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PNEUMATICS & HYDRAULICS PCEE4010

Year 2- HNC Instrumentation Engineering ✓

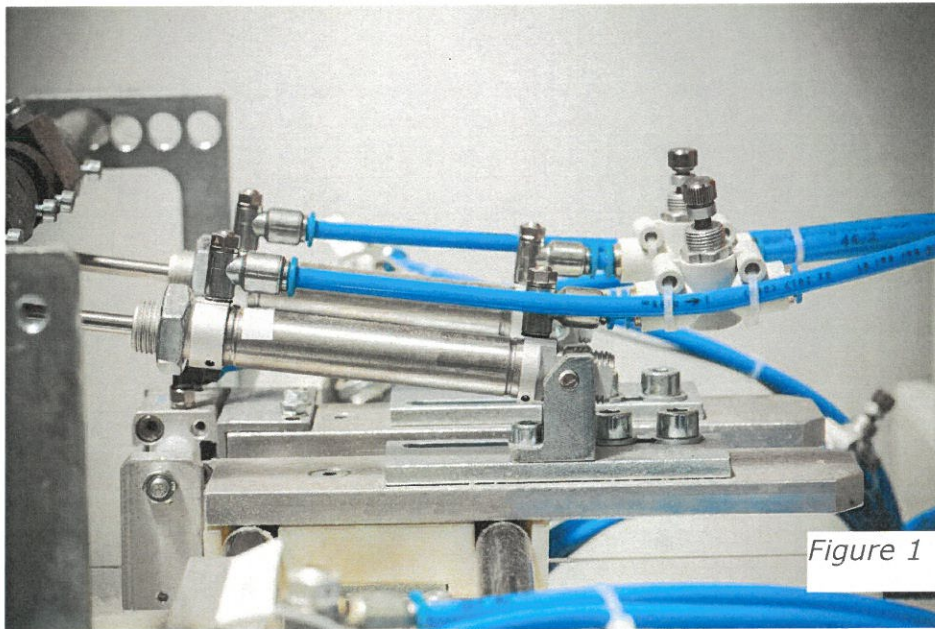


Figure 1

Samuel Davies

Level 4 HNC in Instrumentation Engineering

Pembrokeshire College / UOW Trinity St David

Student no: 146387 / 2221719 [146387@pembrokeshire.ac.uk]



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

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INTRODUCTION

The following assignment will inform the reader regarding Pneumatic and Hydraulic circuits and components, and how various components contribute to the overall system. Linear and Rotary actuators will be explored and described, some calculations carried out in Task 2, and circuit design and analysis in the latter tasks of the report.



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TASK 1 – ACTUATOR CONSTRUCTION & OPERATION

Fluid power is commonly used throughout industry, due to the limitless options in terms of parts, programming, and readily available spares. Pneumatic especially, is widely used as it is ideal for use in high care environments such as medical and food and drink manufacturing. Fluid power is described as “any substance that is not solid and continuously deforms when subjected to an external force”, (Darbyshire & Gibson, 2023)

Linear

Linear fluid power actuators are versatile devices that provide reliable and efficient linear motion in various industrial and mechanical applications. Understanding their construction and operation is essential for optimizing their performance and ensuring their proper integration into systems and machinery.

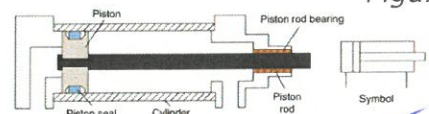


Figure 2

Linear fluid power actuators are essential components in various industrial and mechanical systems where linear motion is required. This report provides an overview of the construction and operation of these actuators, highlighting their key components, working principles, and applications.

Construction of Linear Fluid Power Actuators

Linear fluid power actuators consist of the following main components:

Cylinder: The primary component of a linear fluid power actuator is the cylinder, which contains a piston that moves back and forth within it. The cylinder is typically made of durable materials such as steel or aluminium to withstand high pressure and mechanical stress.

Piston: The piston is housed inside the cylinder and is connected to the actuator's rod. It separates the cylinder into two chambers: the pressure (or power) chamber and the return chamber.

The rod extends from the piston and protrudes outside the cylinder. It serves as the output shaft of the actuator, transmitting linear motion to the external load.

Seals: Sealing elements such as O-rings or piston seals are used to prevent fluid leakage between the piston and the cylinder walls, ensuring efficient operation of the actuator.

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Fluid Ports: Fluid ports are openings in the cylinder that allow hydraulic or pneumatic fluid to enter and exit the actuator, exerting pressure on the piston to produce linear motion.

Operation of Linear Fluid Power Actuators

The operation of linear fluid power actuators involves the following steps:

Where has all of this information originated you need to reference sources.

Fluid Intake: Pressurized hydraulic fluid (in hydraulic actuators) or compressed air (in pneumatic actuators) is supplied to the pressure chamber through an inlet port. This creates a force imbalance across the piston, causing it to move in the desired direction.

