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J.M.

PCEE4010 – Pneumatic and Hydraulics

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Programme title would
be useful.

1 Actuators – Construction and Operation

1.1 Linear type

1.2 Rotary type

2 Actuators - Calculations

2.1 Brief

2.2 Calculations

3 Circuit Analysis

3.1 Pneumatic section

3.2 Electrical section

4 Circuit Design

4.1 Pneumatic Conveyor

4.2 Hydraulic Winch

Appendix

Bibliography

References

- NO table of content heading,
figures list, introduction,
page numbers.

+ clear sections.

no page numbers.

1 | Actuators – Construction and Operation

1.1 | Linear Type

In their simplest form, a linear type of actuator consists of a piston (pushrod with a large, circular plate on one end) which moves within the bored-out interior of an enclosed cylinder (think of the construction of syringe).

The concept of operation is that as a pressure is exerted to either side of the piston head, the pushrod will extend from, or retract into the body of the cylinder. Although, the cylinder may be single-acting, meaning that air (or process gas) can only be exerted through one side of the cylinder, with a large spring being implemented to return the pushrod to its natural position, the position in which depends on the composition of the actuator.

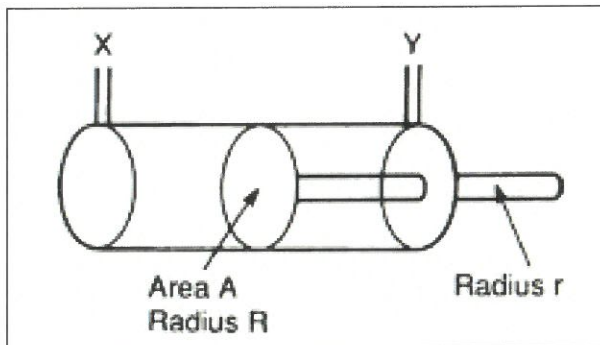


Figure 1: Linear Actuator (Hydraulics and Pneumatics, Parr, pg.119)

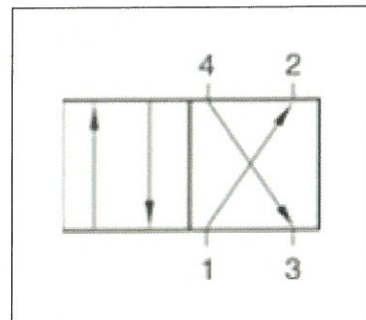


Figure 2: 4/2 Flow control valve (hafner-pneumatik)

As can be seen above in *figure 1*, the double-acting cylinder will operate by either extending or retracting, depending on which port is currently being used to supply a larger pneumatic pressure.

For rod extension, instrument air would flow through the port labelled *X* in the diagram, where it would then begin to fill the volume of the section of cylinder to the left of *Area A* until the pressure begins to exert a force against the plate, causing the pushrod to extend. Although, this is subject to there being no pressure currently present on the opposite side of the cylinder. Alternatively, the pushrod can be retracted back into the cylinder, by switching the input of the instrument airflow to port *Y* and removing the input pressure from port *X*, therefore causing the buildup of pressure against the right-hand side of *Area A*, causing the piston to retract.

With regards to a double-acting cylinder, the input of the airflow would be controlled by a flow direction controller (4/2 control valve for example), which would be installed into the system downstream of the actuator. This flow controller will alternate (depending on the input signal/condition) between two settings, one which will direct the pressure feed to port *X*, and feed any pressure from port *Y* to atmosphere, or reservoir, and vice-versa occurring for the alternate position (as seen in *figure 2*).

-no references within the text to validate.

