

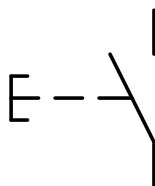
Blandede automasjonsoppgaver

Oppgaver

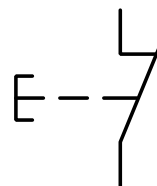
Oppgave 1

Brytere, om de er operert for hånd, en aktuator eller en fysiks prosess, kommer i to varianter: *normalt åpen* og *normalt lukket*. Du er sikkert vant til å se begge typer i skjemaer.

Normally-open pushbutton switch



Normally-closed pushbutton switch

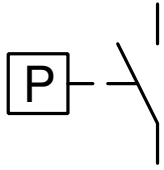


Normalt åpne brytere lukker (slepper strøm i gjennom) når de aktiveres. Når de deaktiveres, går tilbake til utgangposisjonen eller normalposisjonen.

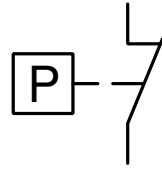
Normalt-lukkede brytere er helt motsatt: de åpner (stopper strømmen) når de aktiveres og går tilbake til lukket (normal) posisjon når de deaktiveres.

Definer "normalposisjonen" for disse bryterene. Med andre ord forklar hvilken prosess egenskap som må til for å holde den i normalposisjon og hva som aktiverer den.

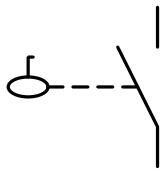
Pressostat NO



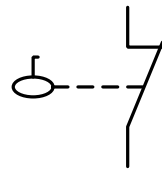
Pressostat NC



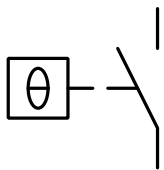
Niv bryter NO



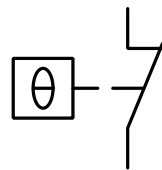
Niv bryter NC



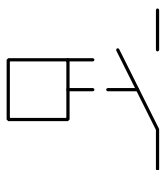
Temperaturbryter NO



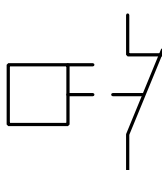
Temperaturbryter NC



Strømningsbryter NO



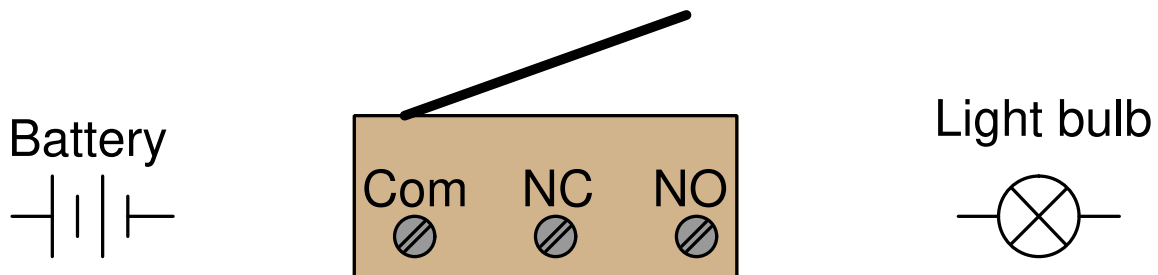
Strømningsbryter NC



Oppgave 2

Endebrytere er elektriske brytere som er laget slik at de aktueres ved bevegelse eller posisjon til et objekt, istedenfor at et menneske skal trykke inn en knapp. Enkle endebrytere bruker direkte fysisk kontakt med en arm, og av og til en rulle på enden for lav friksjon.

Direct-contact limit switch



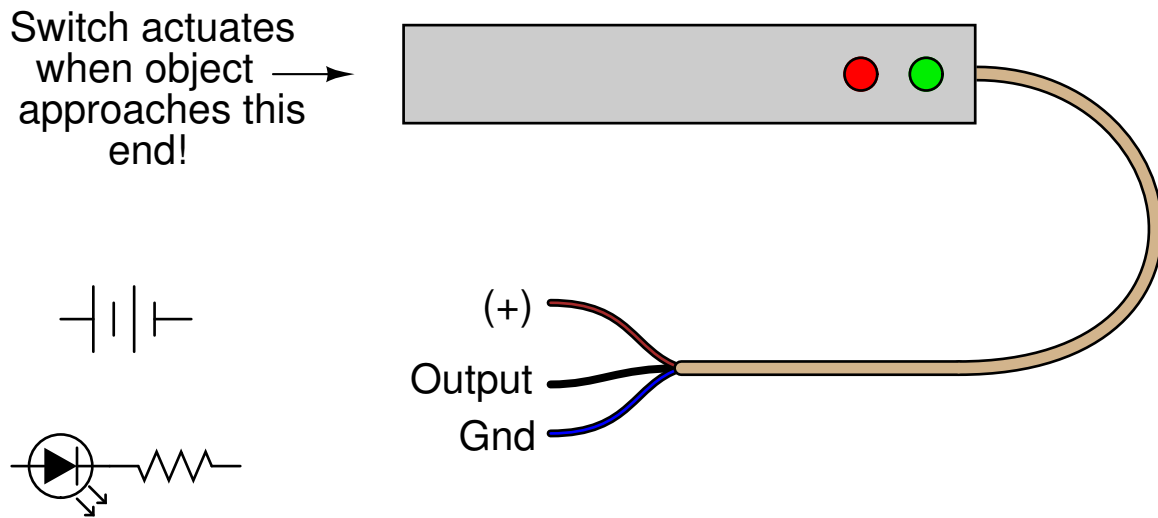
Vis hvordan du ville koblet kretsen ovenfor slik at endebryteren slukker lyset når den aktueres. Lyset skal altså normalt være på.

[file i02242](#)

Oppgave 3

En forbedring i forhold til endebrytere med fysisk kontakt kan i mange tilfeller være induktive nærhetssensorer. Denne type bryter aktiveres ved at et objekt kommer nærme den. Det er ikke nødvendig med fysisk kontakt. Forklar hvordan denne type bryter virker, og hvilke materialer den kan detektere.

Induktive nærhetssensorer trenger driftsspenning. Det er vanlig med +24V DC. Utgangen er normalt ikke en potensialfri kontakt, men en transistor.



Vis hvordan du ville koblet kretsen nedenfor slik at LED-en lyser når sensoren aktiveres. Anta at utgangen er sourcing (PNP).

Suggestions for Socratic discussion

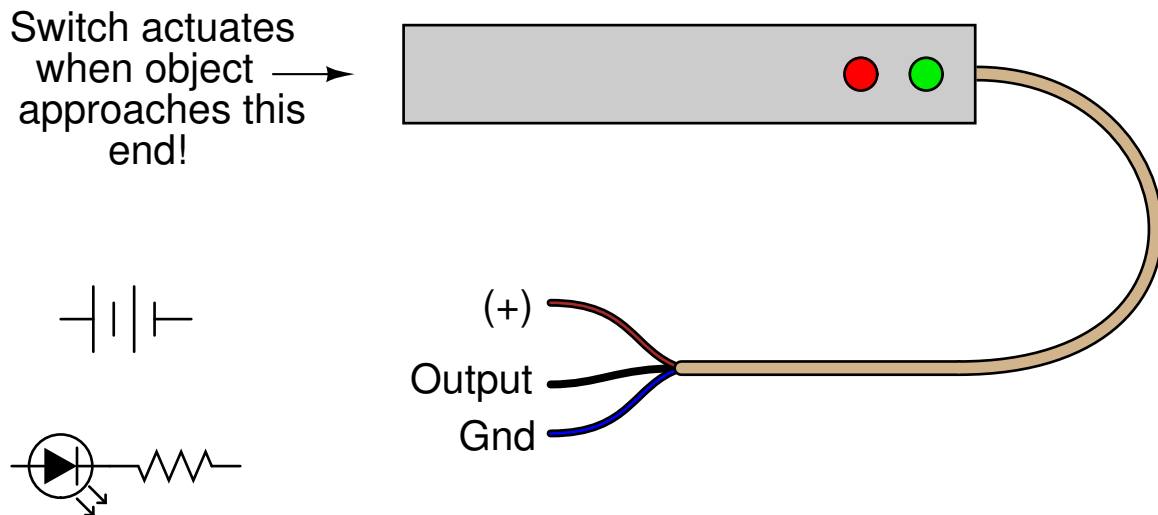
- Identify an object a capacitive proximity switch would be able to detect.
- Identify an object an ultrasonic proximity switch would be able to detect.
- Identify an object an inductive proximity switch would *not* be able to detect.
- Identify an object an optical proximity switch would *not* be able to detect.

[file i02243](#)

Oppgave 4

En forbedring i forhold til endebrytere med fysisk kontakt kan i mange tilfeller være kapasitive nærhetssensorer. Denne type bryter aktiveres ved at et objekt kommer nærme den. Det er ikke nødvendig med fysisk kontakt. Forklar hvordan denne type bryter virker, og hvilke materialer den kan detektere.

kapasitive nærhetssensorer trenger driftsspenning. Det er vanlig med +24V DC. Utgangen er normalt ikke en potensialfri kontakt, men en transistor.



Vis hvordan du ville koblet kretsen nedenfor slik at LED-en lyser når sensoren aktiveres. Anta at utgangen er sinking (NPN).

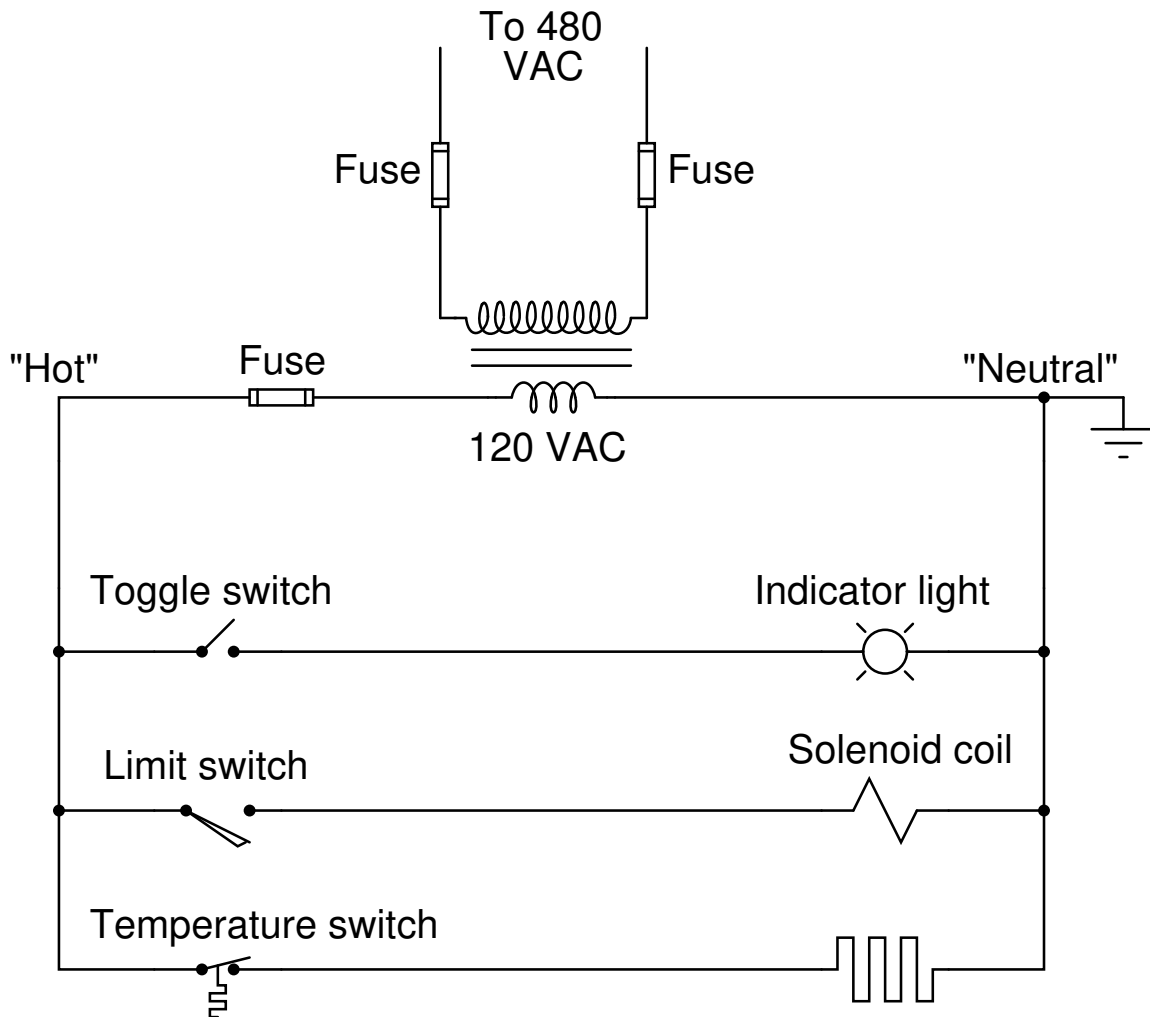
Suggestions for Socratic discussion

- Identify an object an inductive proximity switch would be able to detect.
- Identify an object an optical proximity switch would be able to detect.
- Identify an object a capacitive proximity switch would *not* be able to detect.
- Identify an object an ultrasonic proximity switch would *not* be able to detect.

[file i02244](#)

Oppgave 5

I USA tegnes styrestrømsskjema i noe som kalles stigediagram eller ladder diagram. I denne type skjema er snudd 90° i forhold til norske skjema.

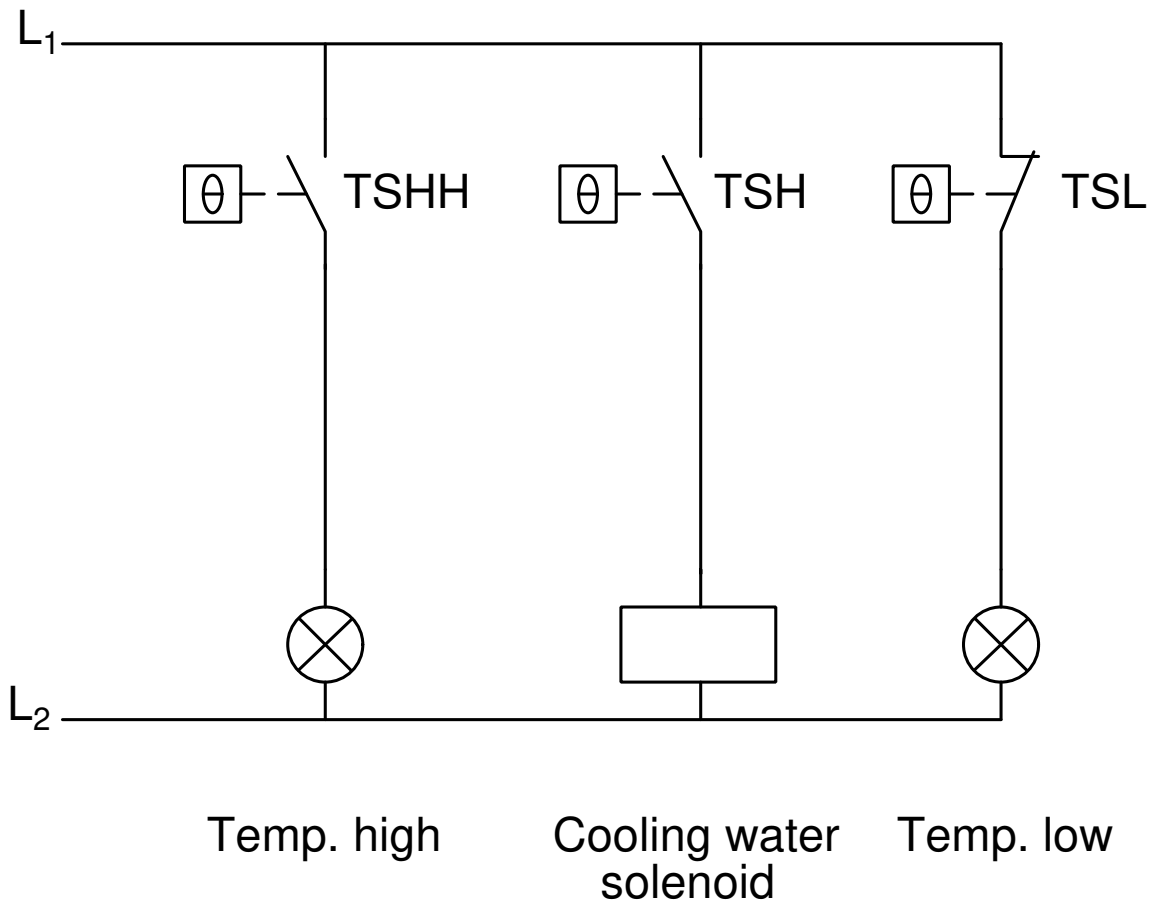


Tenk deg frem til betydningen av skjemaet ovenfor og tegn det på norsk måte (styrestrømsskjema). Du kan tegne på papir eller i PC|Schamtic.

[file i02302](#)

Oppgave 6

Forklar funksjonen til dette styrestrømsskjemaet. Skriv også opp navn på symboler og hva referansebetegnelse står for.

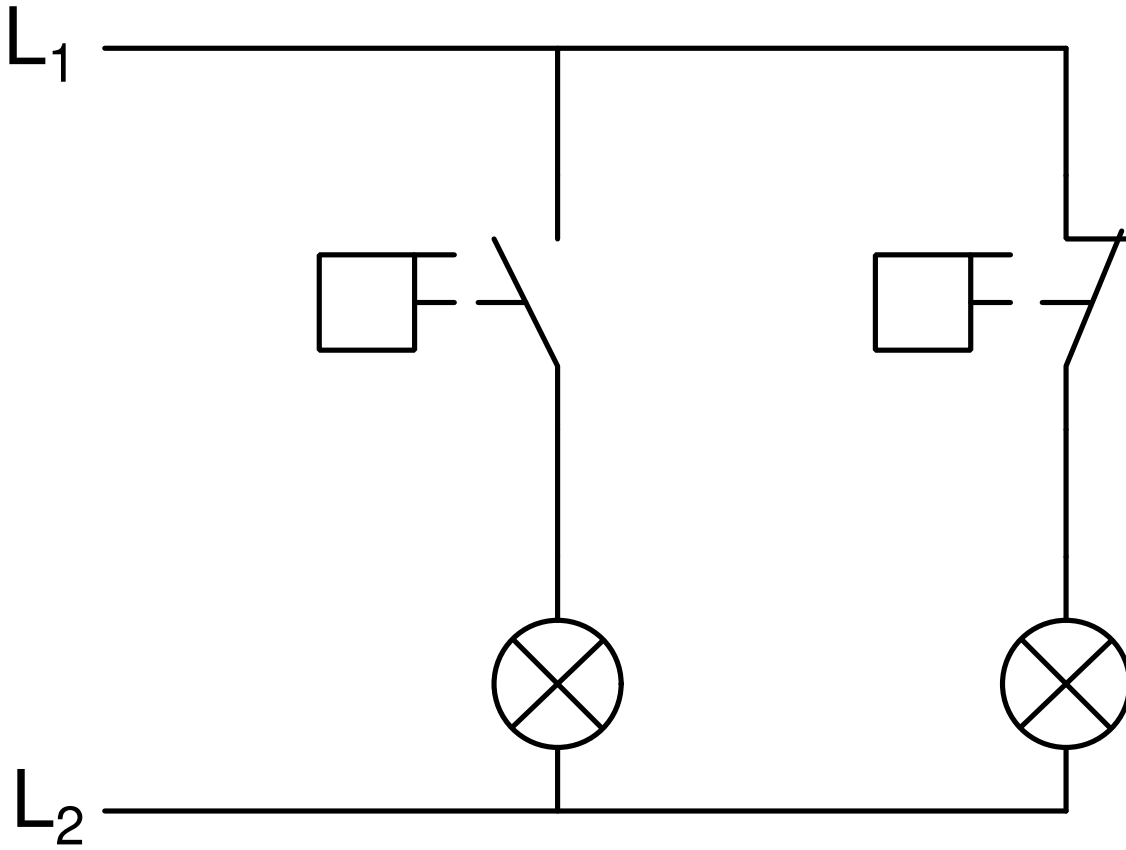


Suggestions for Socratic discussion

- Explain why the TSHH uses a *normally-closed* contact instead of a *normally-open* contact.
- Explain why the TSL uses a *normally-closed* contact instead of a *normally-open* contact.
- Based on what we see in this diagram, determine whether the electric solenoid valve allows cooling water to flow when energized, or when de-energized.
- What do the designations “L1” and “L2” refer to in ladder-logic electrical diagrams?
- Suppose switch TSL has a trip setting of 105 °F (falling) and a deadband value of 2 °F. Explain how this switch will respond to a rising and falling temperature.
- Suppose we wished to have switch TSHH activate *two* different alarm lights instead of just one. Modify the circuit diagram accordingly.

Oppgave 7

Dette styrestrømsskjemaet viser en alarmkrets for høy strømning (FAH) og lav strømning (FAL). Merk hver av bryterne med FAH og FAL.