Piston Movement: The pressure of the fluid pushes the piston in the direction of the load, extending the actuator's rod. As the piston moves, it displaces fluid from the pressure chamber into the return chamber through an exhaust port.

Load Movement: The linear motion of the actuator's rod is transmitted to the external load, which performs the desired mechanical work or movement.

Fluid Release: After the actuator reaches its desired position, the fluid pressure is released from the pressure chamber, allowing the piston to retract under the influence of external forces (e.g., springs or gravitational forces).

Linear fluid power actuators find wide-ranging applications across industries, including:

Industrial Automation: They are used in manufacturing processes for tasks such as material handling, assembly, and positioning of components. ✓

Robotics in the food and drink industry: Linear actuators play a crucial role in the movement and manipulation of robotic arms, grippers, and other robotic mechanisms. It is more common for pneumatics to be used in the food industry, as “pneumatic actuators offer advantages such as high speed, simplicity, and robustness. These actuators are widely used in automation systems, robotics, manufacturing, and various other fields where quick and precise motion control is required”, (Yamaguchi, Nishikori & Arai, 2019) ✓

Aerospace: They are employed in aircraft systems for functions like landing gear deployment, cargo door operation, and control surface actuation.

Construction Machinery: Linear actuators are utilized in construction equipment for tasks such as extending and retracting booms, raising/lowering platforms, and tilting attachments.

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Rotary

Rotary fluid power actuators play a crucial role in various engineering applications, enabling controlled rotational motion in systems where precise positioning and force transmission are required. This report provides an in-depth analysis of the construction, working principles, and applications of rotary fluid power actuators, focusing on both hydraulic and pneumatic variants.

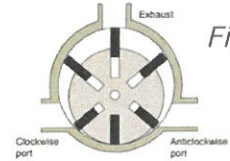


Figure 3

Rotary fluid power actuators typically comprise the following essential components:

Rotary Shaft: The rotary shaft serves as the output component of the actuator, transmitting rotational motion to the connected machinery or load.

Actuator Body: The actuator body houses the internal components, including the fluid chambers and the rotary shaft. It is constructed from durable materials such as steel or aluminium to withstand the forces generated during operation.

Fluid Chambers: Rotary actuators contain chambers filled with hydraulic fluid (in hydraulic actuators) or compressed air (in pneumatic actuators). These chambers exert pressure on the actuator's internal components, inducing rotational motion.

Seals: Sealing elements, such as O-rings or lip seals, are employed to prevent fluid leakage within the actuator and ensure efficient operation.

Ports: Fluid ports facilitate the entry and exit of hydraulic fluid or compressed air into the actuator, connecting it to the fluid power source.

The operation of rotary fluid power actuators involves the following fundamental steps:

Fluid Supply: Pressurized hydraulic fluid (in hydraulic actuators) or compressed air (in pneumatic actuators) is supplied to the actuator's fluid chambers through inlet ports. The fluid applies pressure to specific areas within the actuator, inducing rotational motion.

Rotational Motion Generation: The pressure imbalance created by the fluid forces causes the actuator's internal components to rotate. This rotational motion is transmitted to the rotary shaft, which rotates in the desired direction.

Torque Transmission: The rotational motion of the rotary shaft is utilized to perform mechanical work or transmit torque to connected machinery or components.

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Fluid Release: Upon completing the desired rotational movement, the fluid pressure is released from the actuator's chambers, allowing it to return to its initial position or remain in the desired orientation.

Applications of Rotary Fluid Power Actuators

Rotary fluid power actuators find widespread applications across diverse industries, including:

Industrial Automation: Used in machinery and equipment for tasks such as valve actuation, conveyor belt operation, and robotic arm manipulation.

Aerospace: Employed in aircraft systems for functions such as flap deployment, landing gear retraction, and engine control.

Automotive: Utilized in vehicle steering systems, throttle control mechanisms, and braking systems.

Marine: Applied in ship steering mechanisms, rudder control, and navigation systems.

Rotary fluid power actuators are indispensable components in engineering systems requiring controlled rotational motion. Understanding their construction and operation is essential for designing efficient and reliable hydraulic and pneumatic systems across various industries.

As the above shows, rotary actuators can be used in a wide range of industries, due to the benefit of rotational movement as opposed to just linear actuators, "Rotary actuators play a crucial role in various industrial processes, offering precise and reliable motion control solutions. From simple rotational tasks to complex motion sequences, rotary actuators find applications in automation, robotics, aerospace, and many other fields where rotational motion is required", (Johnson & Smith, 2017)

This ~~writing~~ style has not learnt itself well to a technical report.

Written by Samuel Davies

*It seems to be much listed information rather than an easily digestible format.
i.e. paragraphs.*

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TASK 2 – CALCULATIONS

Figure 4 and figure 5, below, shows a table of common formulae used when undertaking mechanical equations, some of which has been used below to obtain the required results.