1.2 | Rotary Type

With regards to concept of general operation (the use of process fluid to drive a piston within an enclosed cylinder), the rotary type of actuator operates in nearly the exact same way as its linear counterpart. The main difference coming from the construction of the actuators themselves, as the rotary variety converts its generated linear force into that of rotational energy, commonly by means of a rack and pinion type set-up. ✓

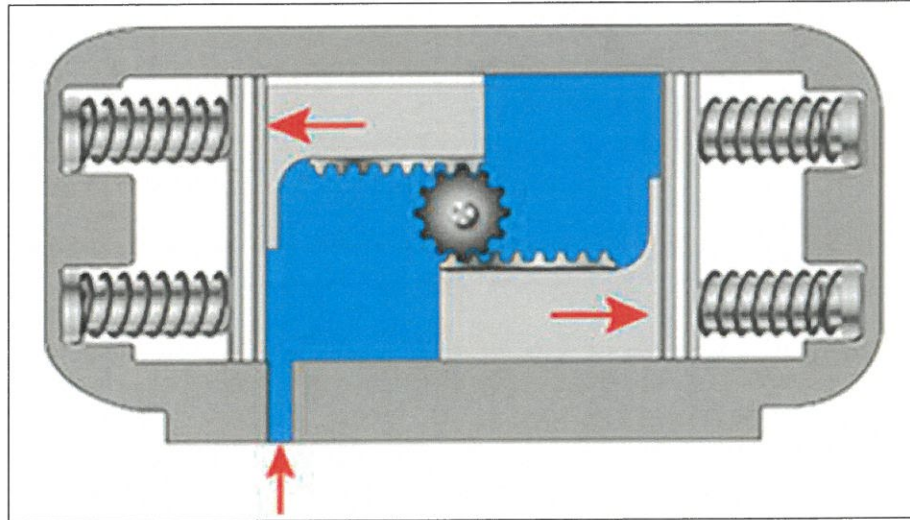


Figure 3: Single Acting, Rotary Actuator (UNOX Valve Co.)

As can be seen in *Figure 3*, a rotary type of actuator still operates with the general concept of a pressure source (be it pneumatic or hydraulic) being applied to a disk-shaped plate within the actuator housing, or in the case of the pictured assembly, two plates.

As with its linear alternative, the rotary actuator can be found in both single and double acting variants, with the same principle of operation as stated above in chapter 1.1. However, it can be seen that the applied force is not being enacted to move a piston (pushrod), but instead to drive a central shaft. ✓

The plates within the actuator are constructed to have their own set of 'teeth' which lock against a central shaft with a fluted diameter, allowing for the three parts to fit together with slight free movement. ✓

When a source of pressure is applied to the actuator, the plates will begin to 'push' outwards and begin to rotate the central shaft, converting the applied linear force into that of a rotational force. This construction can also be found as a double acting variety, where instead of the spring force returning the plates and shaft back to their original resting position, a pressure source is instead applied to the opposite side, causing the plates to retract centrally into the actuator. ✓

This variety of actuator would be used to control rotational valves, such as that of the butterfly and globe etc. ✓

2 | Actuators - Calculations

2.1 | Brief

The following brief was supplied to the author.

A double acting hydraulic cylinder has a bore diameter D . The rod diameter is 60mm and the stroke length is S . The rod must produce a pushing force of 50kN. The flow rate available in both directions is Q .

Calculate:

- The system pressure needed.*
- The force with which it pulls, given the same pressure.*
- The time taken to extend fully.*
- The velocity on the outward stroke.*
- The time taken to retract fully.*
- The velocity on the inward stroke.*
- The power transmitted on the outstroke given the cylinder is operating at capacity.*

Table 1 – Values for calculations

Student Number	Values		
	D (mm)	S (mm)	Q (dm ³ /min)
1 (JC)	102	650	16
2 (KC)	125	<u>525</u>	20
3 (SD)	142	550	14
4 (PP)	155	450	12
5 (HR)	150	600	22

Table 1: Self-Titled. (Provided with assignment brief)

2.2 | Calculations

$$a) P = F/A = 50 \times 10^3 / (pi \times 0.125^2 / 4) = 4.074 \text{ MPa} \quad \checkmark$$

$$b) F = P \times A = 4.074 \times 10^6 \times pi \times (0.125^2 - 0.06^2) / 4 = 38.477 \text{ kN} \quad \checkmark$$

$$c) V_e = pi \times 0.125^2 / 4 \times 0.6 = 7.36 \text{ ltrs then, } 7.36 / 20 \times 60 = 22.08 \text{ s} \quad \times$$

$\nwarrow 0.525$ 6.44 14.35 sec

Incorrect stroke length used in calculating volume.