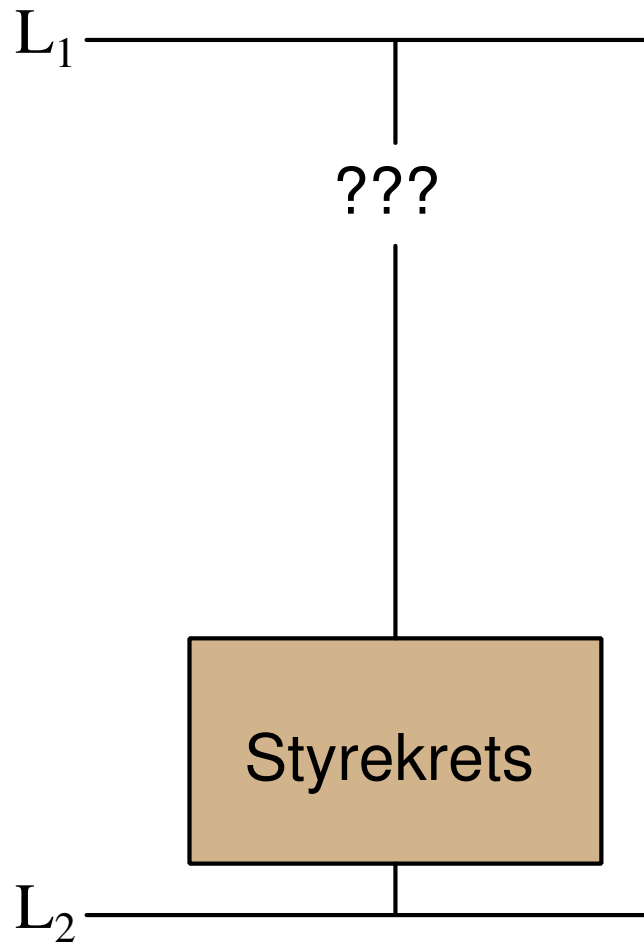


file i00548

Oppgave 8

Endebrytere brukes ofte på elektriske kapslinger for å skru av strømmen når døren åpnes for vedlikehold. Endebryteren monteres ofte slik at døren holder den i aktivert posisjon, når døren åpnes går bryteren til sin normale posisjon.

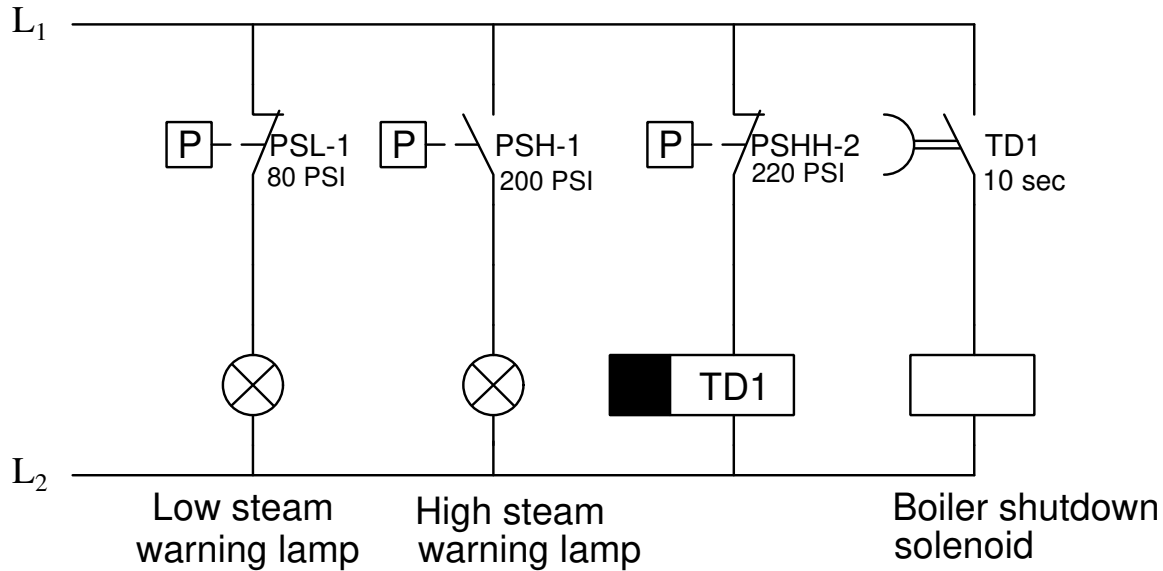
Tegn det nødvendige bryter symbolet i kretsen nedenfor slik at bryteren bryter strømmen til styrekretsen når døren åpnes.



Pass på om bryteren trenger å være NO eller NC
[file i02967](#)

Oppgave 9

Tenk deg frem til funksjonen til alle pressostater og releer i denne kontrollkretsen for en damp generator. Hva betyr diagnostikk meldingene?



Forklar også betydningen av brytersymbolet: NO i forhold til NC. Tidsreleet er spesielt viktig her.

Til slutt skal du legge til en bryter for lamptest. Denne skal "teste" alle lamper når en byrter trykkes inn. Finn også ut hvor i NEK EN 60204-1 det settes krav til kamptest for alarmlys.

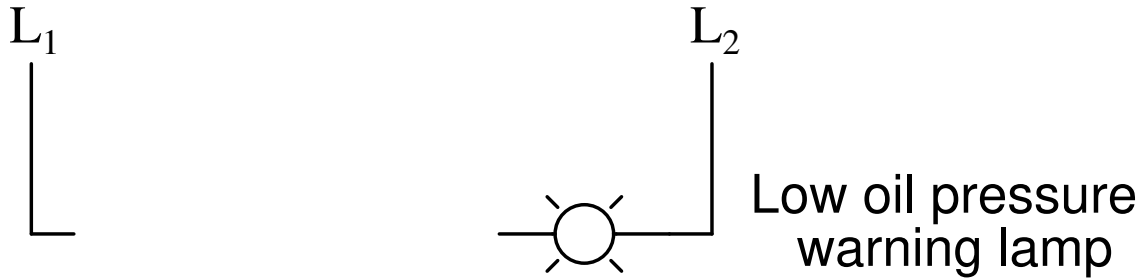
Suggestions for Socratic discussion

- Why do you suppose a time-delay relay is used in this particular control application?
- Is the boiler shutdown solenoid *energize-to-trip* or *de-energize-to-trip*? Explain how we can tell from an examination of the schematic.
- Identify a circuit fault that would cause the boiler to needlessly shut down (a “safe” fault).
- Identify a circuit fault that would cause the boiler to not be able to shut down when it needs to (a “dangerous” fault).

file i00221

Oppgave 10

Tegn det rette trykkbrytersymbolet i dette skjemaet for den lavt trykk alarm (PAL), som skrur på lyset om oljetrykket på en industriell maskin faller under 1 bar.

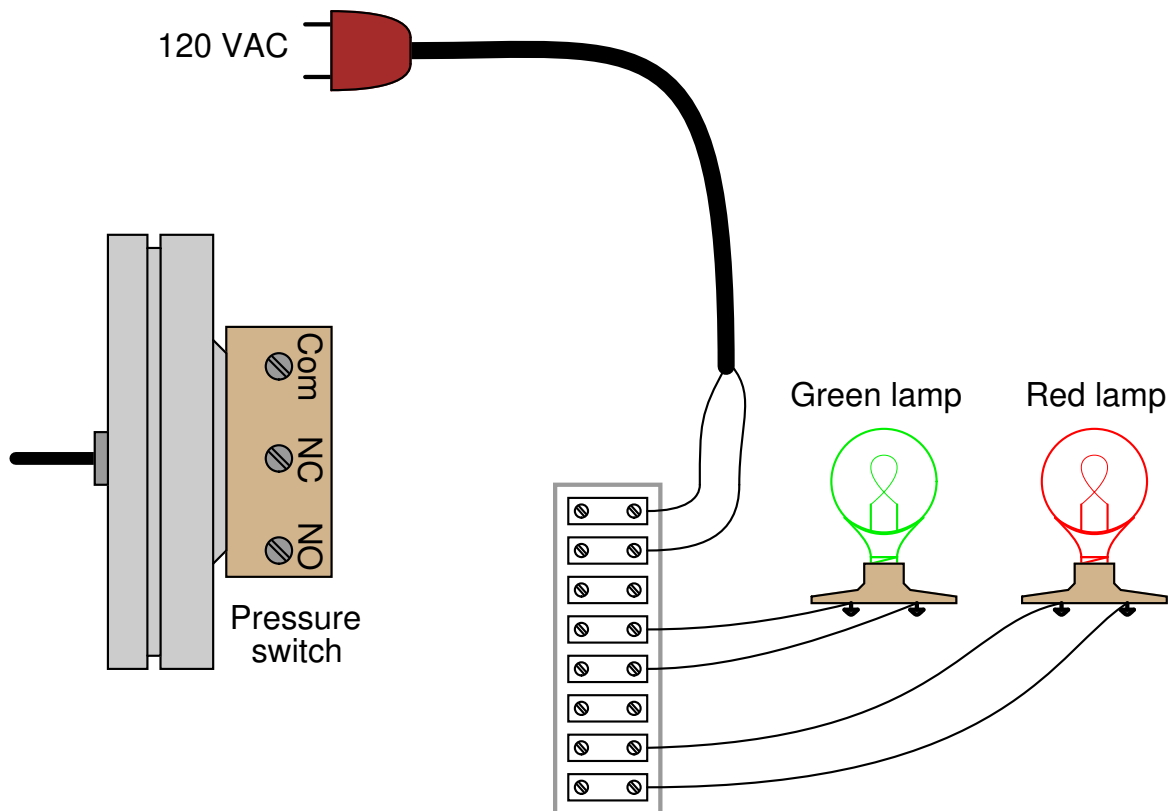


Vær nøde med om bryteren trenger å være NO eller NC.
[file i02965](#)

Oppgave 11

Tegn nødvendige koblinger for å få denne trykkbryteren til å styre lampene på følgende måte.

- Høyt prosesstrykk: grønt lys på og rødt av.
- Lavt prosesstrykk: rødt lys på og grønt lys av.



Hint: remember that the “normal” status of a switch is defined as the status of *minimum stimulus*: when the switch is exposed to the lowest possible degree of process stimulation (in this particular case, to the lowest possible pressure).

[file i03251](#)

Oppgave 12

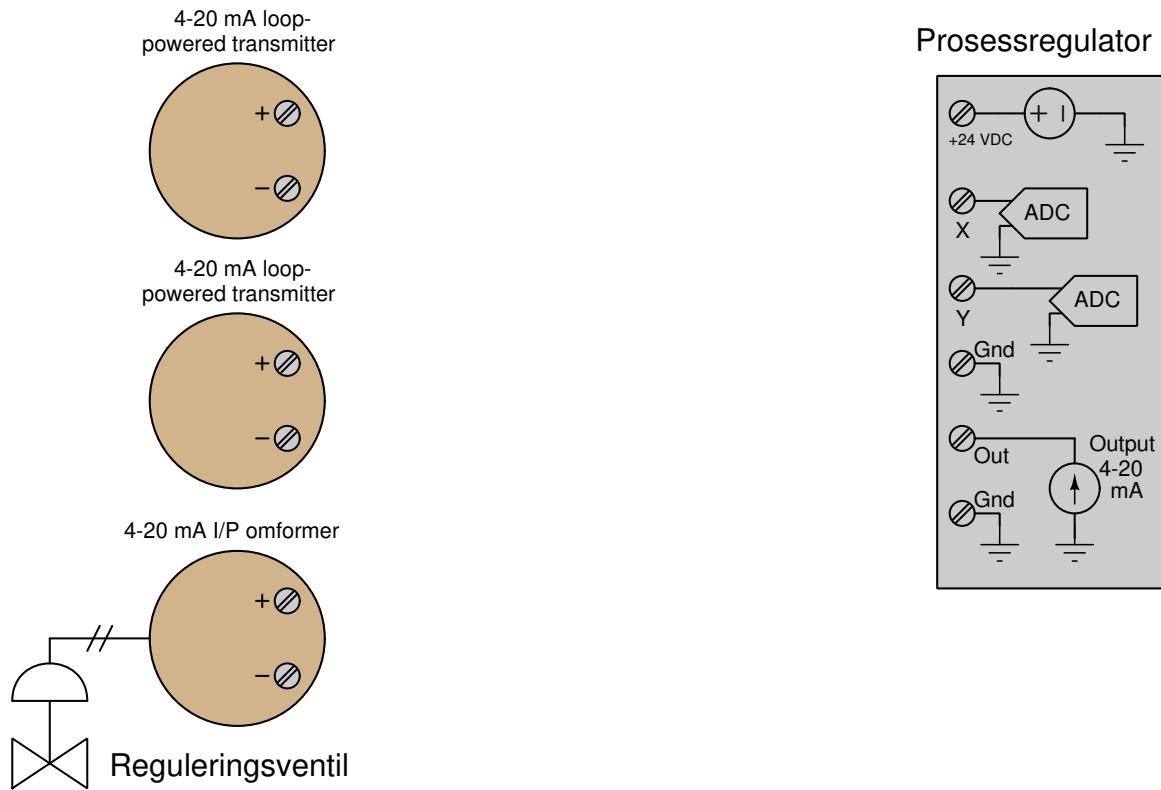
Tegn et styrestrømsskjema for en elektrisk motor til en luftkompressor. Denne kretsen skal å to pressostater som starter motoren når trykket faller under 80 PSI, og en annen som slår den av når trykket kommer over 105 PSI.

Ta også med overbelastningsvern i styrekretsen og inkluder en manuell styring også.

[file i00799](#)

Oppgave 13

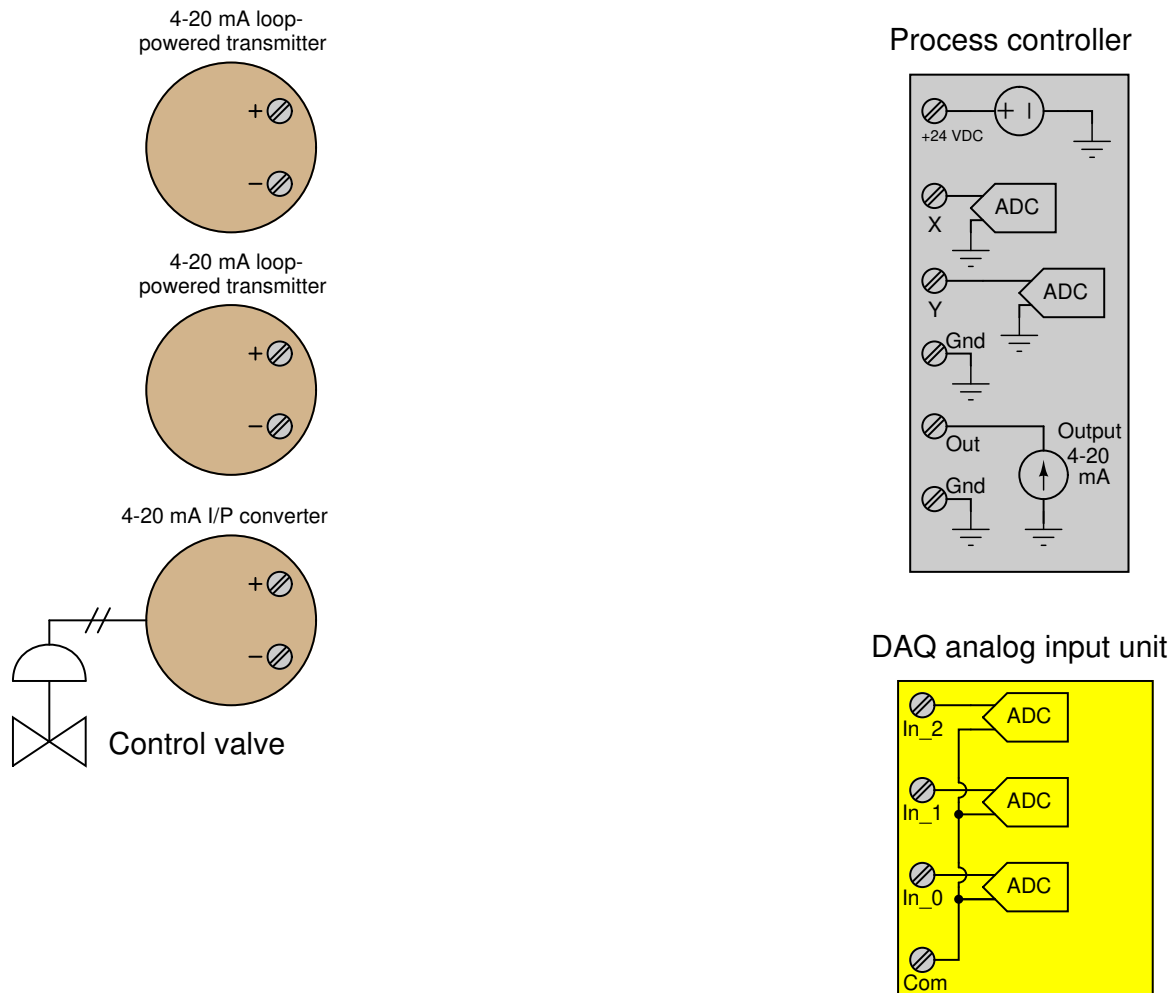
Shown here is a pair of loop-powered 4-20 mA process transmitters, a process controller with dual measurement inputs, and a 4-20 mA I/P (current-to-pressure) converter used to drive a pneumatically-actuated control valve. The controller inputs are ranged from 1 to 5 volts DC, not 4-20 mA:



Show how all three field devices would properly connect to the controller, including the placement of resistors to convert the current signals into voltage signals that the controller's ADC's may interpret. Furthermore, use shielded cable, showing where all shield ground connections should be located.

Oppgave 14

Shown here is a pair of loop-powered 4-20 mA process transmitters, a process controller with dual measurement inputs, a 4-20 mA I/P (current-to-pressure) converter used to drive a pneumatically-actuated control valve, and a DAQ (data acquisition) unit for interfacing to a computer. Both the process controller and DAQ unit inputs are ranged from 1 to 5 volts DC, not 4-20 mA:



Show how all three field devices would properly connect to the controller and to the DAQ unit at the same time, including the placement of resistors to convert the current signals into voltage signals that both the controller and the DAQ may interpret.

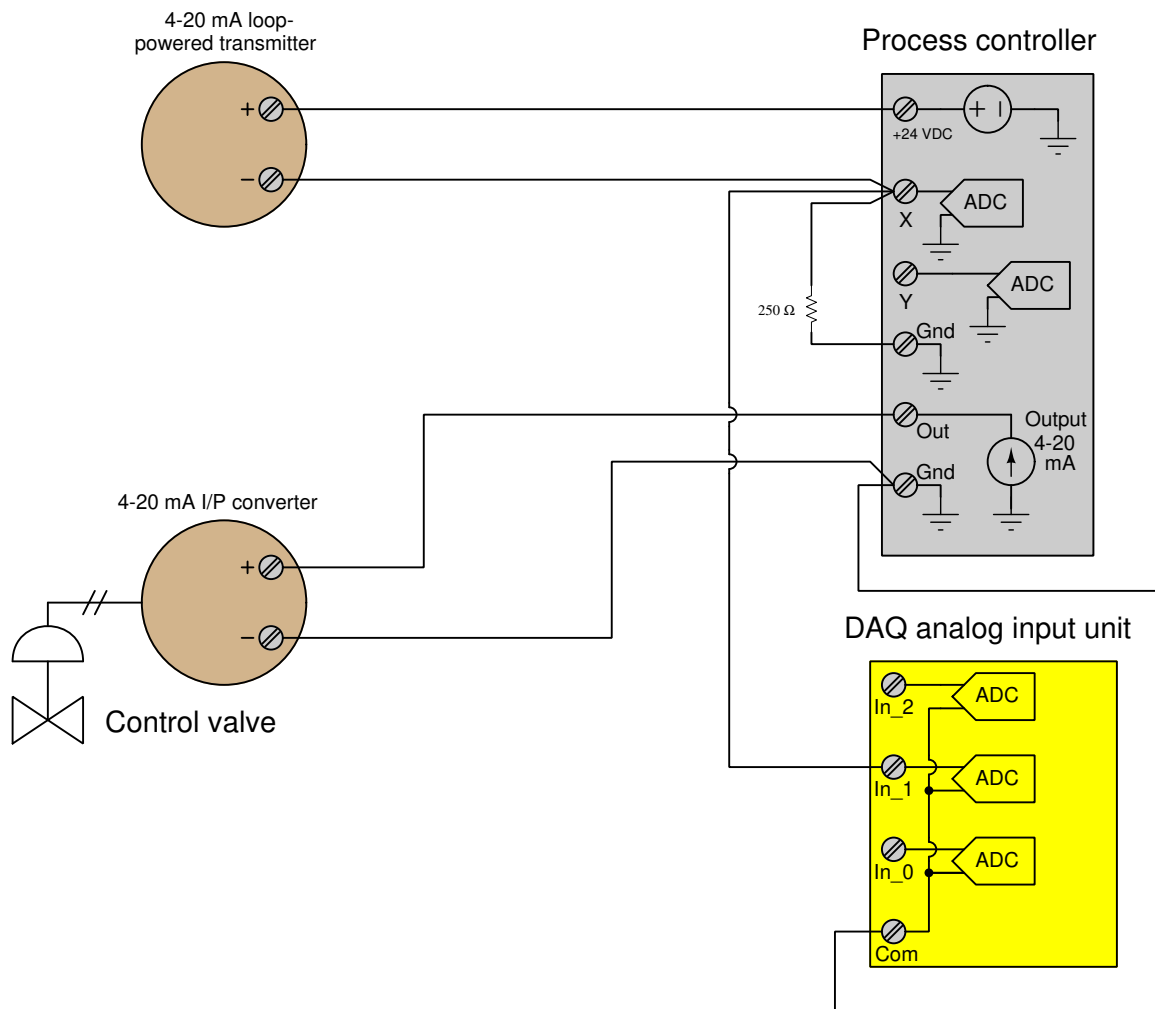
Suggestions for Socratic discussion

- A problem-solving technique useful for making proper connections in pictorial circuit diagrams is to first identify the directions of all DC currents entering and exiting component terminals, as well as the respective voltage polarity marks (+, -) for those terminals, based on your knowledge of each component acting either as an electrical *source* or an electrical *load*. Discuss and compare how these arrows and polarity marks simplify the task of properly connecting wires between components.
- After you have sketched your circuit, evaluate the effects of various components failing either open or shorted, one at a time.

file i02274

Oppgave 15

In this system a loop controller receives a process variable signal from a 2-wire (loop-powered) transmitter, and sends its own 4-20 mA control signal to operate a control valve. A data acquisition unit (DAQ) performs the auxiliary function of monitoring the process variable signal (voltage dropped across the loop resistor) and reporting it over a digital network where it is recorded on the hard drive of a personal computer. If it helps, you may think of a DAQ as being nothing more than a multi-channel voltmeter, sensing voltage between each of its input terminals (In_1 , In_2) and its “common” (Com) terminal:



Unfortunately, the DAQ not only registers the DC signal value, but also any HART pulses present in the transmitter circuit whenever a technician connects a HART communicator to the transmitter to do any maintenance work. The operators are annoyed by the misleading “noise” on the DAQ-recorded signal whenever a technician does routine work on that transmitter, and so they come to you asking for a solution.