Formula	Formula symbols	Units
Acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{v - u}{t}$	m/s ²
Linear velocity	$v = \omega r$	m/s
Angular velocity	$\omega = \frac{\theta}{t} = 2\pi n$	rad/s
Linear acceleration	$a = r\alpha$	m/s ²
Relationships between initial velocity u , final velocity v , displacement s , time t and constant acceleration a	$\begin{cases} v^2 = u^2 + at^2 \\ s = ut + \frac{1}{2}at^2 \\ v^2 = u^2 + 2as \end{cases}$	m/s m (m/s) ²
Relationships between initial angular velocity ω_1 , final angular velocity ω_2 , angle θ , time t and angular acceleration α	$\begin{cases} \omega_2 = \omega_1 + \alpha t \\ \theta = \omega_1 t + \frac{1}{2}\alpha t^2 \\ \omega_2^2 = \omega_1^2 + 2\alpha\theta \end{cases}$	rad/s rad (rad/s) ²
Momentum = mass $\times$ velocity		kg m/s
Impulse = applied force $\times$ time = change in momentum		kg m/s
Force = mass $\times$ acceleration	$F = ma$	N
Weight = mass $\times$ gravitational field	$W = mg$	N
Centripetal acceleration	$a = \frac{v^2}{r}$	m/s ²
Centripetal force	$F = \frac{mv^2}{r}$	N
Density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$	kg/m ³
Work done = force $\times$ distance moved	$W = Fs$	J
Efficiency = $\frac{\text{useful output energy}}{\text{input energy}}$		
Power = $\frac{\text{energy used (or work done)}}{\text{time taken}}$ = force $\times$ velocity	$P = \frac{E}{t} = Fv$	W
Potential energy = weight $\times$ change in height	$E_p = mgh$	J
Kinetic energy = $\frac{1}{2} \times \text{mass} \times (\text{speed})^2$	$E_k = \frac{1}{2}mv^2$	J

Figure 4

Formula	Formula symbols	Units
Kinetic energy of rotation = $\frac{1}{2} \times \text{moment of inertia} \times (\text{angular velocity})^2$	$E_k = \frac{1}{2}I\omega^2$	J
Frictional force = coefficient of friction $\times$ normal force	$F = \mu N$	N
Angle of repose, θ , on an inclined plane	$\tan \theta = \mu$	
Efficiency of screw jack	$\eta = \frac{\tan \theta}{\tan (\alpha + \theta)}$	
SHM periodic time $T = 2\pi \sqrt{\frac{\text{displacement}}{\text{acceleration}}}$	$T = 2\pi \sqrt{\frac{y}{a}}$	s
$T = 2\pi \sqrt{\frac{\text{mass}}{\text{stiffness}}}$	$T = 2\pi \sqrt{\frac{m}{k}}$	s
simple pendulum	$T = 2\pi \sqrt{\frac{L}{g}}$	s
compound pendulum	$T = 2\pi \sqrt{\frac{(k_G^2 + h^2)}{gh}}$	s
Force ratio = $\frac{\text{load}}{\text{effort}}$		
Movement ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$		
Efficiency = $\frac{\text{force ratio}}{\text{movement ratio}}$		
Kelvin temperature = degrees Celsius + 273		
Quantity of heat energy = mass $\times$ specific heat capacity $\times$ change in temperature	$Q = mc(t_2 - t_1)$	J
New length = original length + expansion	$L_2 = L_1 [1 + \alpha(t_2 - t_1)]$	m
New surface area = original surface area + increase in area	$A_2 = A_1 [1 + \beta(t_2 - t_1)]$	m ²
New volume = original volume + increase in volume	$V_2 = V_1 [1 + \gamma(t_2 - t_1)]$	m ³
Pressure = $\frac{\text{force}}{\text{area}}$ = density $\times$ gravitational acceleration $\times$ height	$\begin{aligned} p &= \frac{F}{A} \\ p &= \rho gh \\ 1 \text{ bar} &= 10^5 \text{ Pa} \end{aligned}$	N/m ²

Figure 5

a) System Pressure Needed:

The formula for calculating the force exerted by a hydraulic cylinder is:

$$F = P \times A$$

Where:

F= Force (Newtons)

P= Pressure (Pascals)

A= Area (m²)

Given:

$$F = 50kN \text{ (pushing force)}$$

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$$A = \frac{\pi \times D^2}{4} \text{ cross sectional area of cylinder}$$

Substituting the values, we get:

$$50kN = P \times \frac{\pi \times (0.142)^2}{4} \rightarrow$$

$$P = \frac{50 \times 4}{\pi \times (0.142)^2} Pa$$

$$P = 6.089 \times 10^6 Pa \quad \times$$

$$50 \times 10^3 = P \times \left(\frac{\pi \times 0.142^2}{4} \right)$$

$$\downarrow$$

$$\frac{50 \times 10^3}{\left(\frac{\pi \times 0.142^2}{4} \right)} = P$$

Incorrect transposition.

$$3.16 MPa = P.$$

b) Force with which it pulls.