$$d) \text{Velocity out} = \frac{0.6}{22.08} = 27 \text{ mm/s} \quad \checkmark$$

$$e) V_r = pi \times (0.125^2 - 0.06^2) / 4 \times 0.6 = 5.67 \text{ ltrs then, } 5.67 / 20 \times 60 = 17.01 \text{ s} \quad \times$$

$\nwarrow 0.525$ 14.95

The velocity in and out answers are correct by coincidence. Incorrect length and time.

$$f) \text{Velocity in} = \frac{0.6}{17.01} = 35 \text{ mm/s} \quad \checkmark$$

$$g) Wd = F \times d = 50 \times 10^3 \times 0.6 = 30 \text{ kJ then, } \rightarrow 26250 \text{ J}$$

$\nwarrow 0.525$

$$P = Wd/t = \frac{30 \times 10^3}{22.08} = 1358 \text{ W} \quad \checkmark$$

$26,250 / 19.3$

Methods are broadly correct, incorrect values obtained although correct Power has been established.

3 | Circuit Analysis

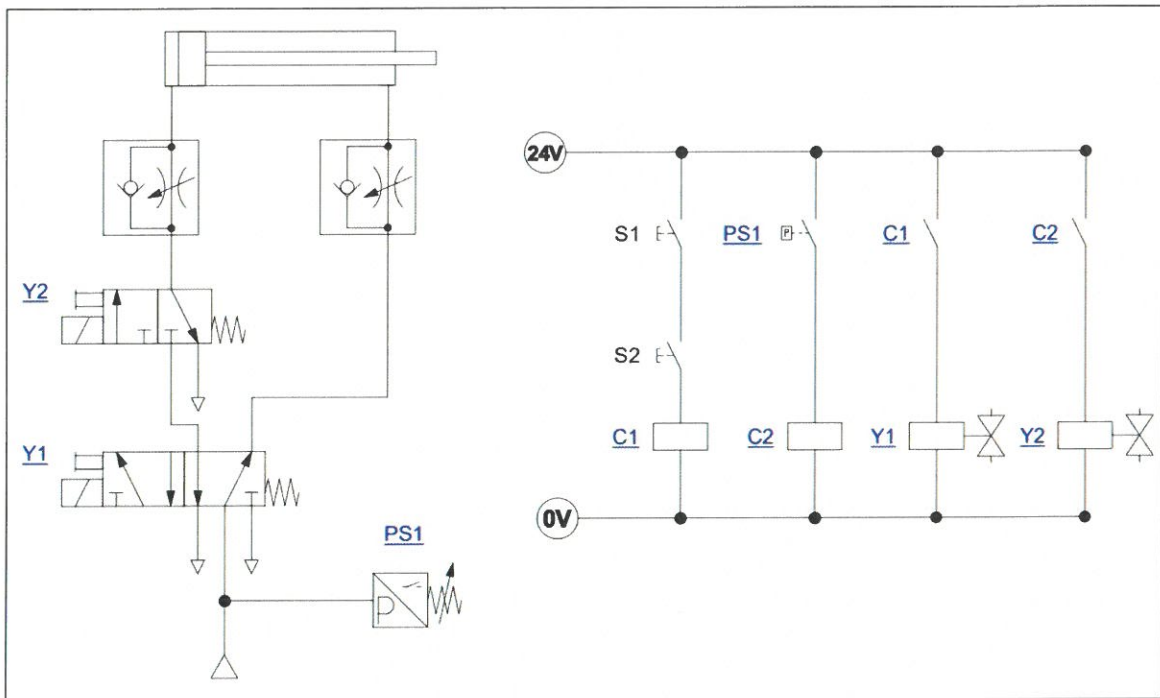


Figure 4: Electro-Pneumatic Cylinder system (supplied with assignment brief)

This pneumatic system illustrates a solenoid operated, double-acting cylinder assembly. ✓

With a step-by-step operation, a pneumatic pressure is applied into the system from an air source (represented by an upright triangle), where the air tees off to a relief valve (PS1) to the right. This valve is used as a means of protection in the event of too much pressure being supplied to the system (possibly from a fault) and damaging the components. This type of relief valve is spring loaded and will be set to lift at a designated pressure. *Switch at 9 bar.* ✓