Devise a simple modification to this circuit that will eliminate (or at least minimize) the “HART noise” seen by the DAQ without impeding its ability to record normal process variable signal values.

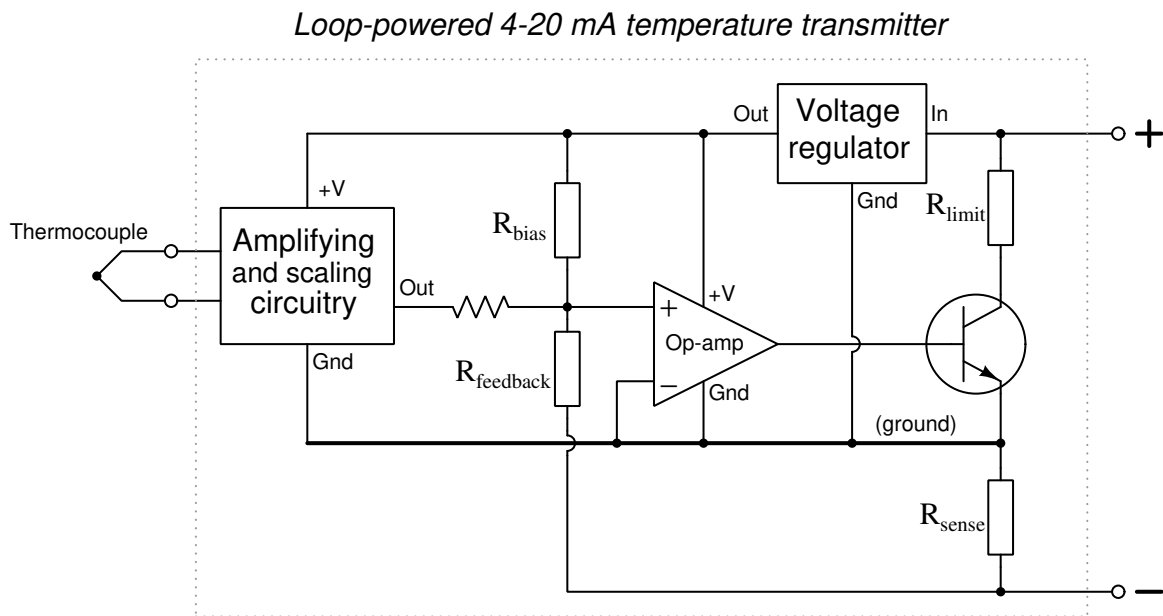
Suggestions for Socratic discussion

- A useful problem-solving technique is to sketch a simple diagram of the system you are asked to analyze. This is useful even when you already have some graphical representation of the problem given to you, as a simple sketch often reduces the complexity of the problem so that you can solve it more easily. Draw your own sketch showing how the given information in this problem inter-relates, and use this sketch to explain your solution.
- A useful analytical technique for any DC electric circuit is to identify all electrical sources and loads in the circuit, annotate the diagram with arrowheads showing the directions of all currents, and also with “+” and “−” symbols (and/or curved arrows) showing the polarities of all component voltages. Show how this helps you analyze the circuit shown in this question.

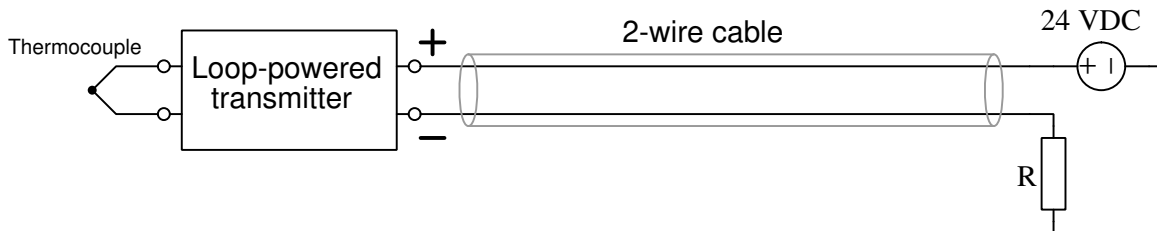
file i02557

Oppgave 16

Kretsen under er for en forenklet 2-leder 4-20mA temperatur transmitter.



Resten av kretsen ser slik ut:



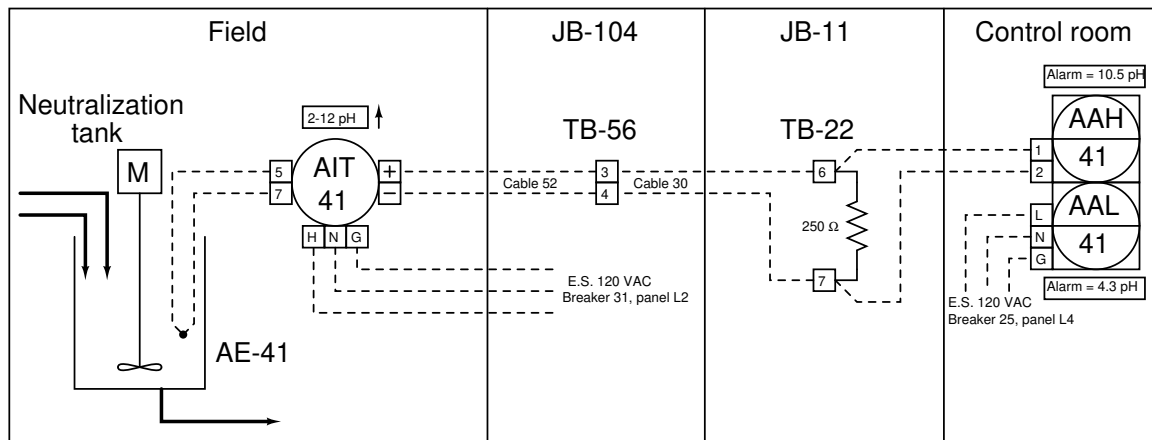
Regn ut strømmen ut fra emitter på transistoren inne i transmitteren, gitt følgende betingelser:

- Måleomtåde = 50 to 250 degrees C
- Temperatur for termoelement = 100 degrees C
- Forsyningsspenning = 24.0 volts
- Sløyferesistans = 250 ohms
- Spenningsregulatorens inngangstrøm = 3.7 mA (konstant)

Tegn også inn strømretning for alle strømmer inne i transmitteren.
[file i00397](#)

Oppgave 17

This pH monitoring system triggers an alarm if the pH value of the process water in the neutralization tank drifts past either of two threshold (trip) values:



Answer the following questions about this pH alarm system:

- If a wire breaks loose at TB56-4, creating an “open” fault in the loop circuit, determine what will happen at the alarm unit (AAH, AAL-41) and also where you would expect to measure voltage in the loop circuit and where you would expect to measure *no* voltage in the loop circuit.
- If breaker #25 in panel L4 suddenly trips, what will happen in this system? Will an operator still be able to read the pH value of the water in the neutralization tank?
- If a fire breaks out near the conduit through which cable 52 runs, causing the plastic insulation around the conductors of cable 52 to melt and consequently causing those conductors to *short* together, what will happen in this system? Where would you expect to measure voltage in the loop circuit, and where would you expect to measure *no* voltage in the loop circuit? Where would you expect to measure current in the loop circuit, and where would you expect to measure *no* current in the loop circuit?
- Calculate the loop current value when the pH measures 6.8 inside the neutralization tank.

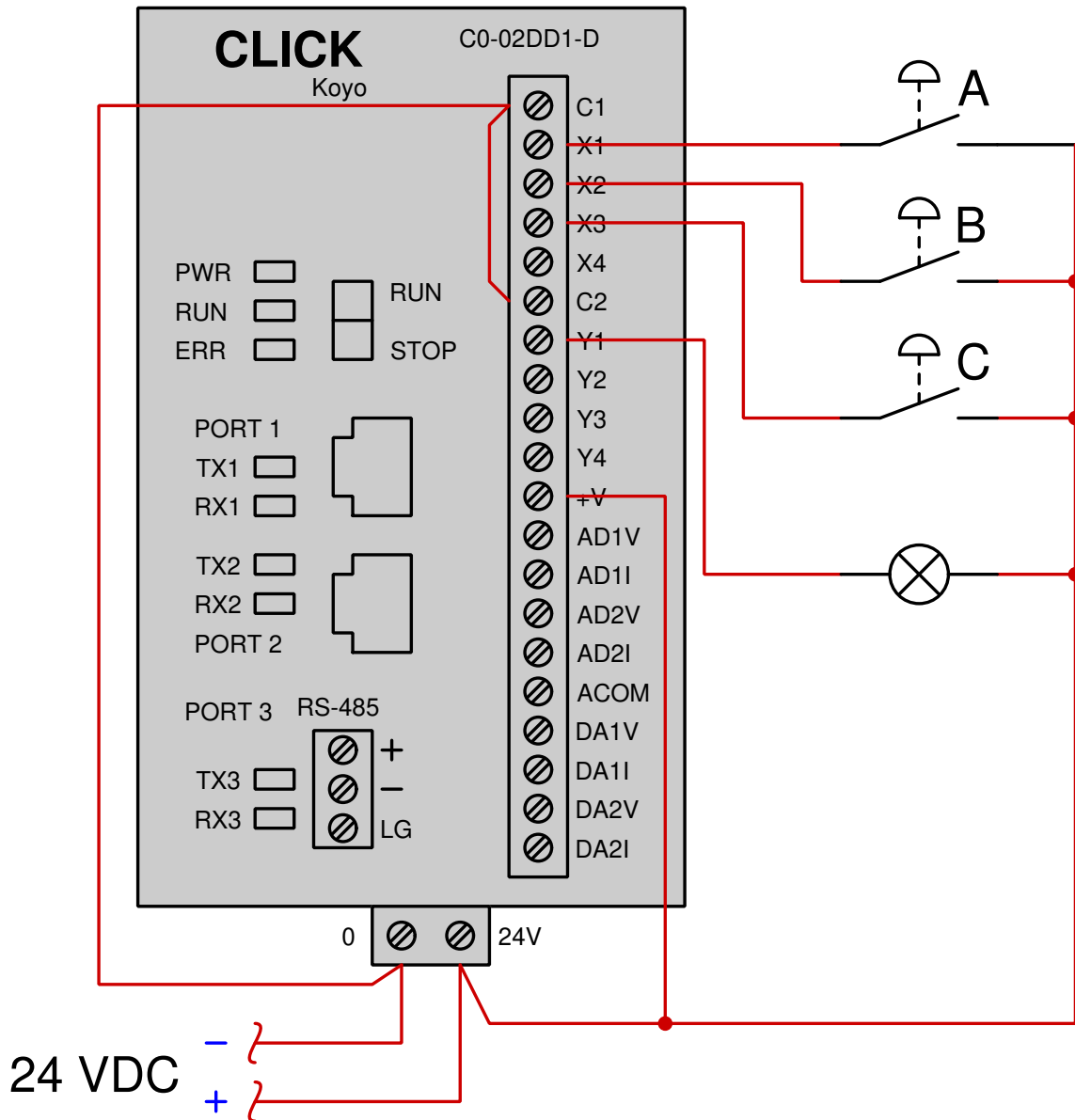
Suggestions for Socratic discussion

- For those who have studied pH measurement, explain why pH “neutralization” is an important control process in industry.
- How can we tell from this diagram whether the 4-20 mA output of transmitter AIT-41 is *active* or *passive* (i.e. *sourcing* or *sinking*)?

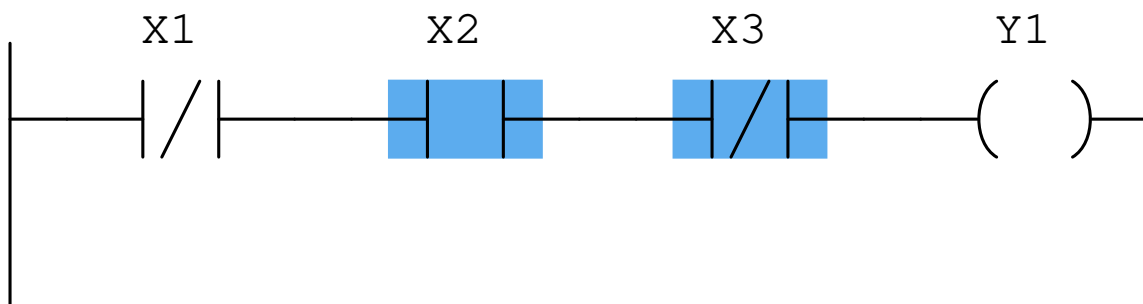
[file i00239](#)

Opgave 18

Suppose we have a Koyo “CLICK” PLC connected to three pushbutton switches as shown in this illustration:



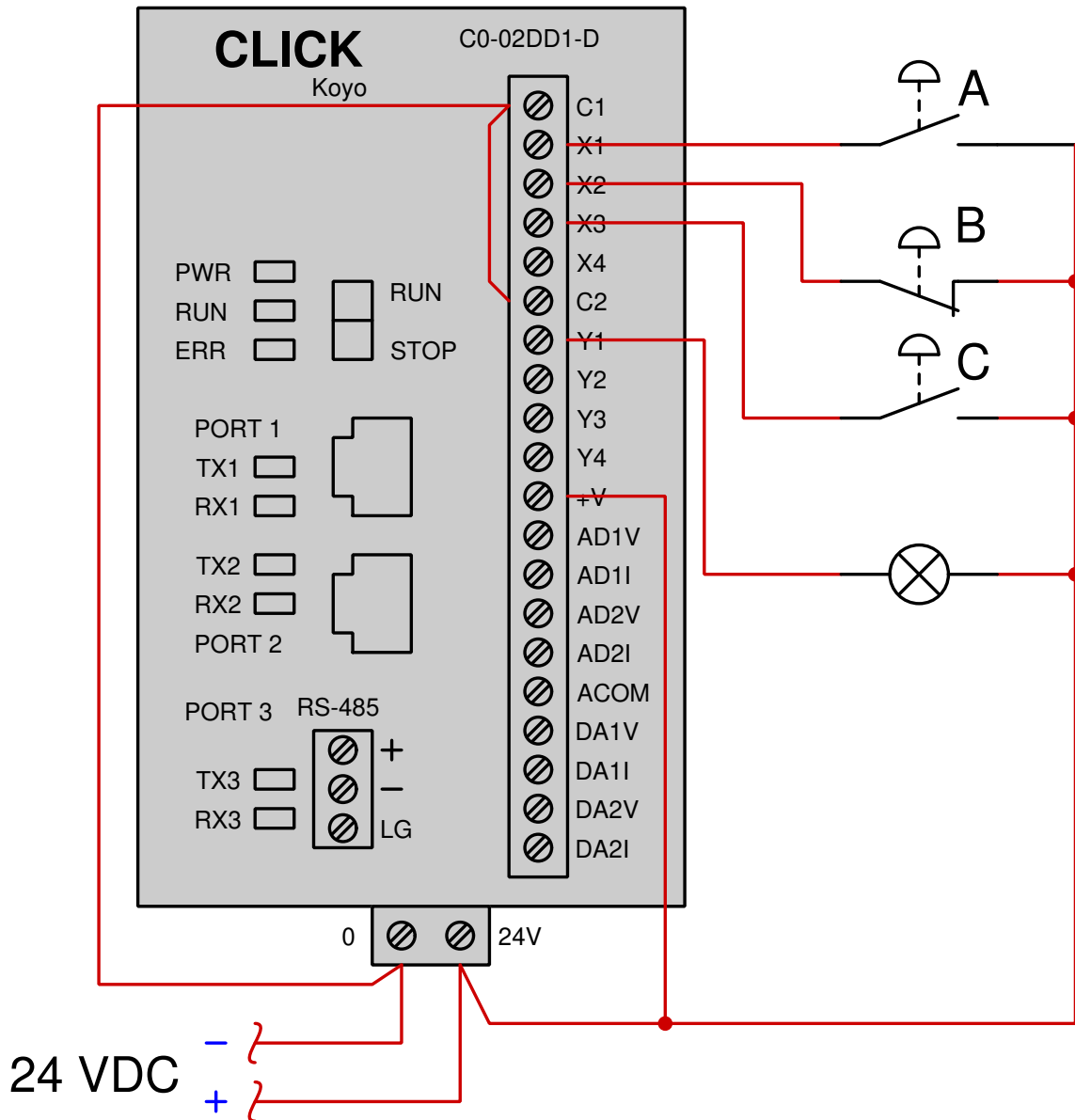
Determine the switch actuation statuses (i.e. pressed versus released) given the “live” display of the ladder logic program shown here:



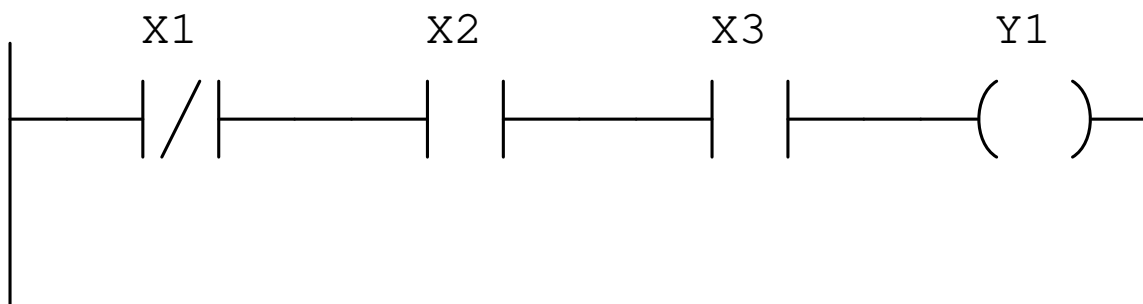
Also, determine the status of the lamp connected to the PLC's Y1 output.
file i04666

Opgave 19

Suppose we have a Koyo “CLICK” PLC connected to three pushbutton switches as shown in this illustration:

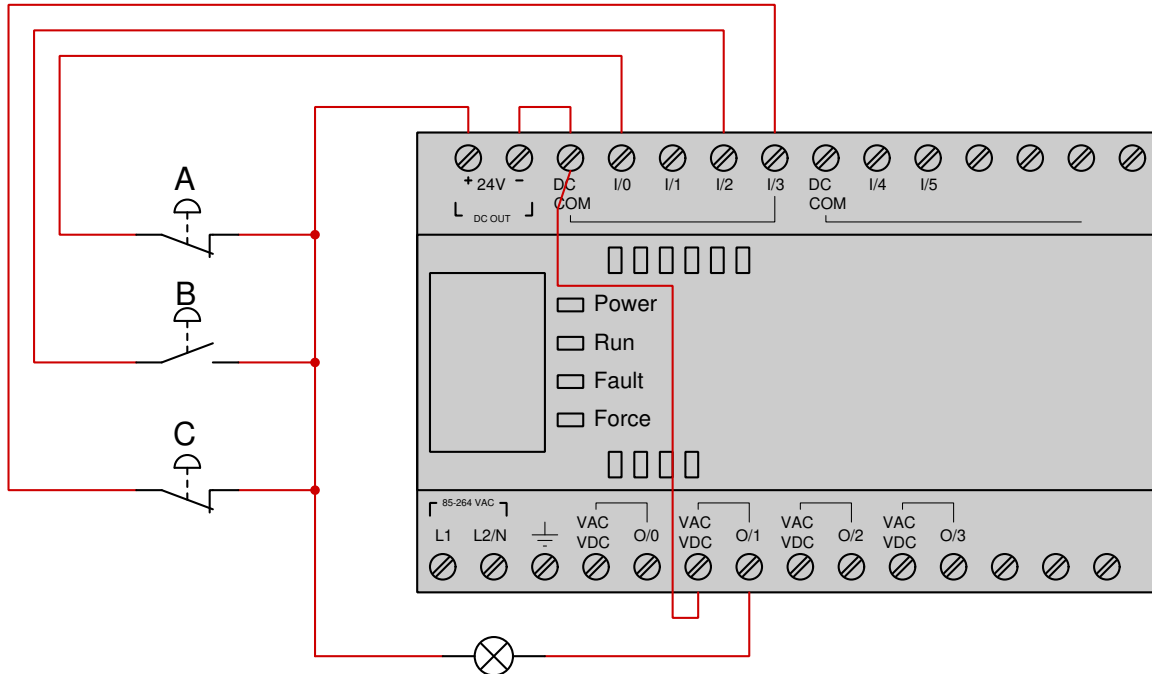


Determine the necessary switch actuation statuses (i.e. pressed versus unpressed) to turn the lamp on given the following program running in the PLC:

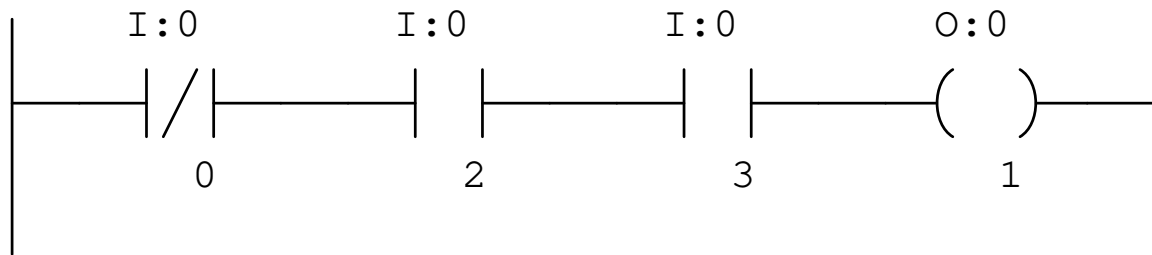


Oppgave 20

Suppose we have an Allen-Bradley MicroLogix 1000 controller connected to three push-button switches as shown in this illustration:

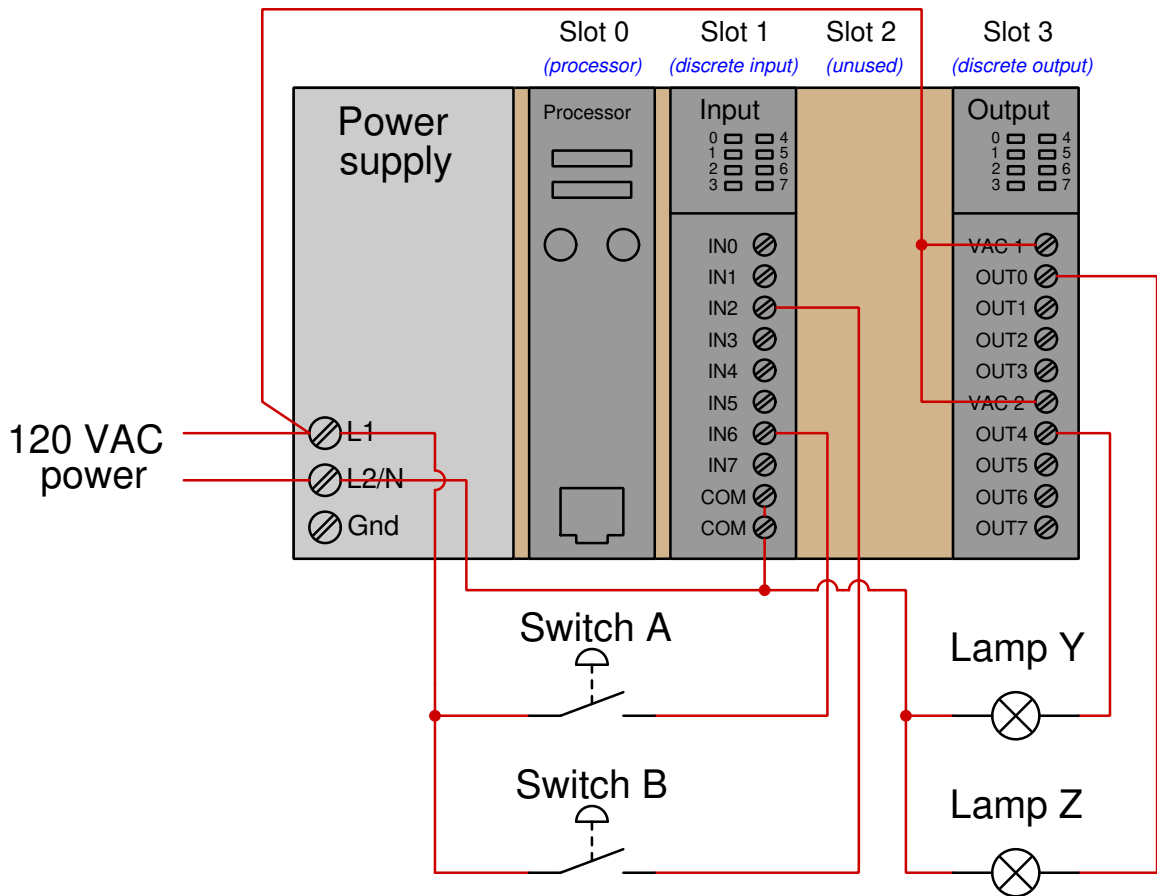


Determine the necessary switch actuation statuses (i.e. pressed versus unpressed) to turn the lamp on given the following program running in the PLC:

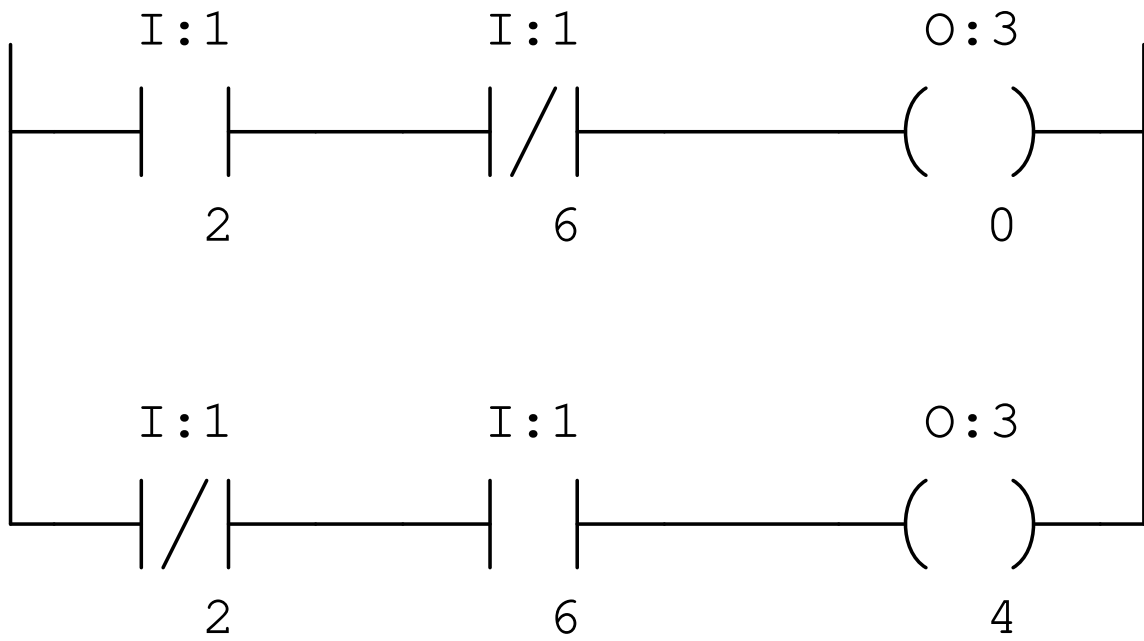


Oppgave 21

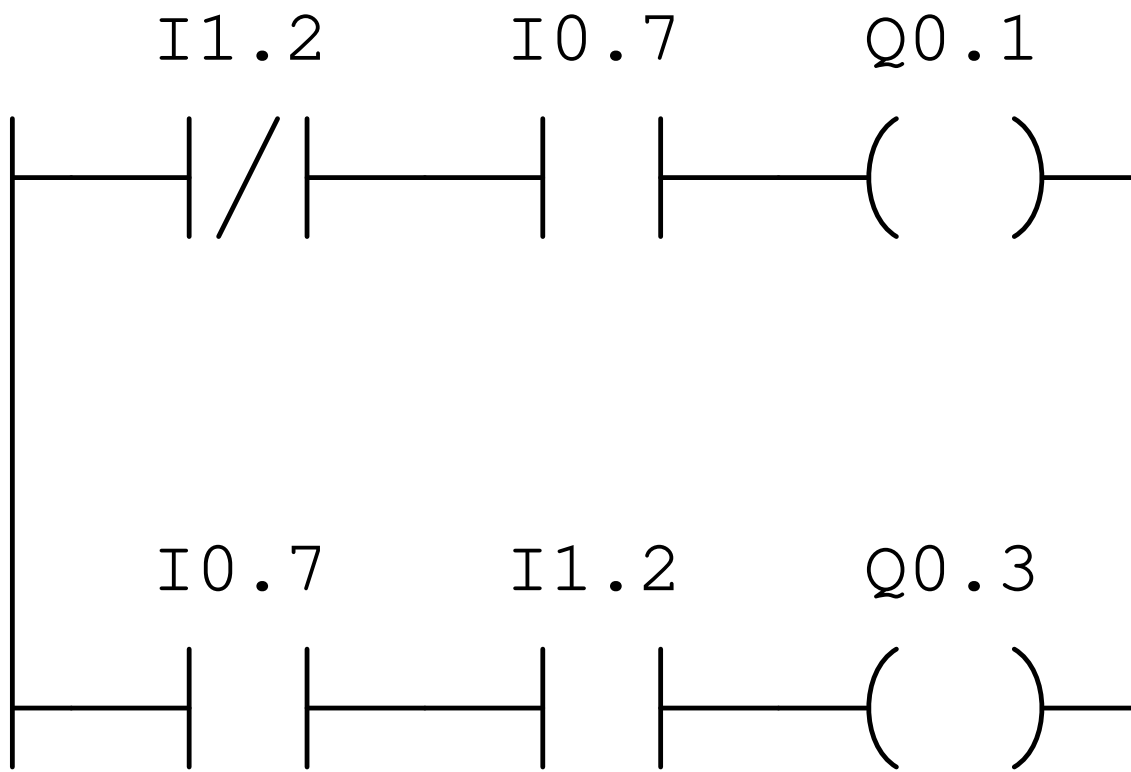
Suppose we have an Allen-Bradley model “SLC 500” PLC connected to a pair of push-button switches and light bulbs as shown in this illustration:



Examine the following relay ladder logic (RLL) program for this Allen-Bradley PLC, determining the necessary switch statuses to energize lamp Y, and the necessary switch statuses to energize switch Z:



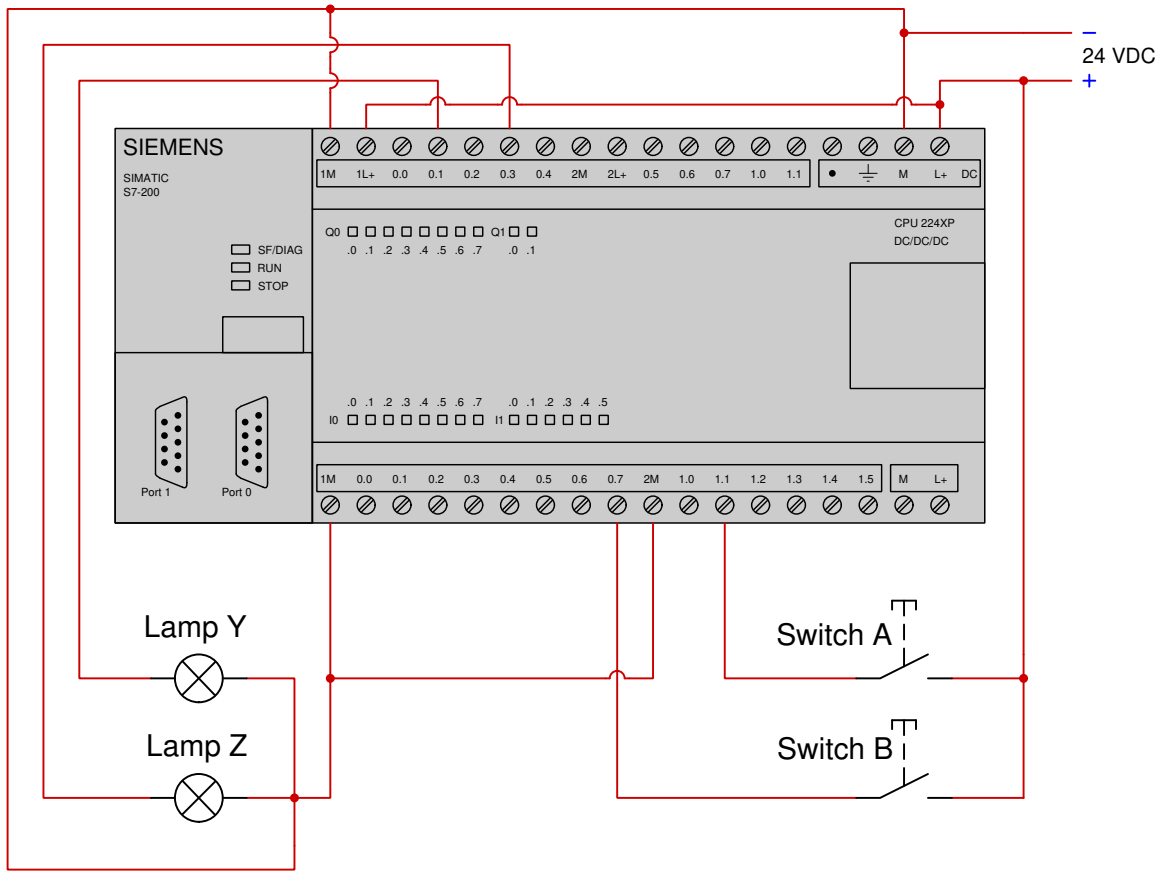
file i04629



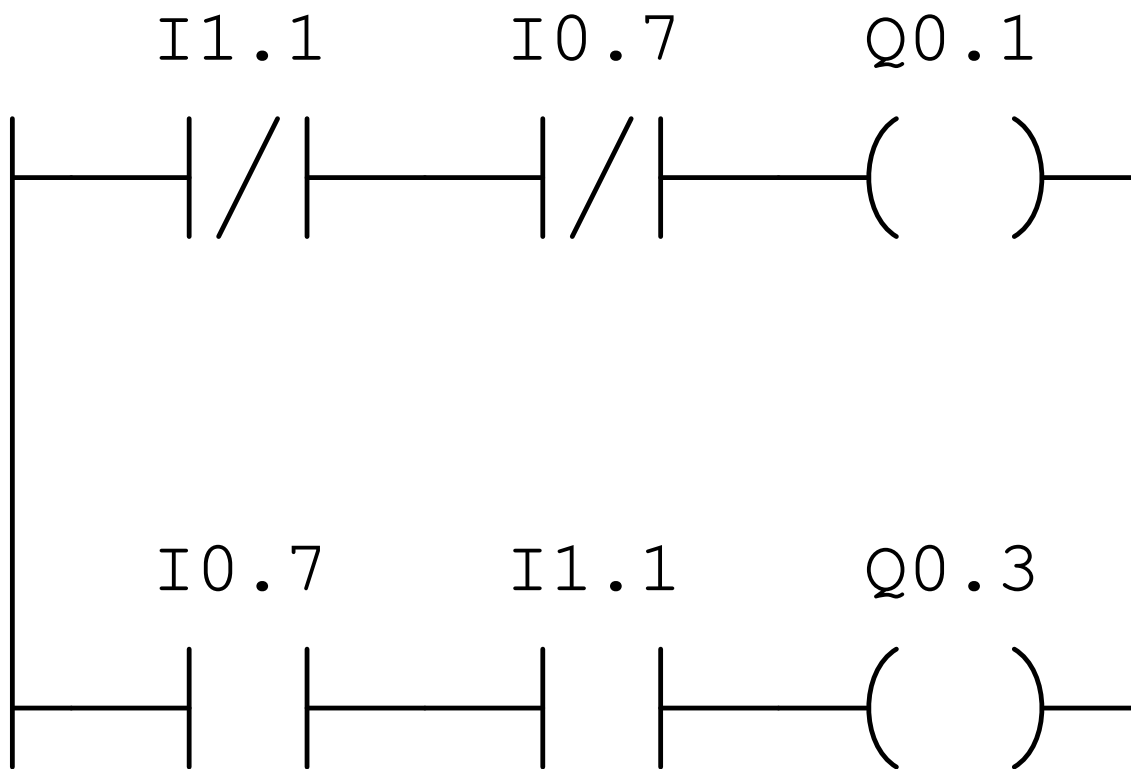
file i04630

Opgave 23

Suppose we have a Siemens S7-200 PLC connected to a pair of pushbutton switches and light bulbs as shown in this illustration:



Examine the following relay ladder logic (RLL) program for this Siemens PLC, determining the statuses of the two lamps provided both switches are simultaneously pressed by a human operator:

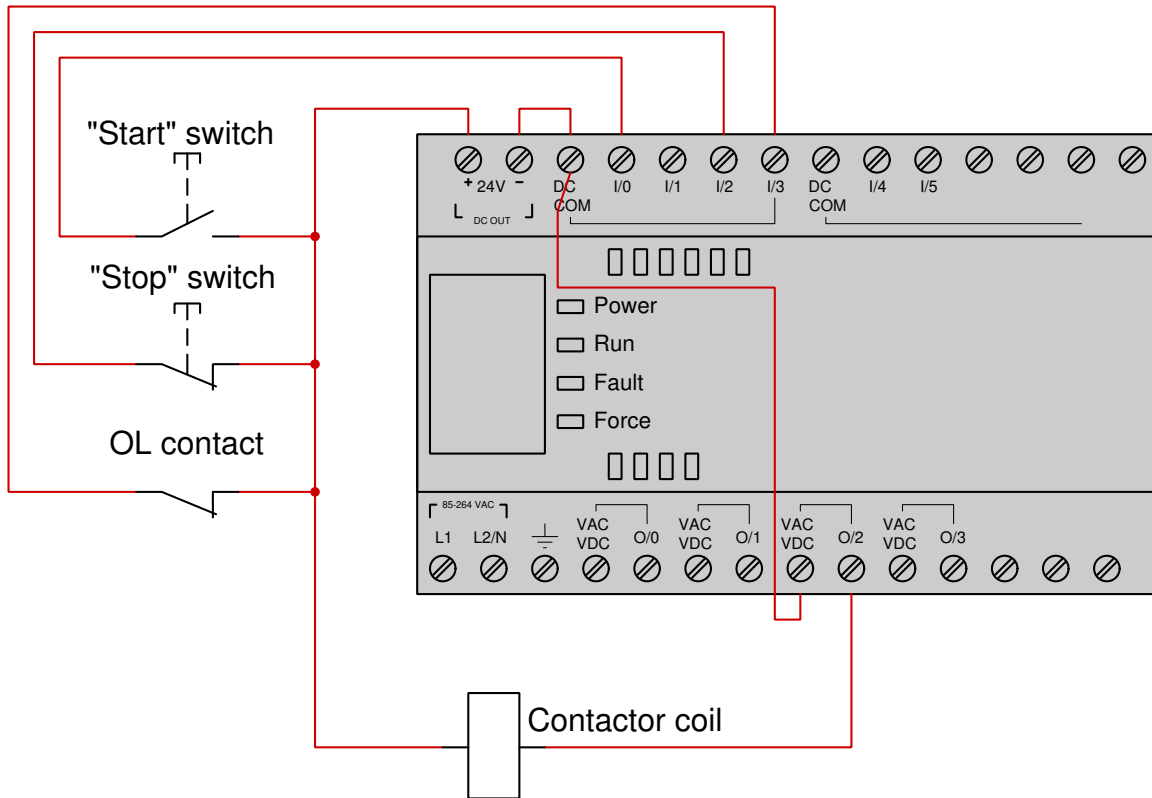


Furthermore, determine the necessary switch actuation statuses (i.e. pressed versus unpressed) to turn lamp Z on.