The force in the pulling direction would be the same as in the pushing direction if the pressure remains the same. X There are different surfaces within the cylinder

c) Time taken to extend fully:

hence there must be different generation of forces based upon Pasca's principle.

We can use the formula:

$$Q = A \times V$$

Where:

Q = Flow Rate (in m³/s)

A = Area of the cylinder (in m²)

V = Velocity (in m/s)

Given:

$$Q = 14 dm^3 min = \frac{14}{1000 \times 60} m^3 s$$

$$A = \frac{\pi \times D^2}{4} \text{ Cross sectional area of cylinder}$$

Substituting the values:

$$\frac{14}{1000 \times 60} = \frac{\pi \times (0.142)^2}{4} \times V$$

The volume of the cylinder has not been calculated in order to solve for $\frac{\text{Volume}}{\text{Flow rate}} = \text{time}.$

$$\left(\left(\frac{\pi \times 0.142^2}{4} \right) \times 0.55 \right) = 0.0087 m^3$$

Area Length

Volume

or.
8.7 ltrs.

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$$V = \frac{14}{\frac{1000 \times 60}{\pi \times (0.142)^2 \times 4}} \text{ m per s}$$

$$V = 0.04326 \text{ m per s}$$

Time taken to extend fully:

$$t = \frac{s}{v} = \frac{0.55 \text{ m}}{0.04326 \text{ m per s}}$$

$$t = 12.7 \text{ s} \quad \times$$

$$= \frac{8.7 \text{ lbs.}}{14} \leftarrow Q \left(\frac{\text{lbs}}{\text{min}} \right)$$

$$\rightarrow 0.62 \text{ min} \times 60 = \underline{37.3 \text{ sec}}$$

d) Velocity on the outward stroke:

Already calculated it in part c.

$$V = 0.4326 \text{ m per s} \quad \times$$

$$\text{Velocity} = \frac{\text{m}}{\text{sec.}}$$

$$0.015 \frac{\text{m}}{\text{s}} = \frac{0.55}{37.3}$$

e) Time taken to retract fully:

Since the flow rate is constant and the volume to retract is the same as to extend, the time to retract fully would also be. $\times$

$$t = 12.7 \text{ s} \quad \times$$

$$30.7 \text{ s.}$$

With reference to the flow rate, one side of the cylinder will fill with fluid far quicker than the other due to the rod on one side.

f) Velocity on the inward stroke:

Same as the outward stroke.

$$V = 0.4326 \text{ m per s} \quad \times$$

$$17.9 \text{ mm/s.}$$



g) Power transmitted on the outstroke:

The power transmitted can be calculated using the formula:

$$P = F \times V \quad \times$$

Where:

P= Power (in Watts) $\checkmark$

F= Force (in Newtons) $\checkmark$

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V = Velocity (in meters per seconds) ✓

Given:

$$F = 50kN$$

$$V = 0.04326m \text{ per second}$$

Substituting the values:

$$P = 50000N \times 0.04326m \text{ per second}$$

$$P = 2163 W \quad \times$$

This gives us the power transmitted on the outstroke.

$$WD = F \times D$$

$$27500J = 50 \times 10^3 \times 0.55$$



$$\text{Power} = \frac{J(WD)}{S(\text{Time})}$$

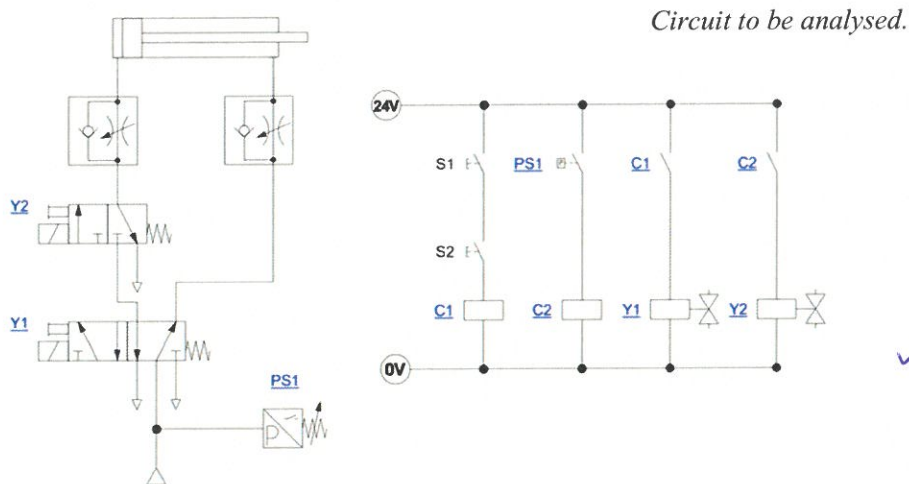
$$\text{Power} = \frac{27,500}{37.3}$$

$$= 737W$$

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TASK 3- CIRCUIT ANALYSIS

In different applications such as electrical, pneumatic and hydraulic, circuit analysis is vital in ensuring the circuit fulfils its purpose, and operates in a safe manner, “understanding the interactions between components such as pumps, valves, actuators, and reservoirs is crucial. By analysing pressure, flow, and energy distribution within the circuit, engineers can optimize performance, ensure safety, and enhance efficiency in hydraulic and pneumatic systems”, (Smith, 2009)



As the above circuit shows, there are 2 sections that make up the circuit. On the right there is an electrical circuit, showing the control side of the circuit, with relays controlling the switching of components. On the left side, there is the pneumatic drawing, show all relevant components.