The pneumatics then flows to a solenoid operated, spring return 5/2 directional control valve (located next to Y1). This type of valve has five I/O ports and two possible settings, with a switching method of an electrical solenoid and spring return. This valve dictates which of the above pictured pipelines either receive the flow pressure or are vented from the system. The two smaller upside-down triangles represent a vent point, either to atmosphere or a reservoir. ✓

Following the left-hand side flow, the pressure flow will travel to another control valve, similar to the first, although with a 3/2 port configuration. This directional valve is used as a secondary means of directing or venting flow from the system. This 'belt and braces' configuration has been installed so that the supply pressure will only reach the cylinder if two conditions are met (described later). ✓ *good.*

Continuing from the second control valve, the flow then passes through a pneumatic pressure gauge, which provides a physical representation of the current flow pressure, at either side of the cylinder. These have been implemented as a way for the user to monitor the system pressure to ensure that the system is operating as intended.

These devices are flow restrictors with non-return bypass valves.

The double acting cylinder is located at the top of the illustration. ✓ As described previously in chapter 1.1, this is a linear cylinder which can be toggled to either extend or retract depending on which input port is being supplied with pressure. ✓ With pressure being applied from the piping to the left of the illustration, the cylinder will extend, and once the control valves have been toggled back to their original positions, the cylinder will retract. ✓

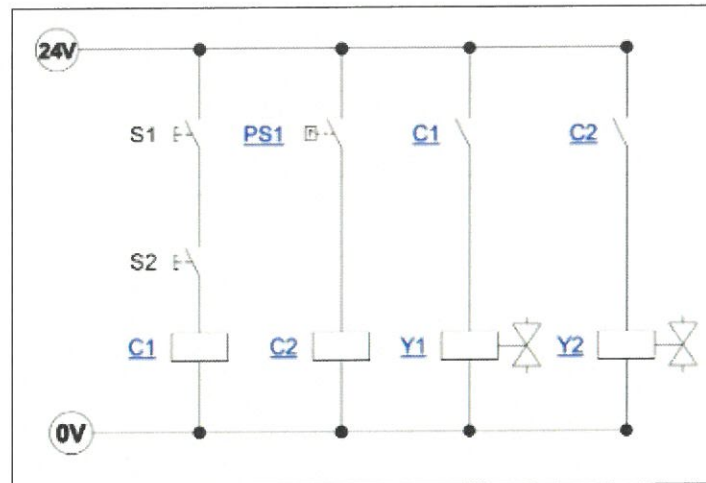


Figure 5: Electrical system (provided with assignment brief)

To elaborate on the electrical control portion of the system from left to right, the circuit begins with two, normally open switches (labelled S1 and S2) which, when activated, will energise an electrical relay (C1). ✓

rung. The second circuit in parallel has a similar construction to the first, however, a normally open input (PS1) has been placed in series with a second relay (C2). This N/O input is controlled by the pneumatic relief valve which was previously detailed. This contact will only be energized if the pneumatic supply pressure is within the set parameters of the relief device.

This previously described 'belt and braces' set-up has been implemented to create a cylinder operation condition with two safety measures, those being that of the two start buttons being pressed, and the system pressure being within an appropriate parameter. ✓ *why?*

The last two parallel circuits of the electrical system are matched in regard to components and operation, but not in what they are controlling. Both circuits feature a N/O switched contact (dictated by relays C1 and C2) in series with a solenoid. The first solenoid (Y1) controls the toggling function of the first directional control valve where, once energized, the solenoid will cause the valve to toggle to its left-hand setting, before spring returning once the solenoid has been de-energized. ✓

Similarly, the second solenoid (Y2) will operate the toggling function of the second control valve, once again switching to its left-hand configuration. ✓

A key component of the electric control system is that of the **electric relay**. ✓

In brief, a relay is used as an electro-magnetic switch, where instead of a standard, manual contact switch (such as a push button), this switch is activated via a small electric current being

applied to an electromagnet which, in turn, attracts a lever to make a contact.