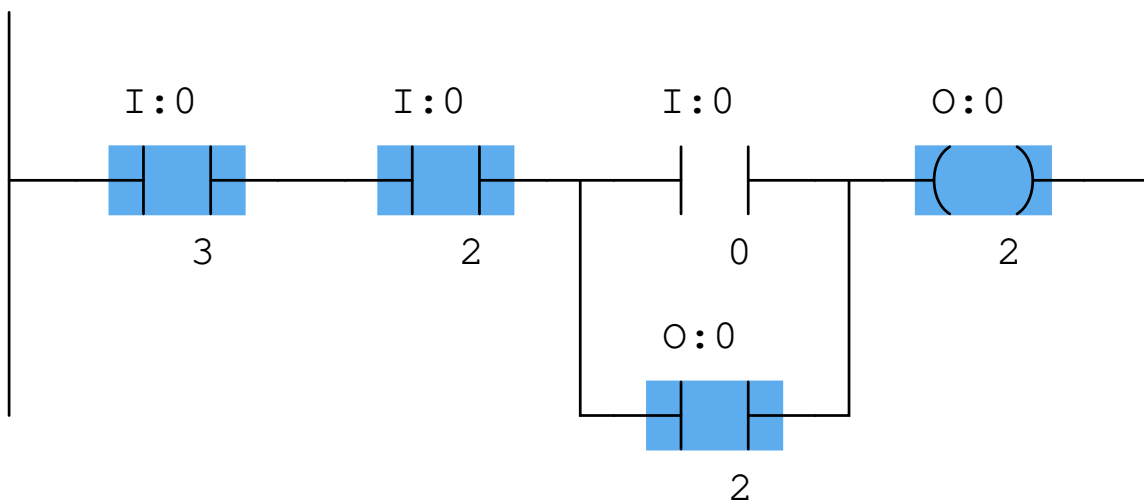
[file i04665](#)

Oppgave 24

Suppose we have an Allen-Bradley MicroLogix 1000 controller connected to a pair of pushbutton switches and contactor controlling power to an electric motor as shown in this illustration:



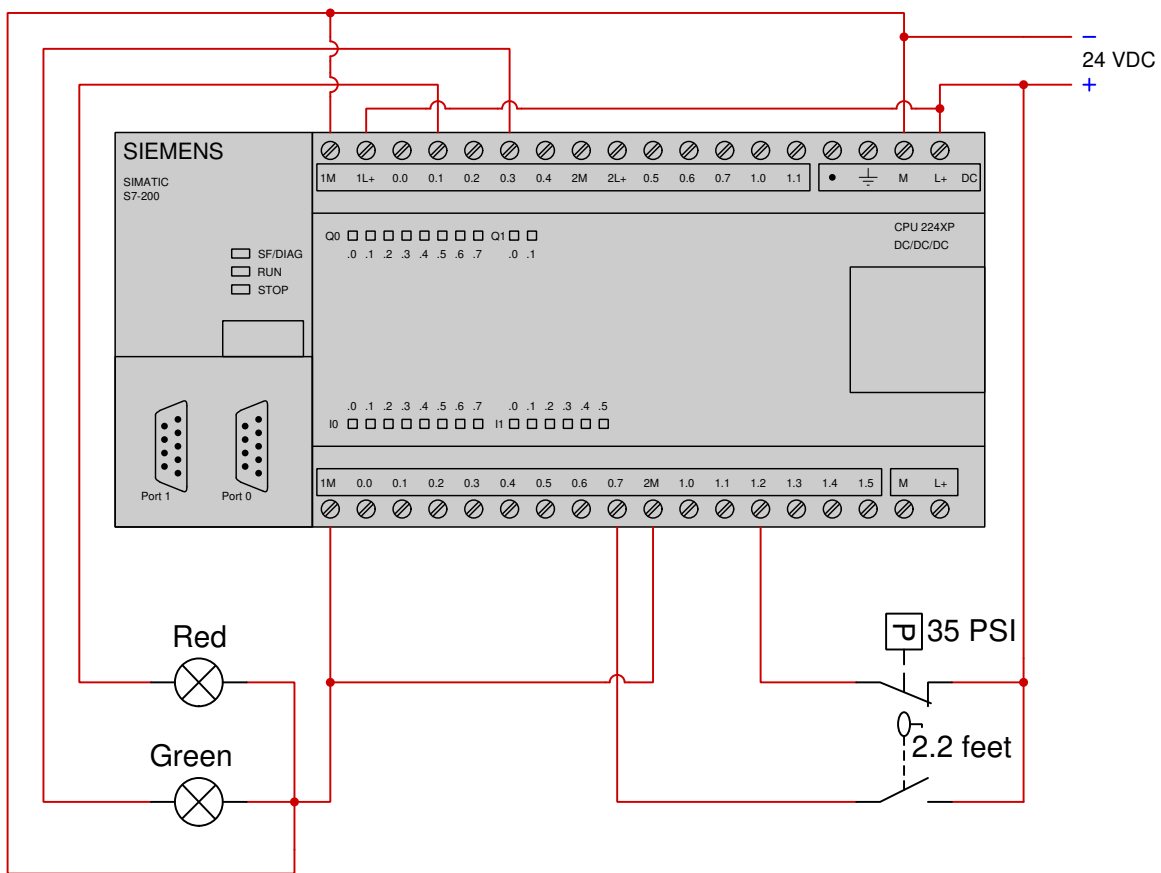
This motor control system has a problem, though: the motor refuses to start when the “Start” pushbutton is pressed. Examine the “live” display of the ladder logic program inside this Allen-Bradley PLC to determine what the problem is:



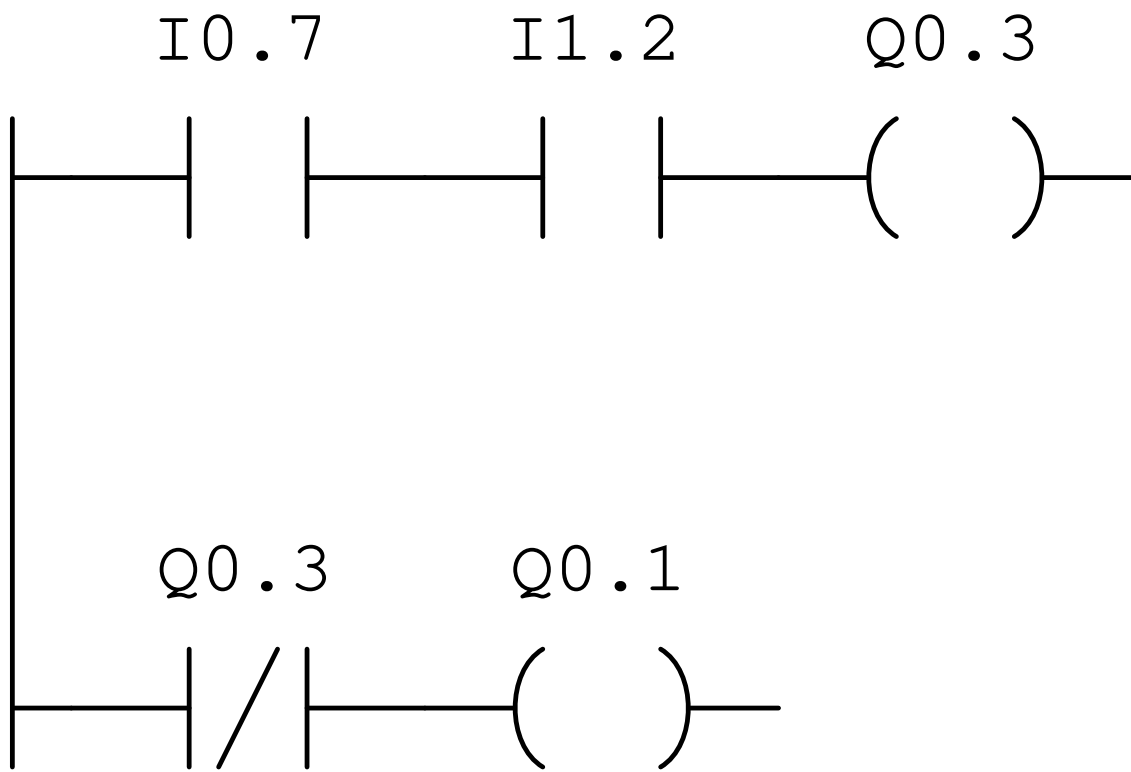
Identify at least two causes that could account for all you see here.
[file i04663](#)

Oppgave 25

Suppose we have a Siemens S7-200 PLC connected to a pair of process switches and light bulbs as shown in this illustration:



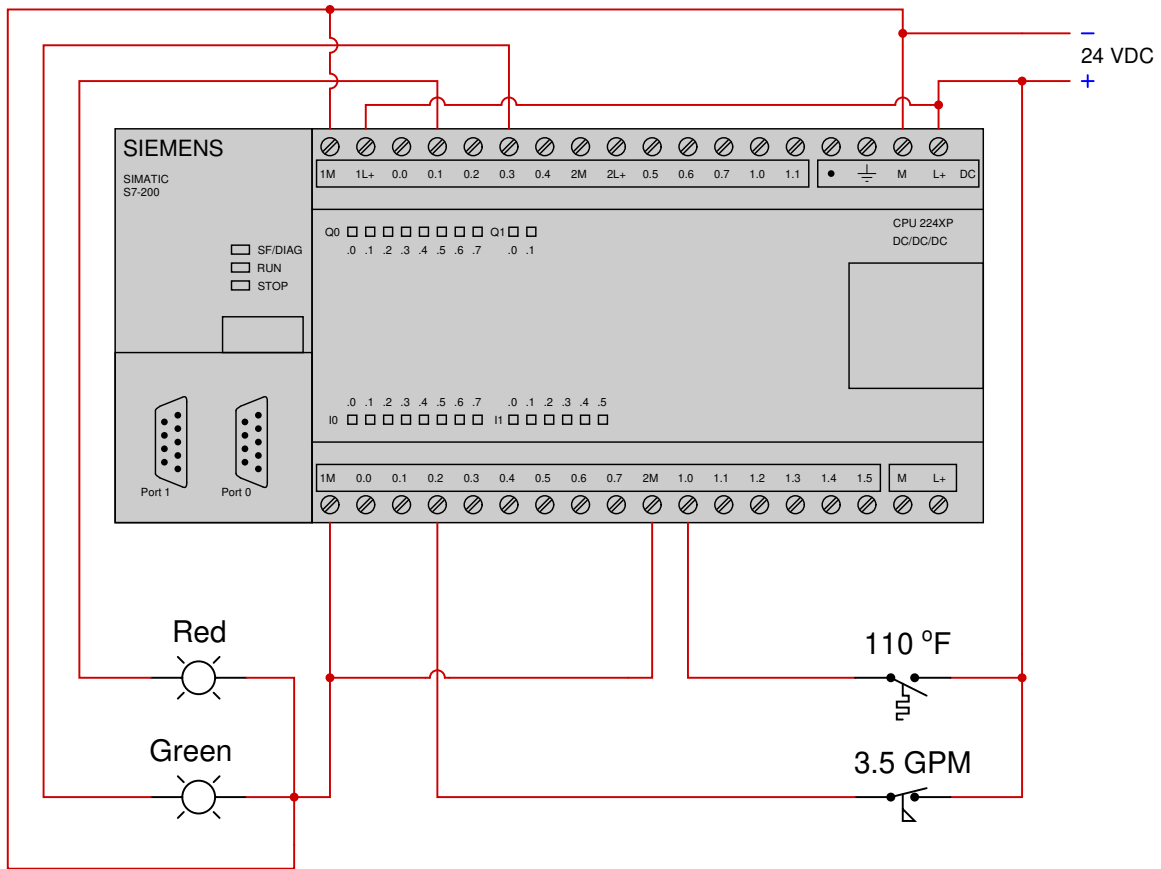
Examine the following relay ladder logic (RLL) program for this Siemens PLC, determining the statuses of the two lamps provided the pressure switch sees a fluid pressure of 30 PSI and the level switch sees a liquid level of 4 feet:



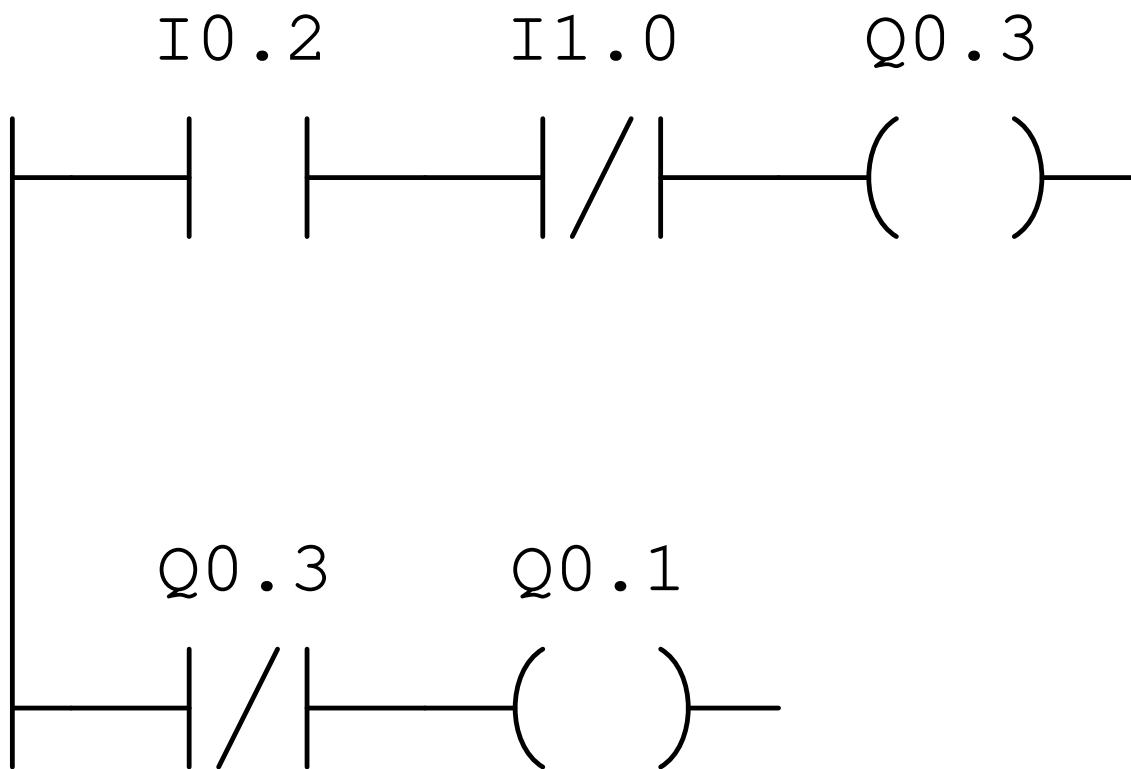
file i04631

Oppgave 26

Suppose we have a Siemens S7-200 PLC connected to a pair of process switches and light bulbs as shown in this illustration:



Examine the following relay ladder logic (RLL) program for this Siemens PLC, determining the statuses of the two lamps provided the temperature switch senses 102 °F and the flow switch senses 4.7 GPM:

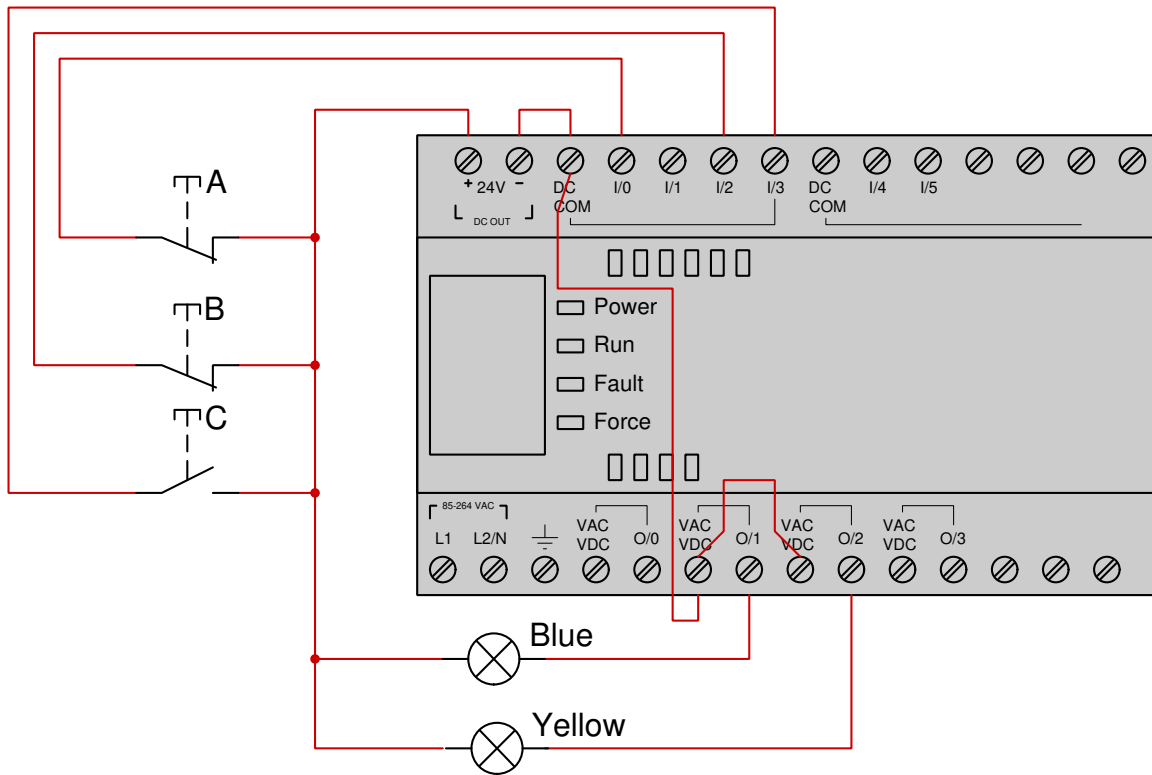


Also, determine whether the inputs on this PLC are *sourcing* or *sinking*, based on how they are connected to the process switches.

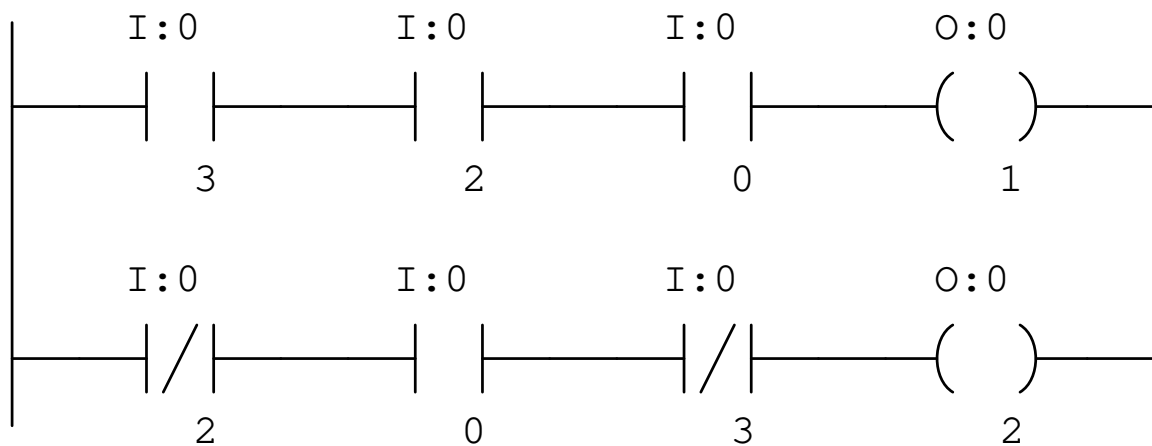
[file i02267](#)

Opgave 27

Suppose we have an Allen-Bradley MicroLogix 1000 controller connected to three push-button switches as shown in this illustration:



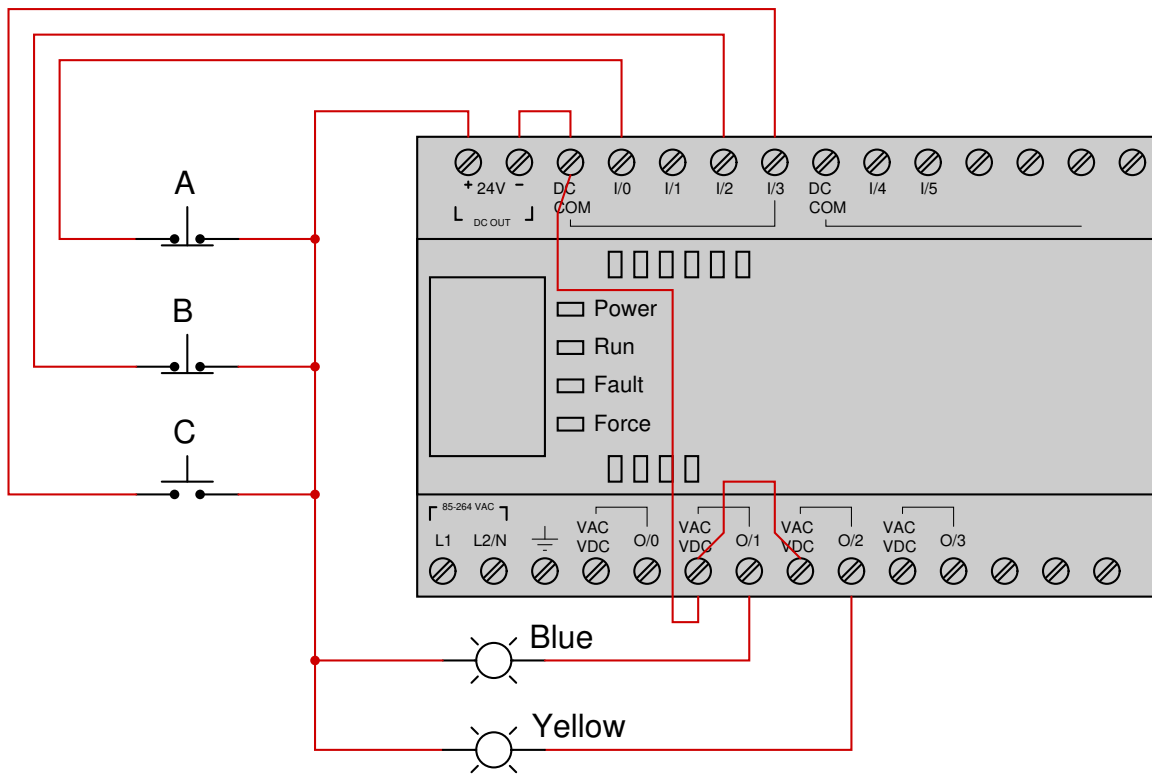
Determine the status of each lamp given the following program running in the PLC, assuming switch A is unpressed, switch B is pressed, and switch C is unpressed:



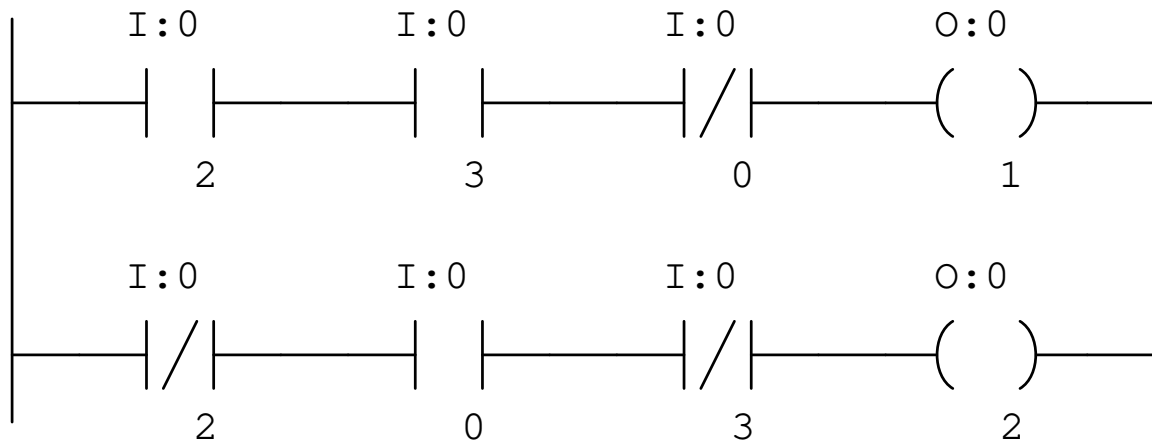
file i04632

Oppgave 28

Suppose we have an Allen-Bradley MicroLogix 1000 controller connected to three push-button switches as shown in this illustration:



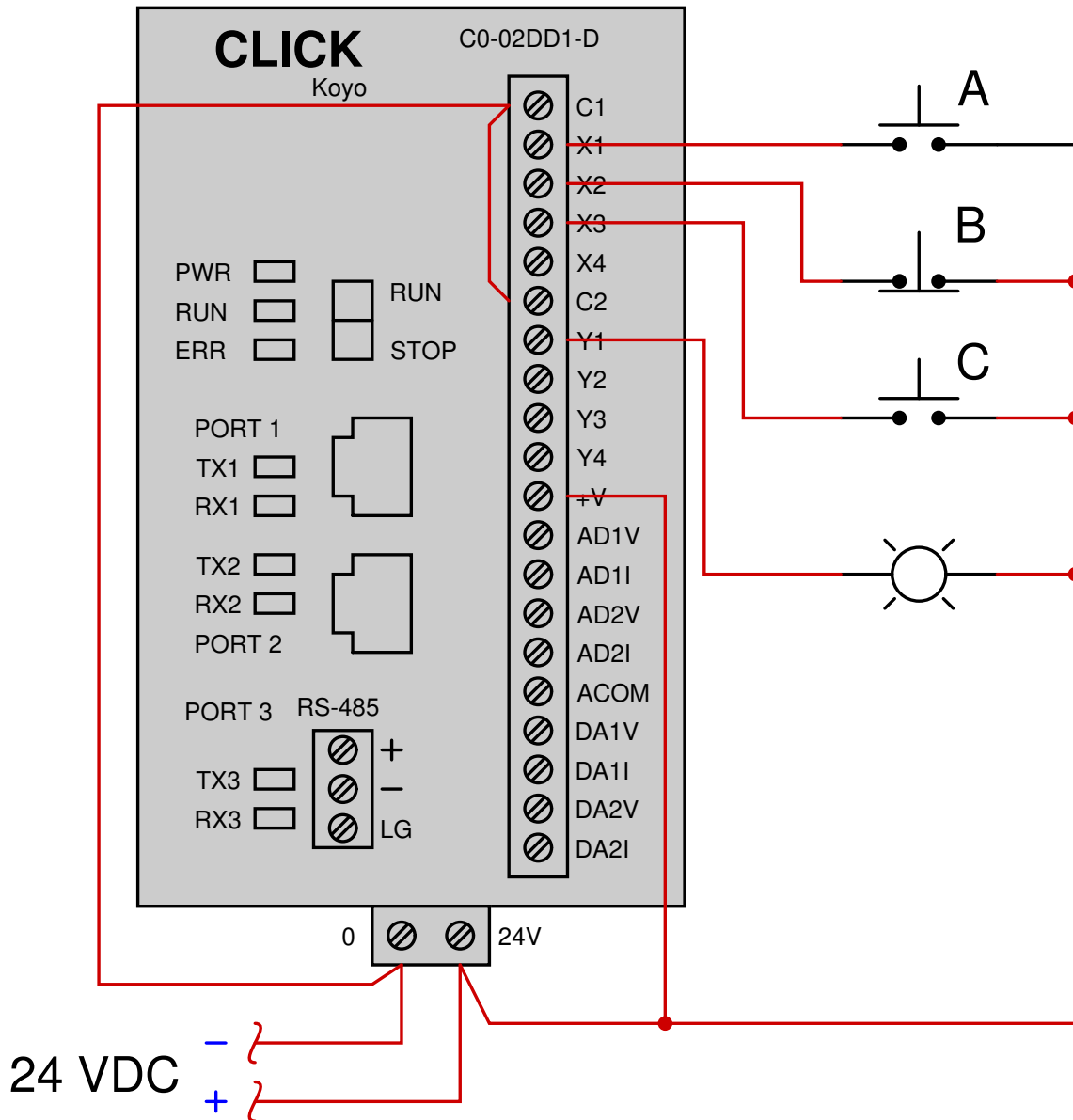
Determine the necessary switch actuation statuses (i.e. pressed versus unpressed) to turn the blue lamp on, given the following program running in the PLC:



file i04633

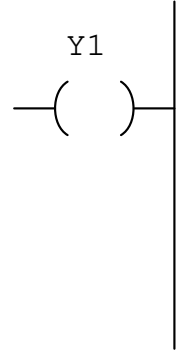
Opgave 29

Suppose we have a Koyo “CLICK” PLC connected to three pushbutton switches as shown in this illustration:



Sketch a Ladder Diagram program for this PLC to energize the lamp if the following input conditions are met:

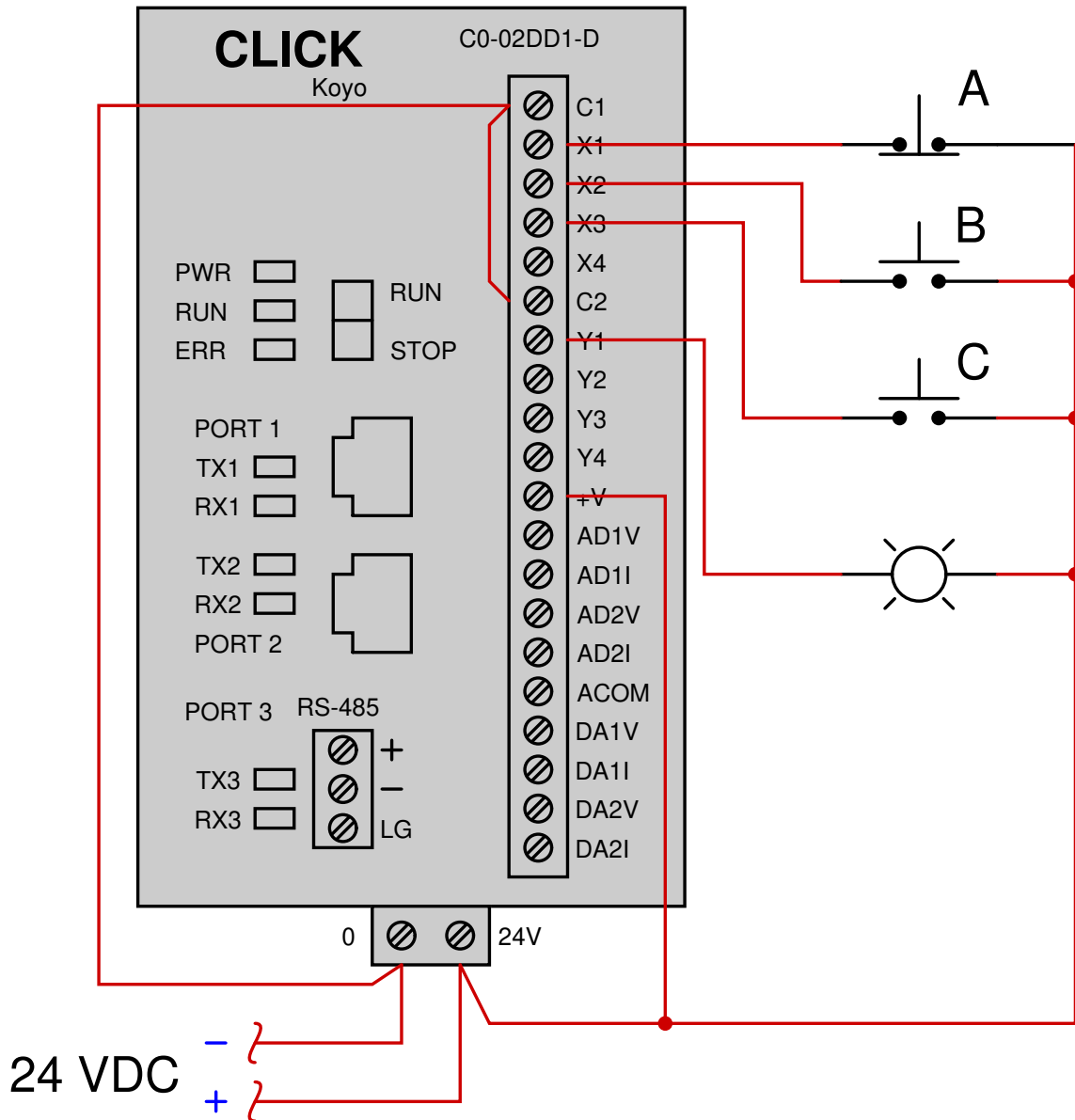
- Switch A pressed
- Switch B pressed
- Switch C unpressed



file i02037

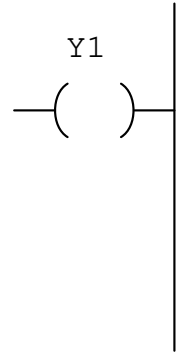
Opgave 30

Suppose we have a Koyo “CLICK” PLC connected to three pushbutton switches as shown in this illustration:



Sketch a Ladder Diagram program for this PLC to energize the lamp if the following input conditions are met:

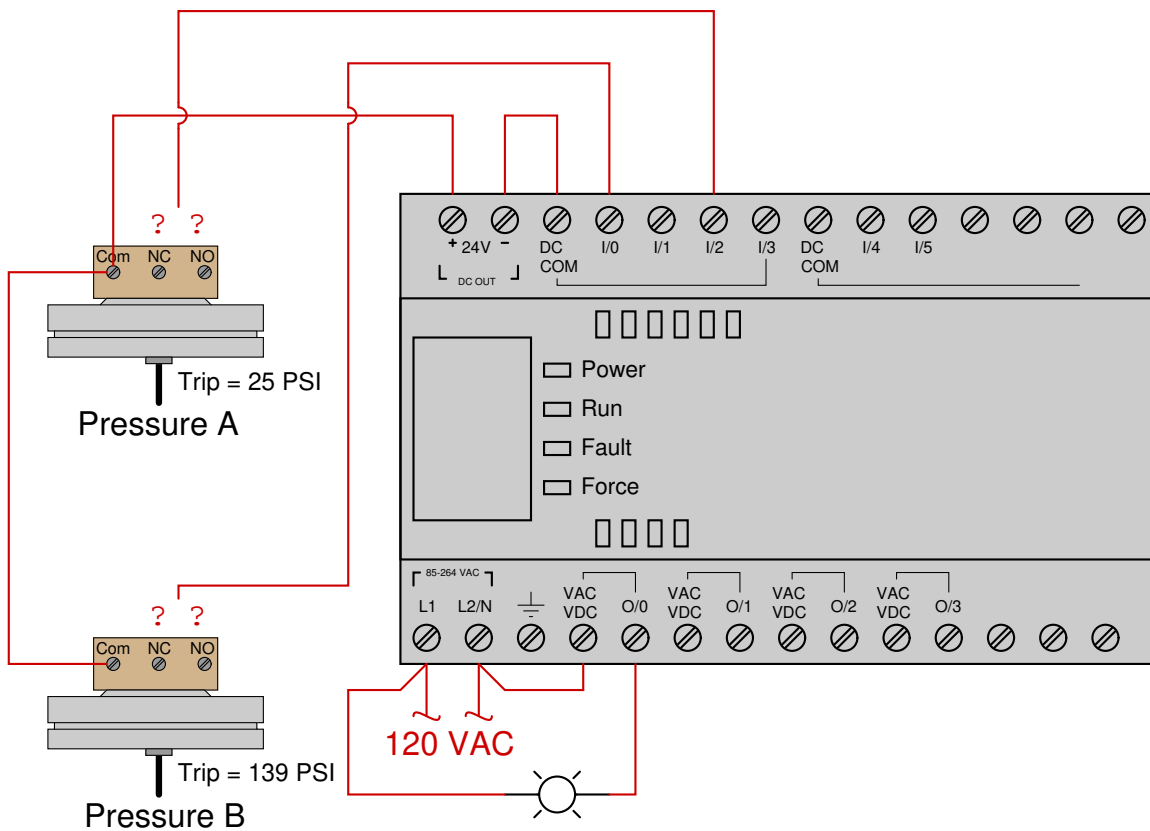
- Either switch A or switch B pressed
- Switch C unpressed



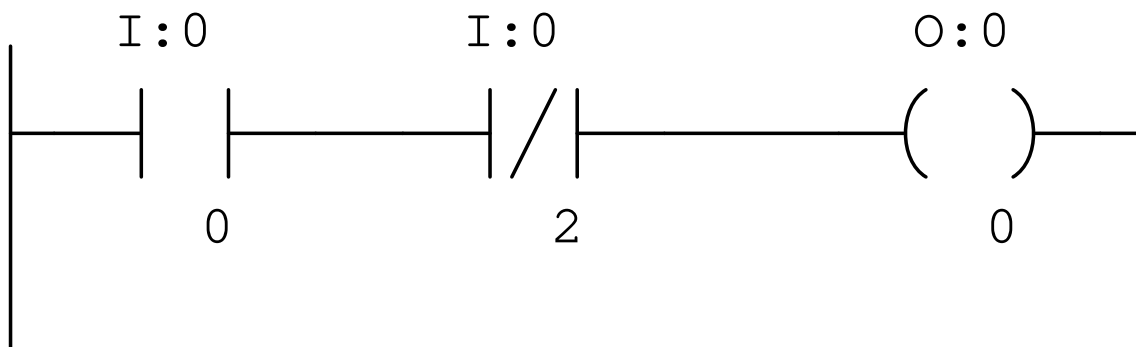
file i02038

Opggave 31

Suppose we have an Allen-Bradley MicroLogix 1000 PLC and two pressure switches we need to connect to it:



Determine the necessary contacts on each pressure switch (NO versus NC) we need to connect to the PLC inputs in order to make the lamp turn on when pressure A exceeds 25 PSI and pressure B drops below 139 PSI, given the following program running in the PLC:

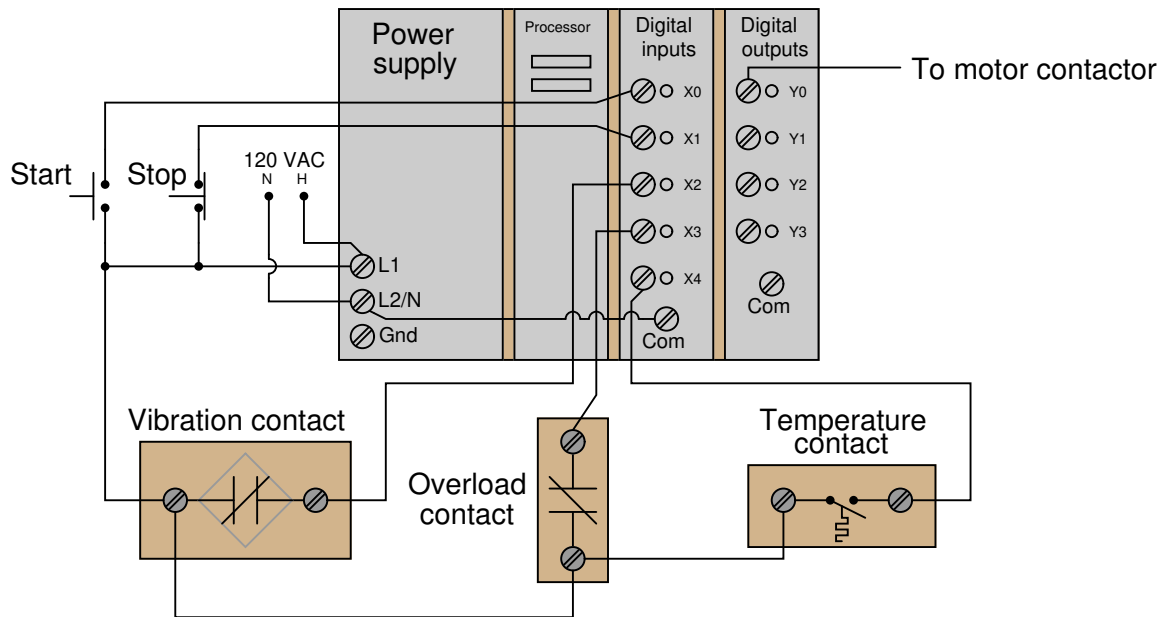


file i04639

Opgave 32

This PLC is being used to start and stop an electric motor, and also to shut it down automatically if any of three “shutdown” conditions occur:

- Excessive vibration
- Overcurrent (overload heater contact)
- High winding temperature



The status of each shutdown contact is as follows:

- Vibration contact: *closed* when okay, *opens* when vibration becomes excessive
- Overload contact: *closed* when okay, *opens* when overloaded
- Temperature contact: *open* when okay, *closes* when hot

Draw a PLC ladder-logic program to start and stop this motor. Be sure to make the program latching so that the operator does not have to hold the Start button to keep the motor running.