The below table outlines each component and its purpose.

Component	Purpose
Pneumatic	
Cylinder	Converts pneumatic pressure into mechanical motion ✓
Pressure Relief Valve <i>X There is no PRV in system.</i>	Relieves the system of excess pressure during a change of direction in system pressure
Pressure Source	Source of pneumatic pressure, such as a oilless compressor, generates systematic pressure ✓
Exhaust port	Point of escape for pressure, used in pneumatic, hydraulic would be back to tank. ✓

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Spring loaded solenoid valve	Valve controlled by a solenoid contact, can change position on the block via electrical control	✓
Electrical		
24V	24V power source, used to power electrical components used in control circuits	✓
0V	0V used in electrical control circuits	✓
Y1/Y2	Solenoid valve as above	✓
S1/S1 N/O pushbutton	2x normally open pushbuttons. Normally open so when pressed/ energised, contacts close. Used in circuit control for different applications.	✓
PS1 pressure switch	Used to control the incoming pressure, will adjust as system requires.	✓
C1/C2	Relays used to transfer signal from pushbutton to solenoid control	✓

The circuit operates when the 2 push buttons S1 and S2 are energised, relay C1 is then energised. C1 further energises Solenoid valve Y1, and once the pressure meets the PS1 setpoint, C2 is energised. In real life, what this circuit is designed to do is operate an actuator back and forth continuously, and after simulating, this circuit achieves this. *What is the purpose of 2 switch actuation?*

A relay is a common electrical component, often used in electro-pneumatic circuits as above. They are widely used as “Relays are indispensable components in modern electrical systems, serving as key elements in controlling power flow and facilitating automation processes. Their reliability, efficiency, and versatility make them fundamental in industries ranging from telecommunications to transportation”, (Von Meier, 2006)

A relay consists of a magnetic coil, a set of contacts, can be more than one set, springs to hold the contacts when not energised, all encased in a plastic casing. When the relay is energised, dependant on the state, either normally open (contacts are not made), or normally closed (contacts are made), the coil generates a magnetic field and attracts the relay to open or close. Relays normally require a power source, such as 12 or 24V DC, and also a control signal. The control signal normally operates through the A1, A2 terminals.

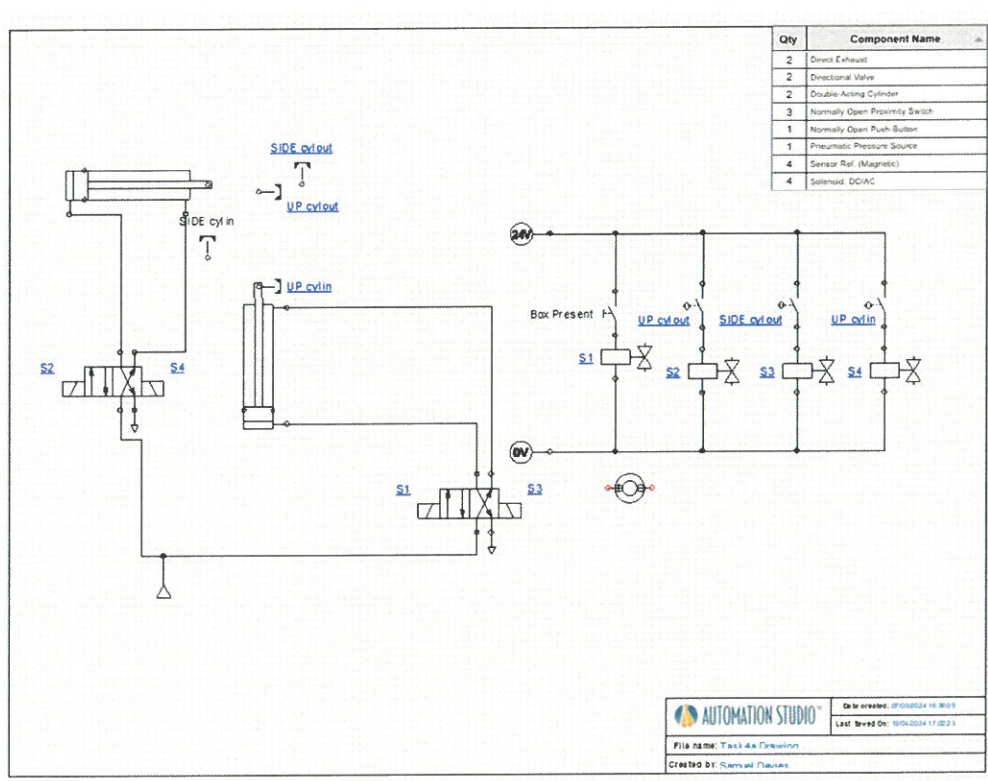
Diagram of a relay would be useful.