One of the main attractions towards using a relay is that they can be used to control multiple switches implemented in multiple circuits, from one power signal. As well as being able to use a small control current to energise a larger current rated circuit. ✓

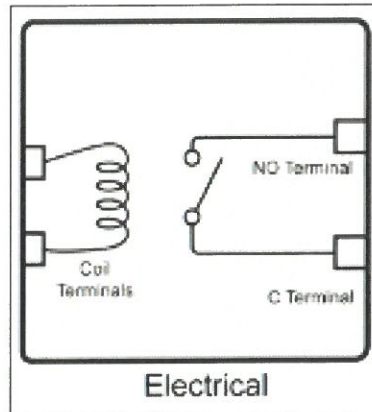


Figure 6: Magnetic relay (Automation Direct) (ref. date?) ✓

The use *figure 6* as a very basic visual aid, the current input will be applied to one side of the electrical coil (shown to the left of the illustration) which, when current is flowing through it, will produce an electromagnetic field within the housing of the relay. ✓

Once this magnetic field has been produced, it begins to attract the contact lever of the switch (central to the illustration) until the lever makes contact with the second pad of the switch, allowing for current to flow through the connected circuit. ✓

Relays come with a set amount of n/o and n/c contacts built in to the housing, allowing for the switching of multiple contacts at the same time. The input contacts (coil contacts) of the relay are commonly referred to as A1 and A2, with any subsequent, separate contacts being labelled as C1, C2 etc. ✓

4 | Circuit Design

4.1 | Pneumatic Conveyor

The following was requested within the assignment brief,

“At the end of a conveyor section, boxes are to be detected then lifted by a pneumatic cylinder, then pushed onto a second conveyor by a second cylinder. On this installation it is vital that the second cylinder should not return until the first one has fully retracted.”

The following circuit was designed and tested by the author.