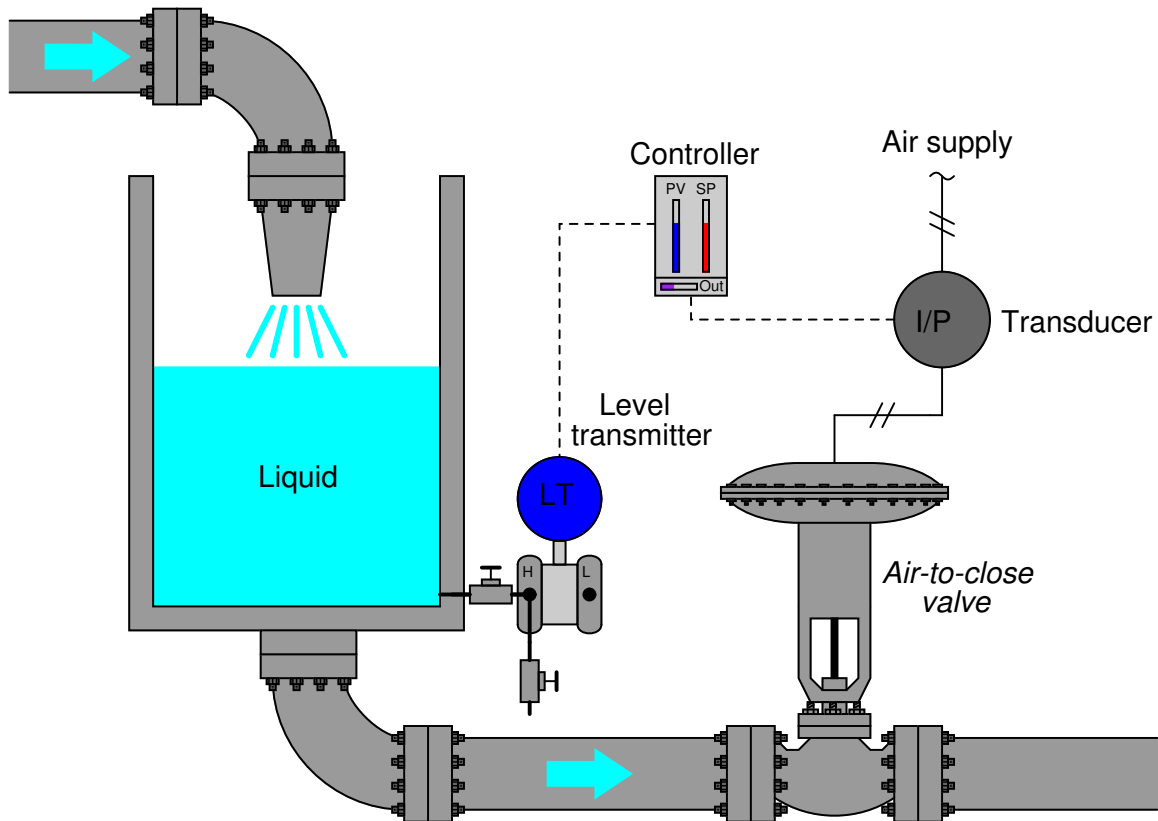
PLC program

Oppgave 33

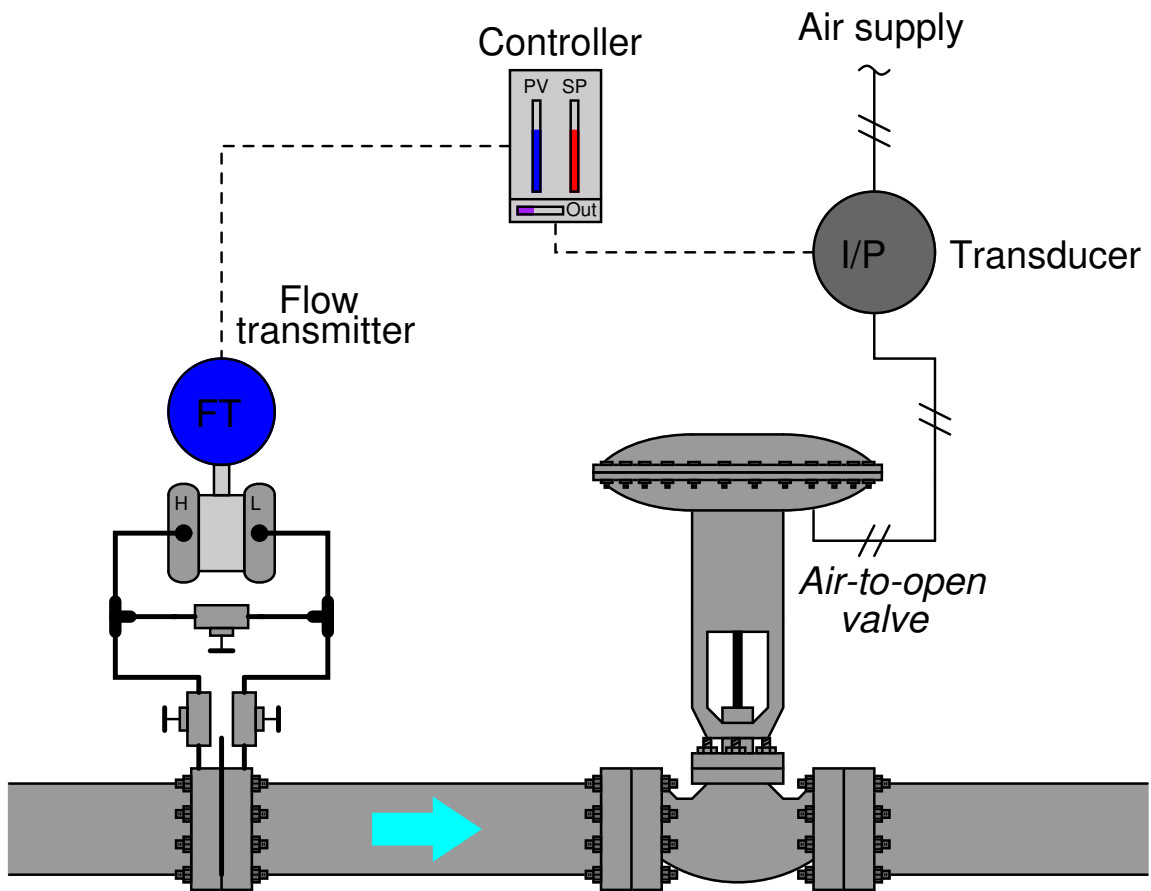
I alle disse eksemplene på reguleringsystemer har transmitteren et økende utgangssignal med økende inngangssignal og I/P omformerer gir et økende utgangssignal med økende inngangssignal.

Din oppgave er å avgjøre om regulatoren skal ha *direkte* eller *reverserende* virkning.

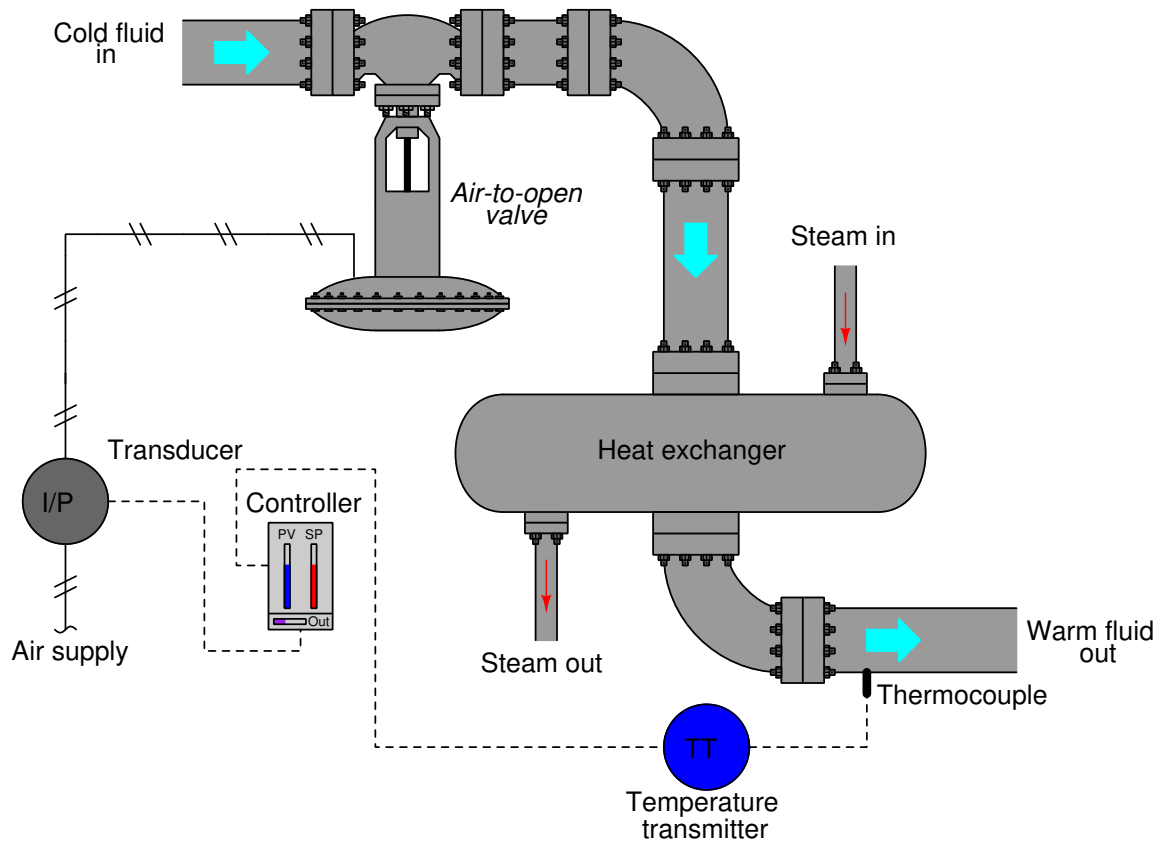
Eksempel 1:



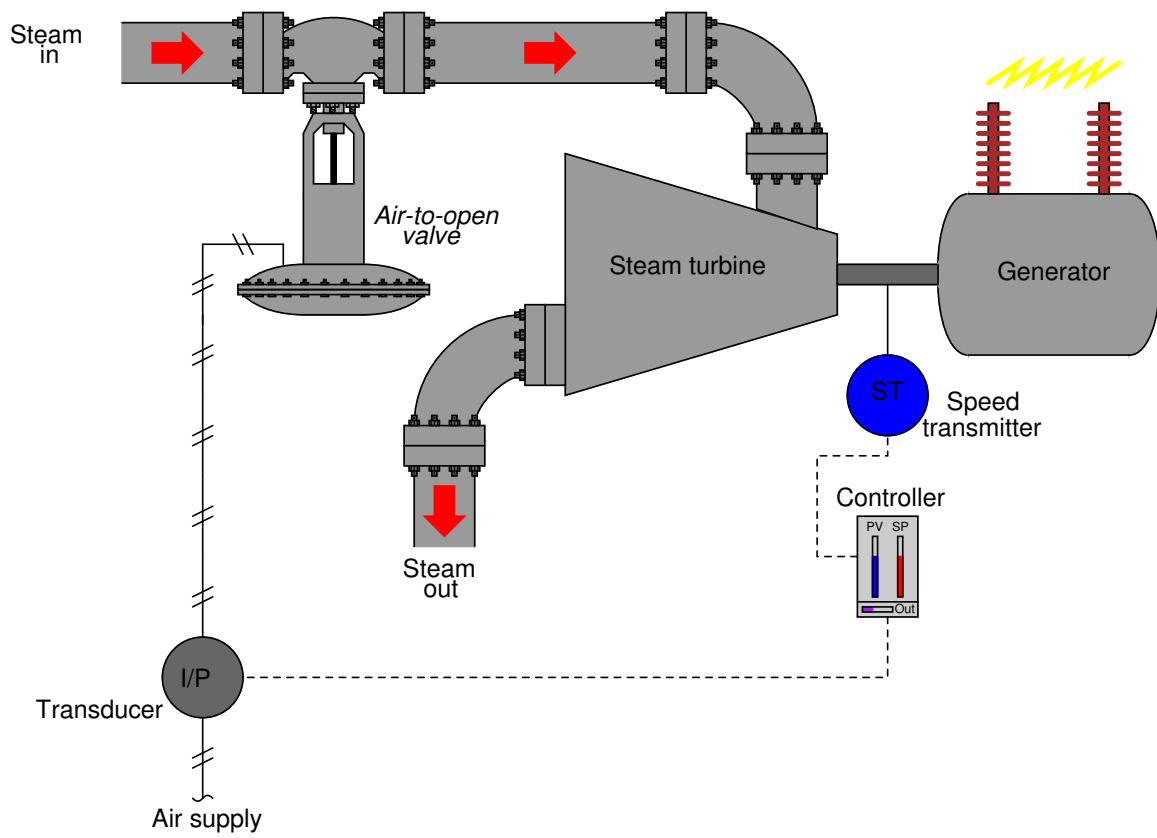
Eksempl 2:



Eksempel 3:



Eksempel 4:



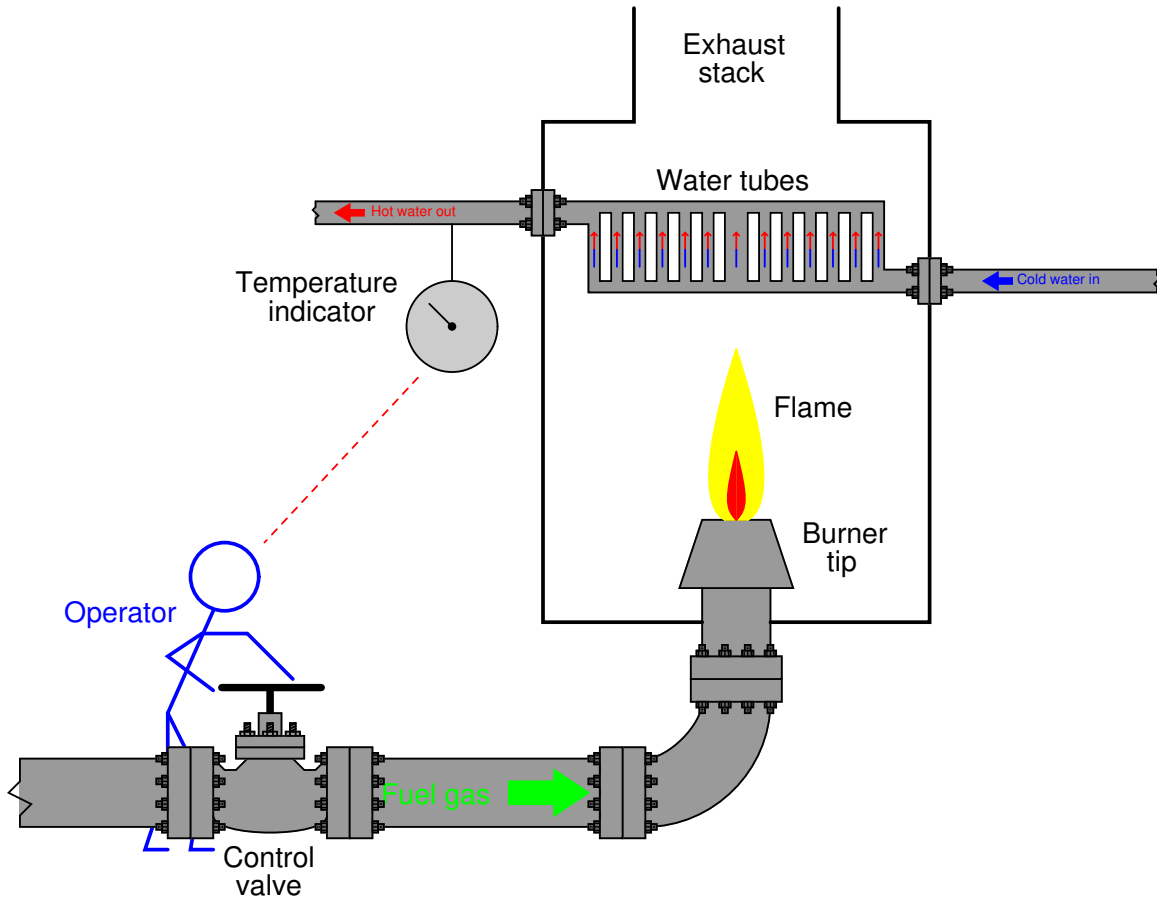
Suggestions for Socratic discussion

- As always, what is more important than arriving at the correct answer(s) is to develop a clear and logical *reason* for your correct answers. Explain the problem-solving technique(s) you used to determine correct controller action in each of these process control examples.
- A powerful problem-solving technique is performing a *thought experiment* where you mentally simulate the response of a system to some imagined set of conditions. Describe a useful “thought experiment” for any of these process control loops, and how the results of that thought experiment are helpful to answering the question.
- Explain how to reliably identify the process variable (PV) in any controlled process presented to you.
- Explain how to reliably identify the manipulated variable (MV) in any controlled process presented to you.
- Identify and explain the deleterious effect(s) caused by a process controller configured with the wrong action.
- Identify an instrument mis-calibration or mis-configuration that could cause the process variable to settle at a greater value than it should be, assuming all other components in the system are functioning properly.
- Once you have identified the proper controller action for any given process example, identify something that could be altered about the process to require the *other* control action.

[file i00788](#)

Oppgave 34

Suppose a gas-fired water heater is controlled manually, with a human operator observing a temperature indicator on the hot water outlet pipe and actuating a fuel gas control valve:



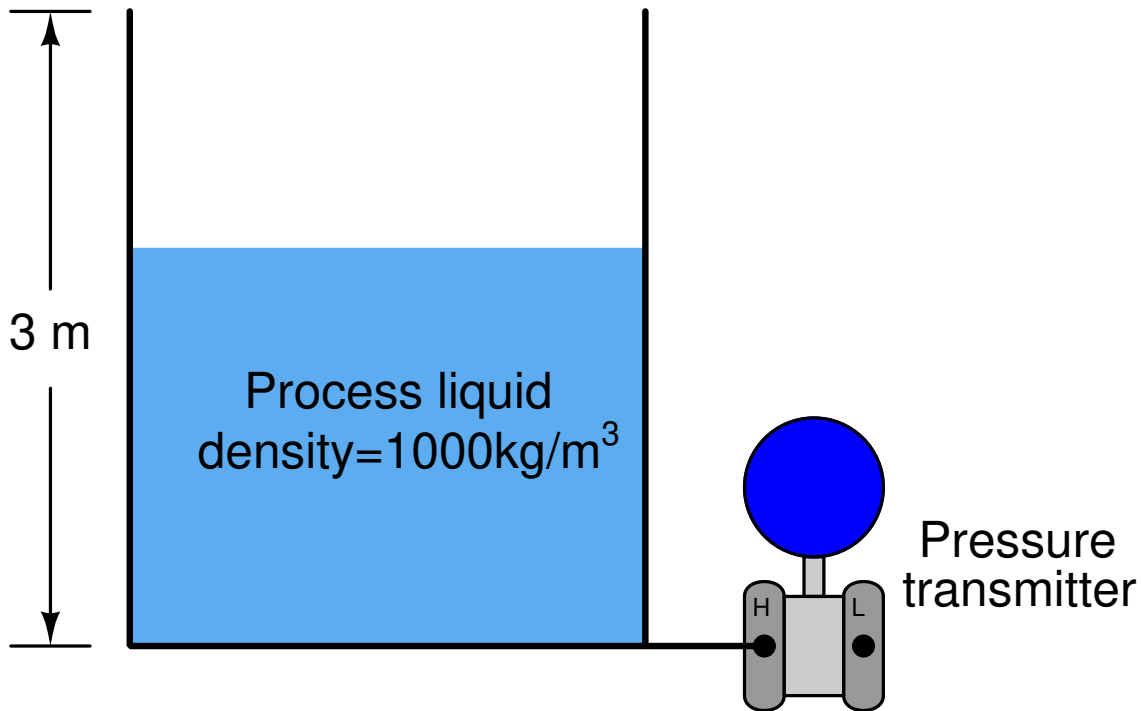
Does the operator play the part of a *direct-acting* controller, or a *reverse-acting* controller, in this process control scenario?

Also, identify the *process variable*, *setpoint*, and *manipulated variable* in this manual control system.

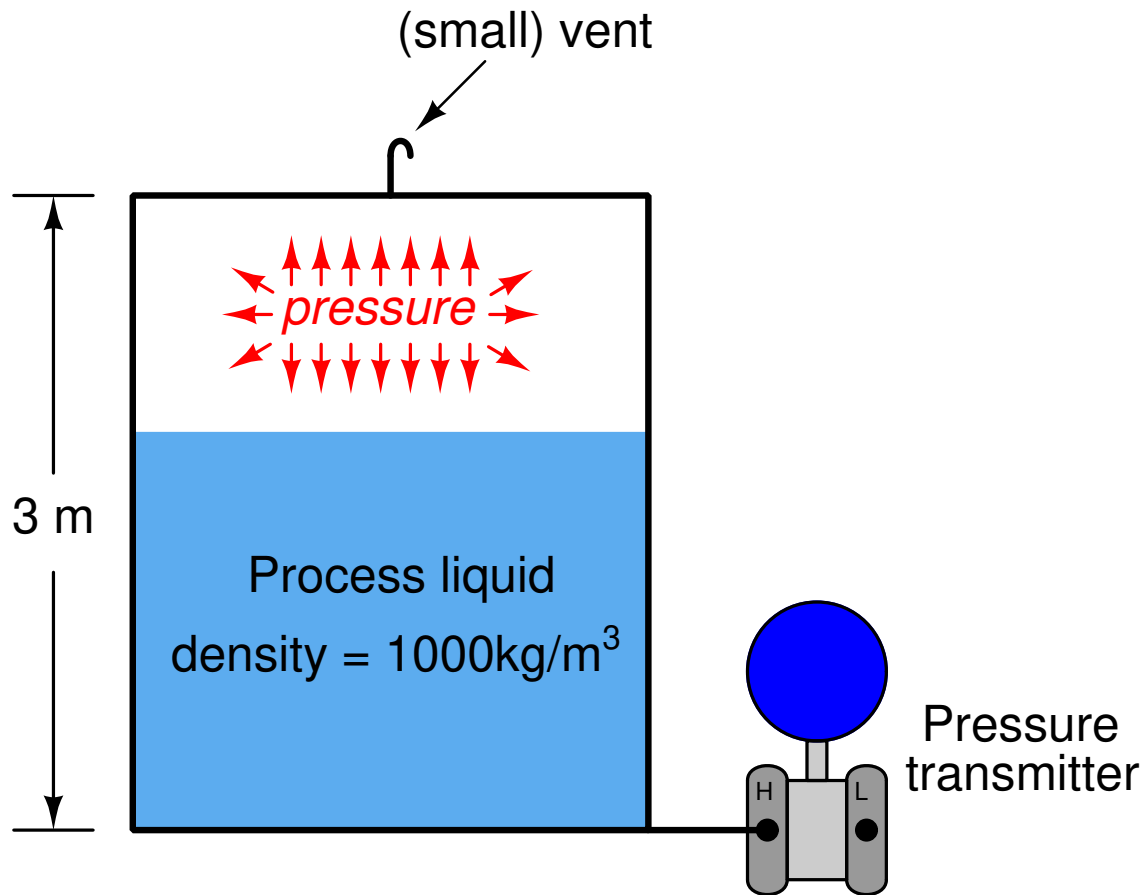
[file i01452](#)

Oppgave 35

A vessel holding some process liquid needs to have its level monitored. The range of level in this vessel is 0 to 3 meters, and the process liquid has a density of 1000 kg/m^3 like water. Someone decides to attach a pressure transmitter to the bottom of the vessel to infer level from hydrostatic pressure like this:



Later, a top is added to this vessel to keep rain from entering in. Unfortunately, though, this process liquid tends to emit vapor which will be trapped by the closed vessel and create a pressure inside of it. A small vent is added to the top of the vessel to permit the vapor to escape, but it is a *small* vent, not big enough to ensure a total absence of vapor pressure buildup at all times:

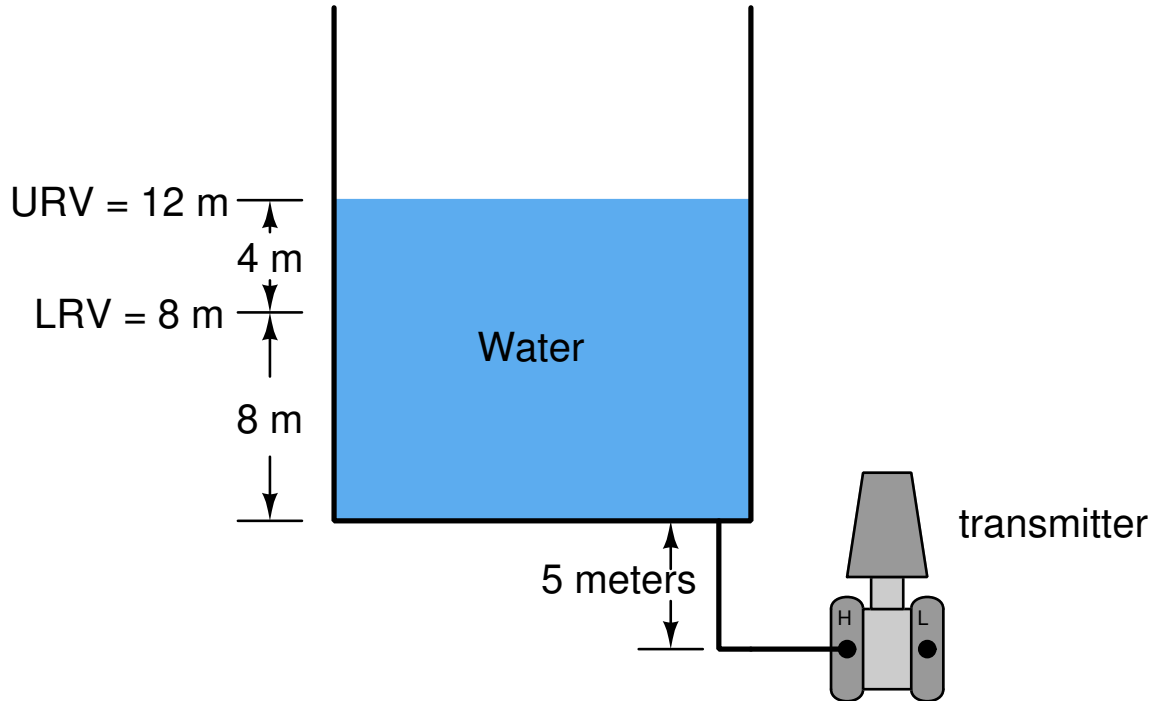


What problem in level measurement will result from there being an occasional vapor pressure buildup inside this vessel? How may this problem be corrected so that the liquid level will be accurately measured at all times?