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TASK 4- CIRCUIT DESIGN

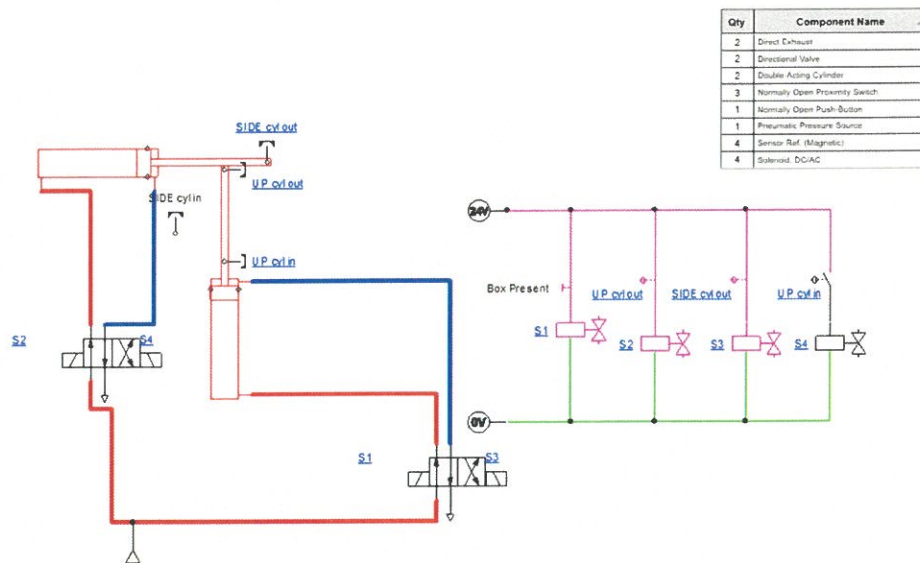
A) Conveying System with Pneumatic Lift

This circuit was designed to transport a box onto a conveyor system that is a level up. A box is lifted via UP Cyl and pushed onto the conveyor using SIDE cyl onto the conveyor. The below screengrabs show the circuit in simulation, and there are some comments alongside. ✓



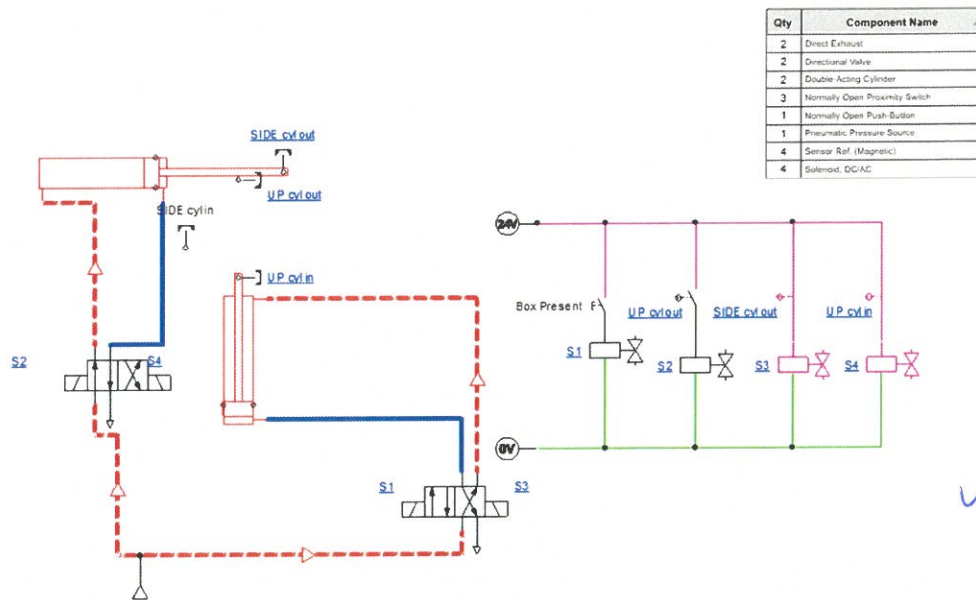
This screenshot shows the overview of the pneumatic and electrical control circuit designed. The top right lists all components used to bring the brief to practice. The circuit is designed to lift a box up, with “UP cyl”, and then push across using “SIDE Cyl”, onto a conveyor system. ✓

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The above shows that when a box is present, as per “box present” sensor, the up cylinder lifts until the top sensor is made. Once this is made, the side cylinder then extends until the side cyl out sensor is made. These sensors are all normally open proximity sensors, and when they are made the contacts close.