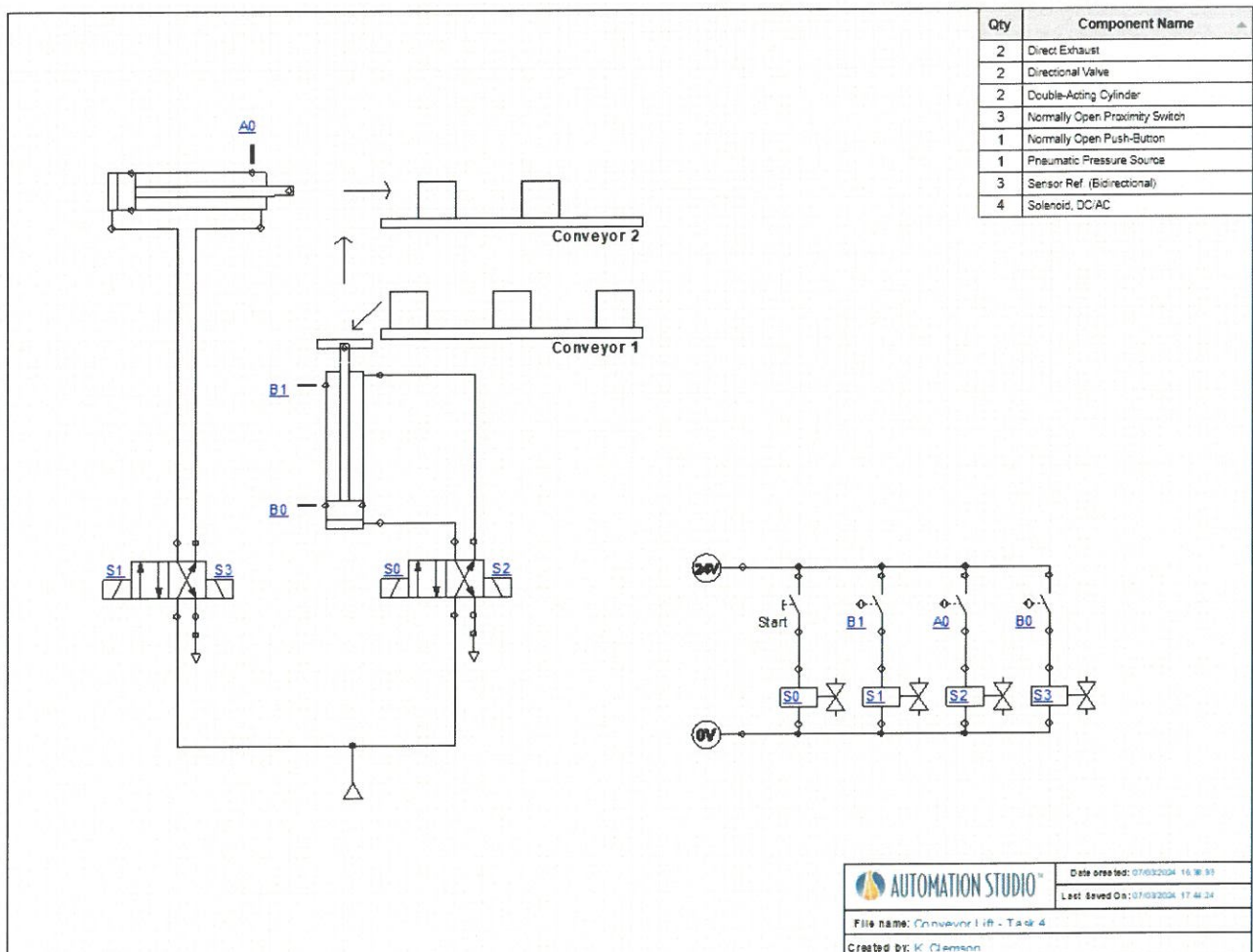


Figure 7: Pneumatic circuit designed by author, using Automation Studio

This system shares a similar operation to the one detailed previously in section 3 of the assignment, with the difference of no multiple start conditions being installed (from a pressure control valve or multiple start buttons) and only one direction control valve being used to control the direction of cylinder travel.

Another difference is the type of control valve being used. This system utilizes two 4/2 control valves which are solenoid operated on both sides of the valve, instead of a spring return.

The system has been designed so that both cylinders operate in a sequence (Up, right, then down, left) which satisfies the requirements of the assignment brief. ✓

This has been achieved by implementing three proximity sensors onto the base of each cylinder (A0 for the top cylinder, B0 and B1 for the lower cylinder) which tracks the current position of the cylinder piston.

Once the start button is pressed, the lower cylinder extends (controlled by solenoid 0). This extension is detected by proximity sensor B1, which closes an electrical contact and energises Solenoid 1 (S1), which toggles the control valve of the upper cylinder, allowing the piston to extend. ✓

Proximity sensor A0 detects this extension, and energises Solenoid 2 (S2), causing the lower control valve to toggle and the vertical cylinder to retract.

Finally, the retraction of the lower cylinder is detected by sensor B0, allowing Solenoid 3 to be energized and the upper cylinder to retract. ✓

