend and retract rapidly.
- The sequence is started using a latch switch and the system must run continuously until the latch is switched. Once the latch is switched back, the circuit must continue and finish its cycle and stop.

Using the previous task design as a basis, the current task is to explore methods to create accurate time delays with proper sequencing.

Design

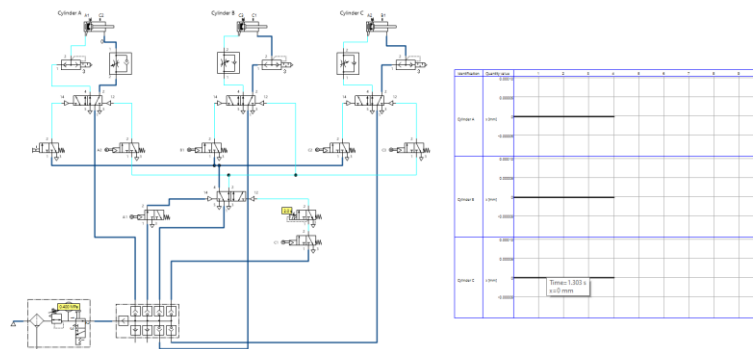


Figure 8: Pistons Controlled in Circuit (Closed)

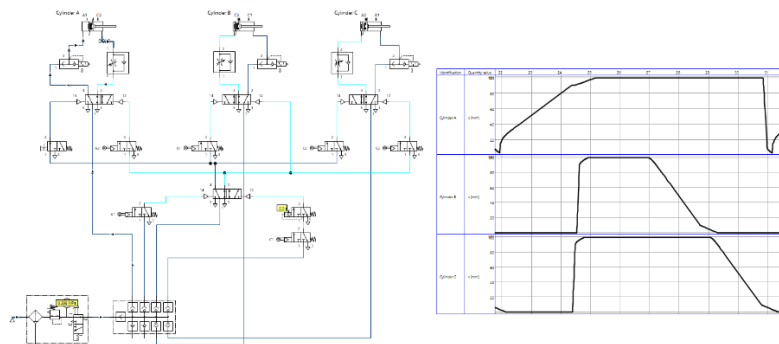


Figure 9: Pistons Controlled in Circuit (Open)

Figures 8 and 9 present the finished circuit: Figure 8 shows airflow in the idle state, Figure 9 shows airflow during activation. The accompanying timing chart on the right confirms the sequence runs accurately.

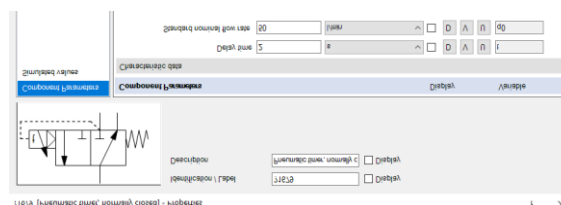


Figure 10: Timer Component Showing 2 Second Time Delay

Figure 10 shows the timer valve set to a 2-second delay—once pressurised, it waits 2 s before opening to pass air.

Analysis

he Task 2 circuit reuses the manifold, start-up valve, air supply, and double-acting cylinders from Task 1 but adds normally closed 3/2 roller valves. Each valve is “labelled” to a piston position, e.g., it switches when the rod is fully in or out, so A1 and C1 regulate overall supply, while A2, B1, C2, C3 steer their respective cylinders.

A throttled reservoir was first tried for timing, but it lacked fine adjustment and caused cycles to speed up as it filled, so it was replaced by a precise timer valve.

A state diagram now plots piston positions versus time, giving an exact visual check of sequence and timing.

Process

- Latch ON = main 5/2 to extend = A extends slowly (throttled).
- A halfway = C2 opens = C extends fast.
- C halfway = B1 opens = B extends fast.
- A full out = A1 cuts extend signals; B full out = C1 starts 2 s timer.
- Timer expires = main 5/2 to retract.
- B retracts slowly (exhaust throttled).
- B near home = C3 opens = C retracts slowly.
- C near home = A2 opens = A retracts fast.
- All home = repeat if latch ON, else idle.

Conclusion

Switching from a reservoir to a timer valve, and adding a state diagram, made the circuit both reliable and precise. The timer delivers uniform delays, preventing the reservoir’s accelerating cycles, while the diagram links each roller valve to its piston position and verifies the A C B extend / B C A retract sequence. The time graph confirms every transition, and exhaust throttles fine-tune stroke speeds, so the system now runs steady, repeatable cycles that meet all timing demands.

References

Festo (2025). *Buy Round cylinder, double-acting DSNU online* | Festo USA. [online] Festo.com. Available at: https://www.festo.com/us/en/p/round-cylinder-double-acting-id_DSNU_PUB/?q=%7E%3AsortByCoreRangeAndNewProduct%7E%3ACC_Stroke_combined_mm_C_FP_GLOBAL%7E%3A250.0&page=1 [Accessed 10 Mar. 2025].