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This screenshot shows that after the box is no longer detected at the “box present” sensor, then the up cylinder retracts until the “up cyl in” prox is made, followed by the side cylinder retracting until the “side cyl in” is made. The system is now ready for the next box. ✓

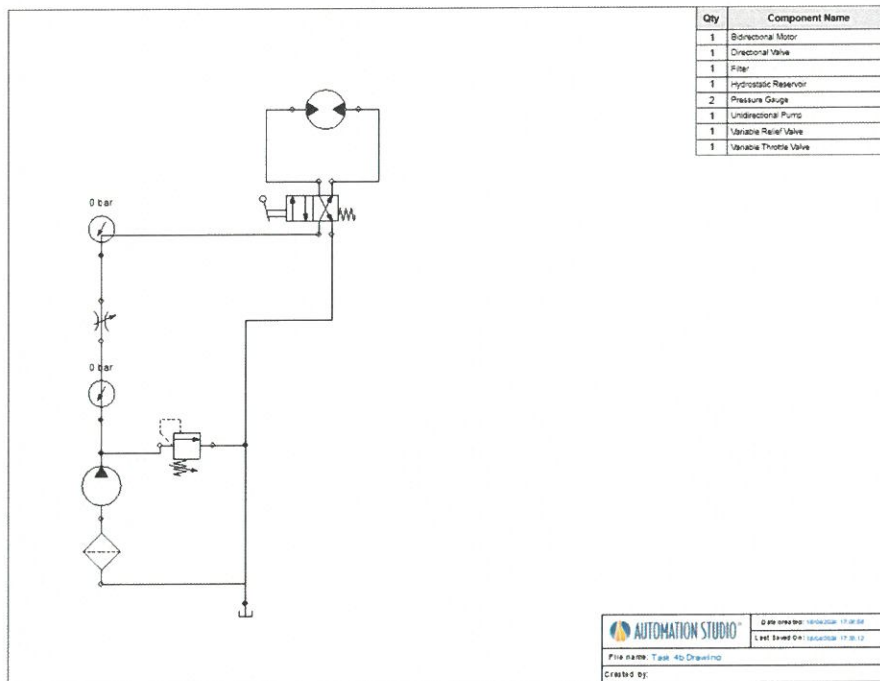
Once the system was built, and through the simulation, it was clear that some modifications could be made to improve the performance, and safety of the machine. ✓ For example, there is no regulation on the operation of either cylinder, so the up / down, out and in is one speed. When looking at this as a real-world application, it is obvious that this could be a serious issue, as if the cylinders move too fast, it could damage the objects being moved (box) or people around the machine. ✓ *+ Good industrial insight.*

Another improvement that could be made, is a proximity sensor, similar to the “box present” sensor, at the top end where the box leaves the cylinder and joins the conveyor belt. Having such a sensor would ensure that the box has left the path of the side cylinder, before the next box is processed. Doing so would uphold the safety of the product/object and people around. ✓ *+ Good consideration.*

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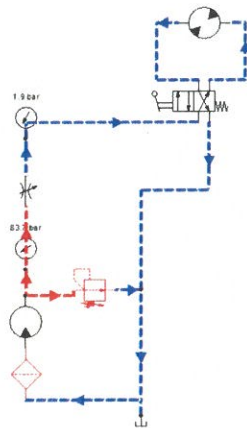
B) Bi-Directional Hydraulic Winch

This circuit shows the design and simulation of a hydraulic, bi directional winch, the screenshots below show the design and simulation of the circuit, with a real world build at the end. This circuit replicates a winch you might find on a car recovery truck or similar. ✓



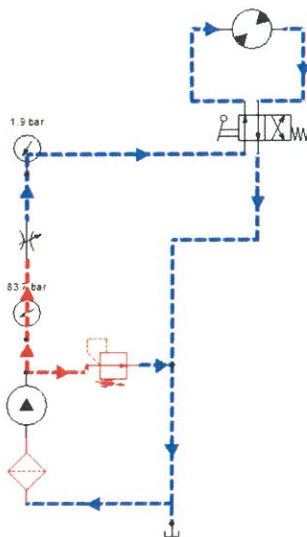
The above screenshot shows the hydraulic circuit produced to create a bidirectional hydraulic winch. Main components consist of a hydraulic reservoir, unidirectional pump, a filter, a directional valve with lever selection etc. ✓

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Qty	Component Name
1	Bidirectional Motor
1	Directional Valve
1	Filter
1	Hydraulic Reservoir
2	Pressure Gauge
1	Unidirectional Pump
1	Variable Relief Valve
1	Variable Throttle Valve