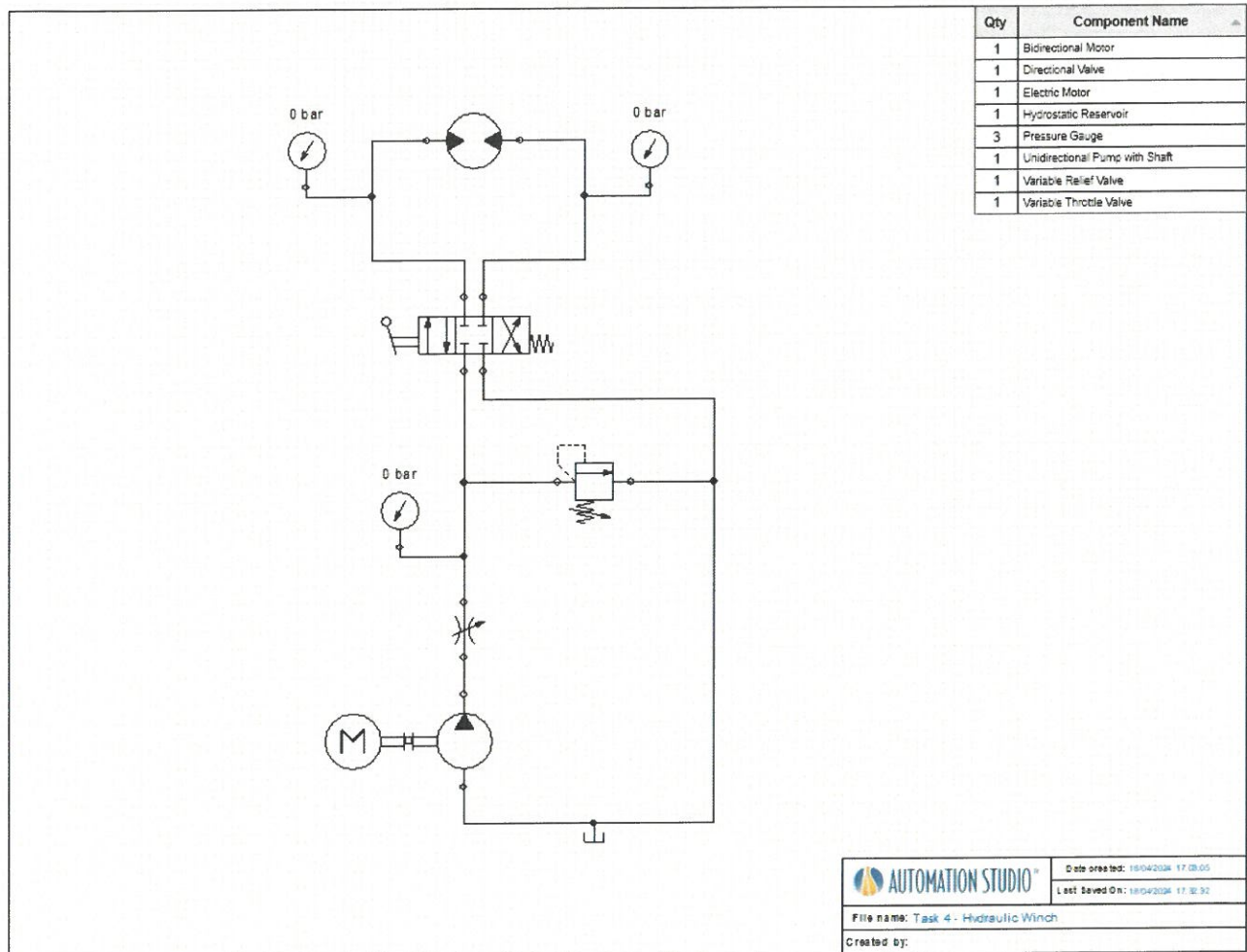
In a real-world industrial situation, the start button would not be a standard push-button, instead being another proximity sensor which would detect the presence of a container that is to be lifted and transferred to the next conveyor, ✓ Good.

4.2 | Hydraulic Winch

The following was requested within the assignment brief,

“A power winch is to be driven by means of bi-directional hydraulic motor the rotation speed of the motor is to be controllable (adjustable) in both directions of travel.”

The following circuit was designed and tested by the author.



For this system, a simple method of direction control has been used to alternate the winch's direction of travel.

The fluid flow pressure is supplied by means of a motor controlled, unidirectional, hydraulic pump, leading to a hydraulic flow speed gauge, and a pressure gauge allowing for the user to monitor the current supply pressure and flow speed.

Teeing off, a spring loaded, hydraulic pressure relief valve has been inserted. This component has been placed with the purpose of giving the supply pressure a route of travel when the winch is not in operation, or when a fault condition is present within the system.

Following from this is a manually controlled 4/3 flow direction control valve, with a spring-loaded return. The toggling of this control valve directly influences the direction of winch travel (clockwise or counter clockwise) depending on which configuration has been selected by the user.

A control valve with a third, stationary position was chosen so that the system can stay energized when the winch is not in operation, allowing for the winch to not be in constant motion, unless the supply motor is de-energised. ✓

Finally, two additional pressure gauges have been installed either side of the bidirectional motor (winch), which allow for the user to monitor the current pressure being transmitted into either side of the winch./ ✓

Appendix

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Automation Direct - <https://library.automationdirect.com/what-is-a-relay/> - (Relay diagram)



END

*Reference list should be
before the bibliography.*