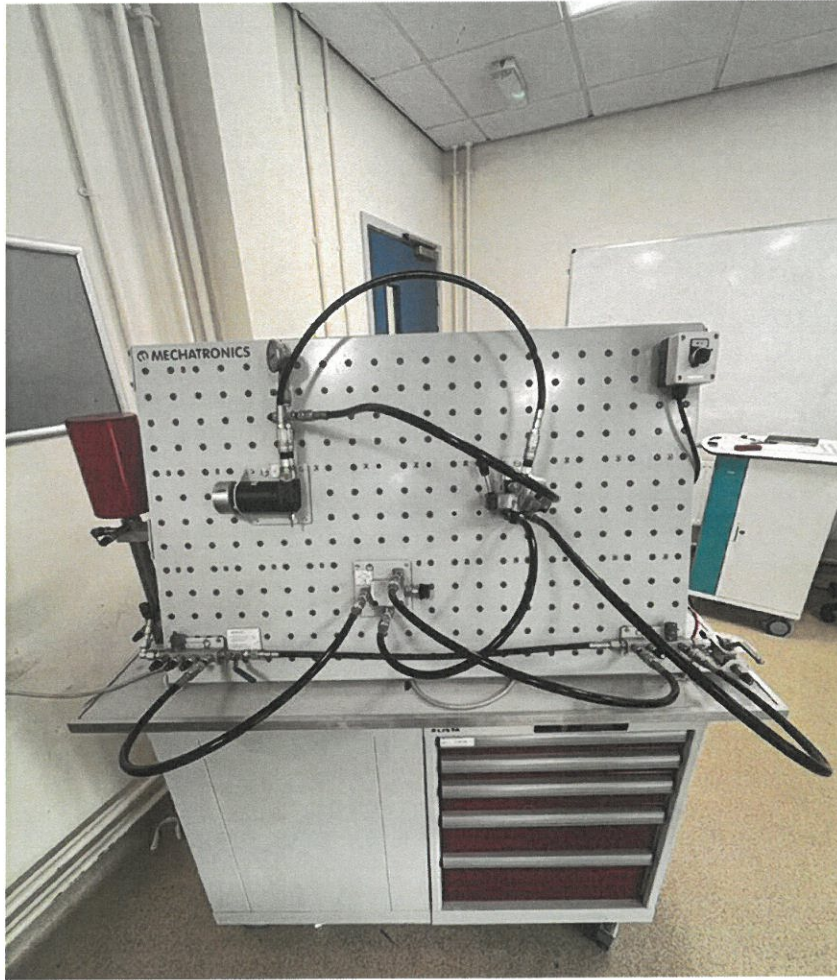
As per above, the circuit is running in the anti-clockwise direction as per the level selector. It is also visible the pressure relief valve is relieving to the tank. ✓



Qty	Component Name
1	Bidirectional Motor
1	Directional Valve
1	Filter
1	Hydraulic Reservoir
2	Pressure Gauge
1	Unidirectional Pump
1	Variable Relief Valve
1	Variable Throttle Valve

The above shows the circuit now running in the opposite direction, as per the winch specification. Again, the pressure relief is draining some pressure to tank. The winch operates as per the brief. ✓

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The above picture shows a real life build of the circuit, which operated as designed during testing. ✓

After testing and simulating the circuit, it is evident there are some changes that could be made to improve the operation. For example, instead of a lever operation, an electro toggle switch could be used, in conjunction with solenoid valves. This would make it easier to operate for the user. Also, speed regulation for the user would be beneficial. ✓

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— Should this reference have editors?

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APPENDIX:

Data Sheet 1- Components, RS. (2019) *Plug in 24V DC Relay* Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://docs.rs-online.com/5b0d/A700000007927364.pdf (Accessed: 18 April 2024).

Figures

Figure 1- Power, P.F. (2022) *What's the difference between pneumatic and hydraulic?*, *Primary Fluid Power*. Available at: <https://www.primaryfp.co.uk/whats-the-difference-between-pneumatic-and-hydraulic/> (Accessed: 04 December 2023).

Figure 2- Darbyshire, A. and Gibson, C. (2023) 'Figure 7.2.7 in Chapter 7.2.5 Actuators' *Mechanical engineering*. Boca Raton, FL: CRC Press, Taylor & Francis Group, pp.435-436'

Figure 3- Darbyshire, A. and Gibson, C. (2023) 'Figure 7.2.9 b in Chapter 7.2.5 Actuators' *Mechanical engineering*. Boca Raton, FL: CRC Press, Taylor & Francis Group, pp.435-436'

Figure 4- Bird, J.O. and Ross, C.T.F. (2020) 'Revision Test 8', in *Mechanical engineering principles*. Abingdon, Oxon: Routledge, pp. 291-292.

Figure 5- Bird, J.O. and Ross, C.T.F. (2020) 'Revision Test 8', in *Mechanical engineering principles*. Abingdon, Oxon: Routledge, pp. 293-294.

*list of figures should be after
the contents page, with references in
the main reference list.*