[file i00248](#)

Oppgave 36

The following storage vessel holds water. The hydrostatic-pressure level transmitter is located 5 meters below the bottom of the vessel, and the desired level measurement range is 8 meters to 12 meters:



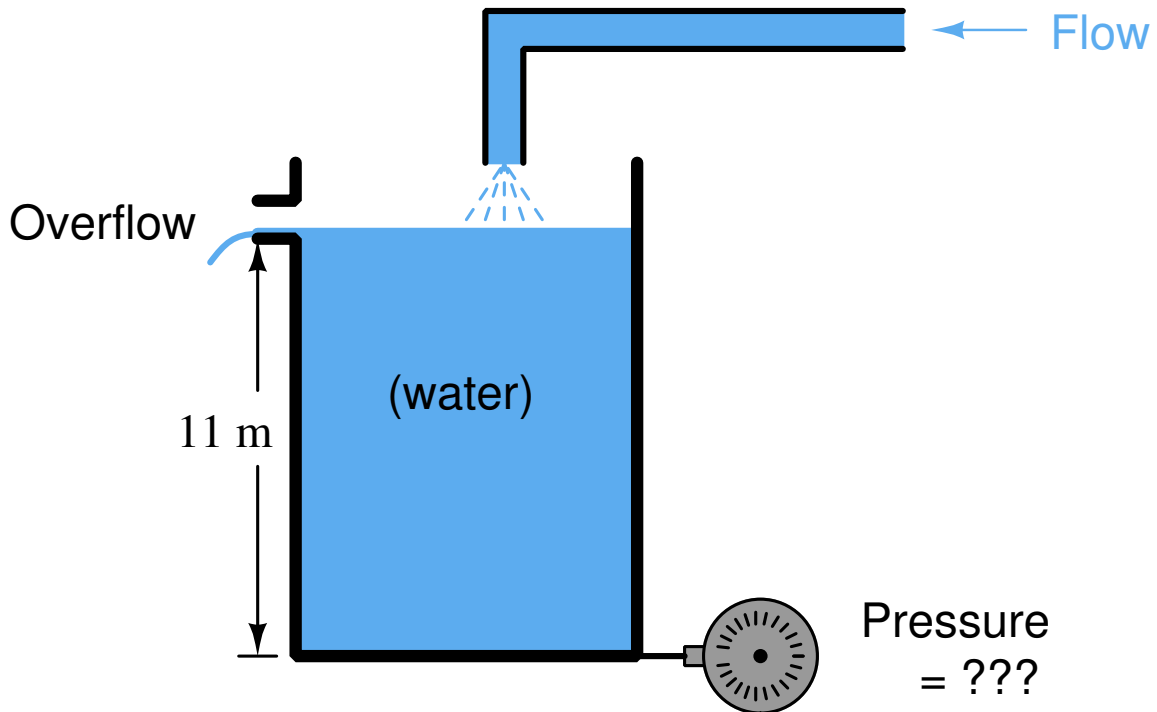
Assuming a pneumatic transmitter with an output range of 4 mA to 20 mA, and a calibration accuracy of +/- 1% of span, complete the following calibration table for the transmitter:

Process level (ft)	Percent of span (%)	Δ pressure sensed ("W.C)	Output signal ideal (mA)	Output signal min. (mA)	Output signal max. (mA)
	0				
	10				
	25				
	50				
	75				
	90				
	100				

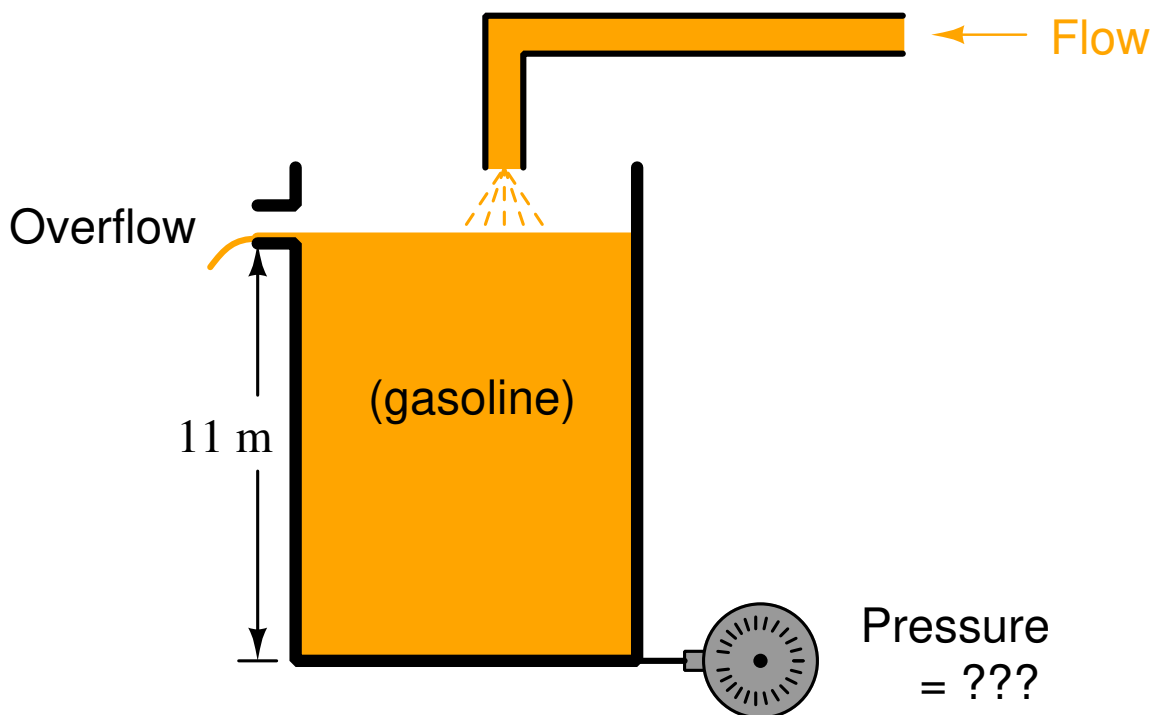
file i00257

Opgave 37

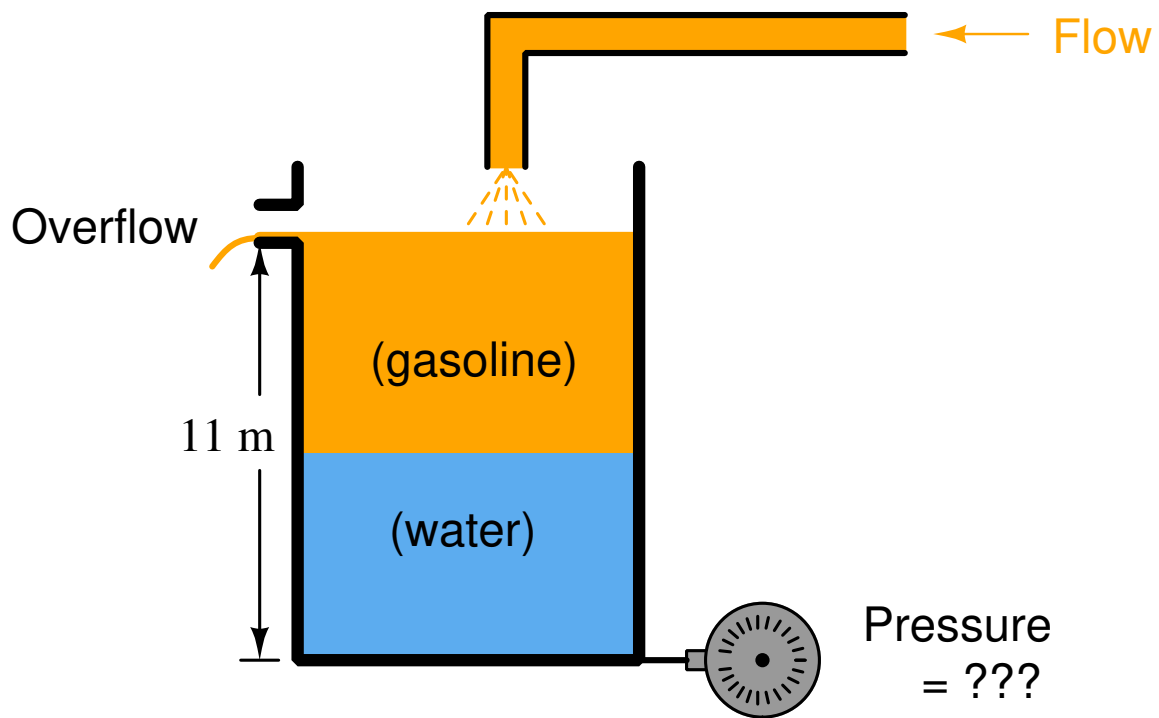
Calculate the hydrostatic pressure generated at the bottom of this vessel (in units of bar) when it is completely filled with water:



Now calculate the hydrostatic pressure at the bottom of this vessel (in units of bar) when it is completely filled with gasoline (density = 672.8 kg/m^3):



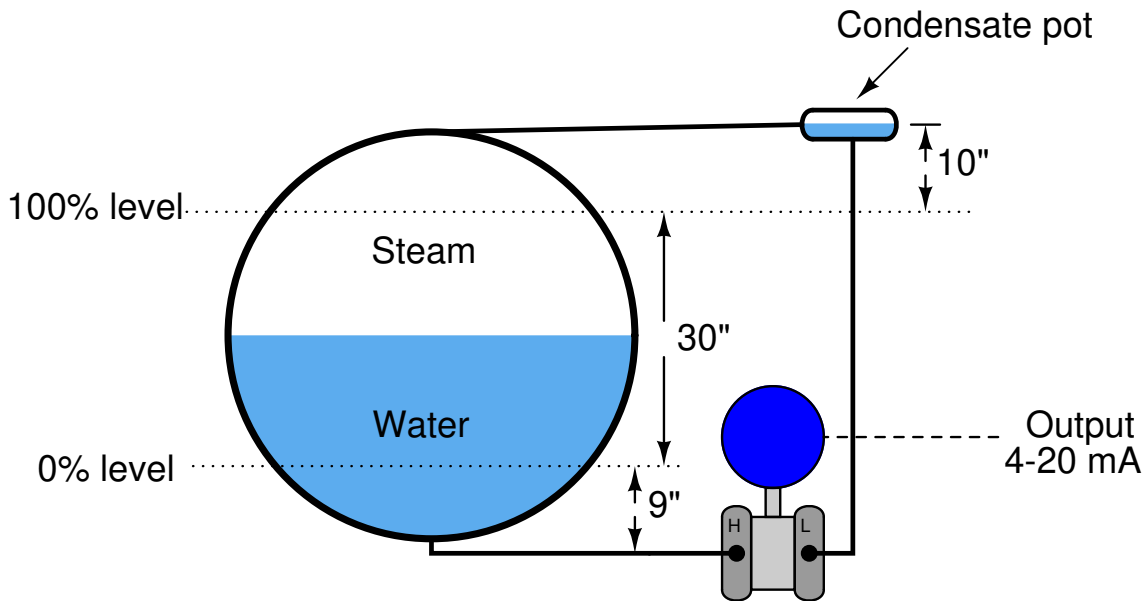
What do you think the pressure will be at the bottom of the vessel if it is exactly half-full of gasoline and half-full of water, with a gasoline-water *interface* at the 5.5 meters mark? Explain your reasoning.



file i00308

Opgave 38

Calculate the differential pressure sensed by the level transmitter at three different water levels in this boiler steam-drum level measurement system: 0%, 50%, and 100%.



Assume a density for (hot) boiler drum water of 36 lb/ft^3 , a density for steam in the drum of 7 lb/ft^3 , and a density for (warm) water in the “wet leg” of 61.8 lb/ft^3 . If the pressure at the “low” (L) side of the transmitter is greater than the pressure at the “high” (H) side, be sure to express the differential pressure quantity as a negative number.

Credit will be given for correctly calculating each of the differential pressures:

- **(6 points)** Transmitter ΔP at 0% water level = _____ "W.C.
- **(6 points)** Transmitter ΔP at 50% water level = _____ "W.C.
- **(6 points)** Transmitter ΔP at 100% water level = _____ "W.C.

file i00516

Svar

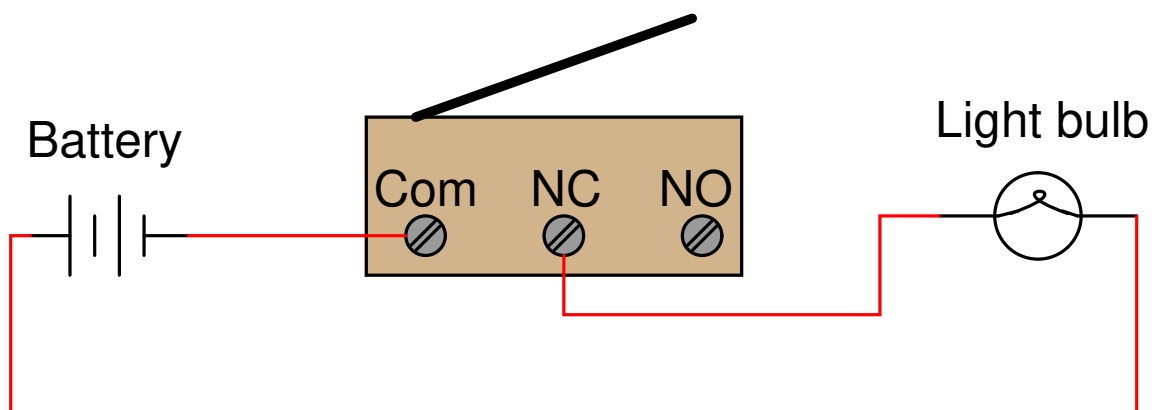
Svar 1

The “normal” condition for a process switch is the condition of *least stimulus*. For example:

- A pressure switch will be in its “normal” state when there is *minimum pressure applied*
- A level switch will be in its “normal” state when there is *no level detected by the switch*
- A temperature switch will be in its “normal” state when it is *cold*
- A flow switch will be in its “normal” state when there is *no flow detected by the switch*

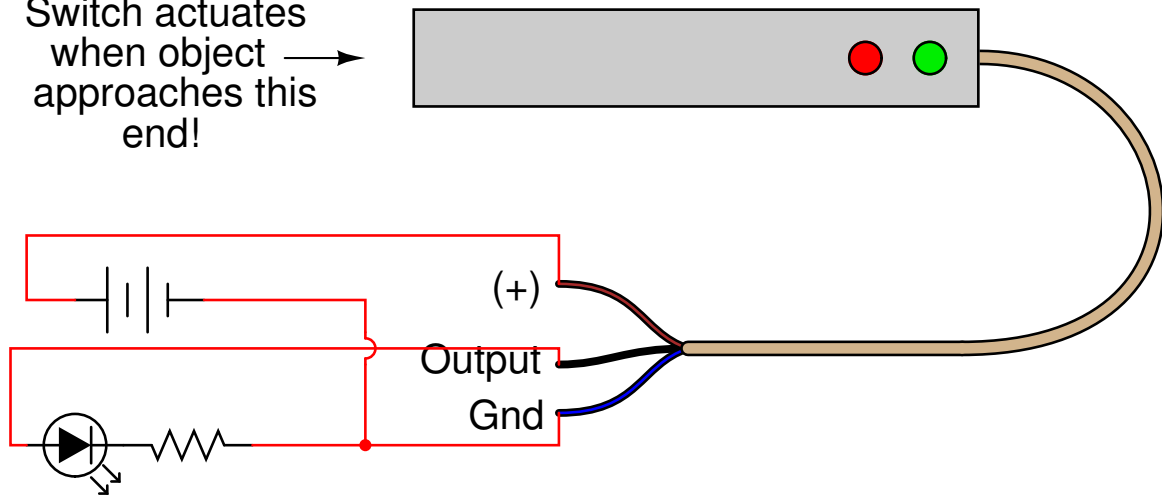
Svar 2

Light bulb turns off when limit switch actuates



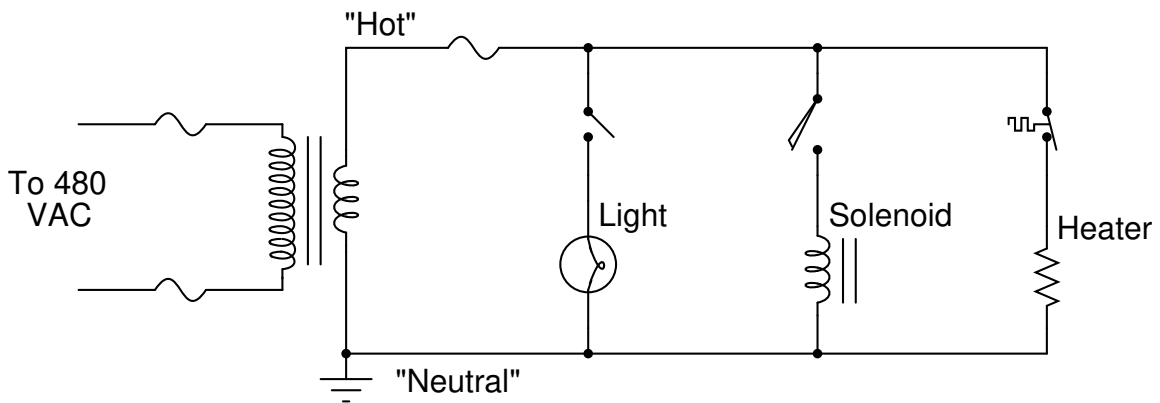
Svar 3

Switch actuates
when object
approaches this
end! →



Svar 4

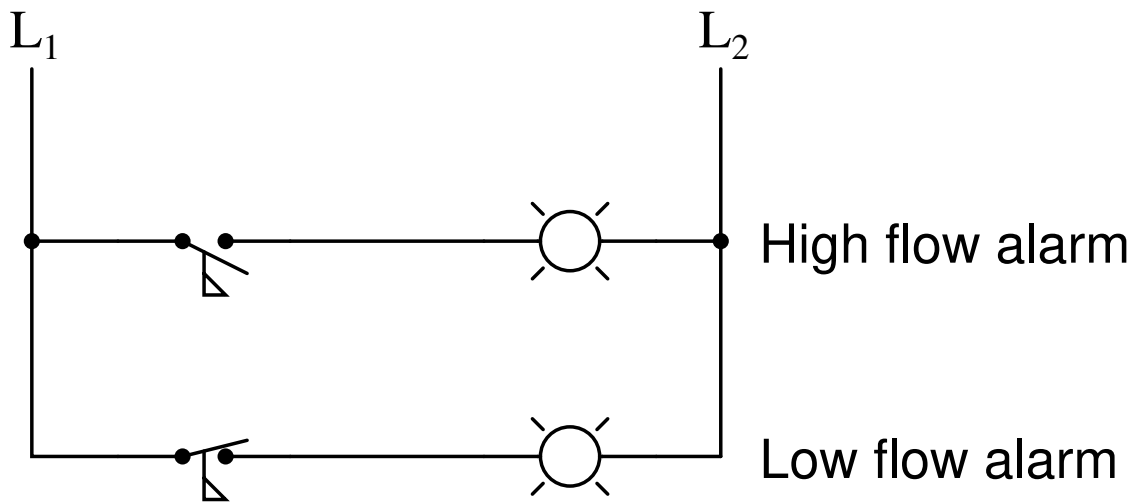
Svar 5



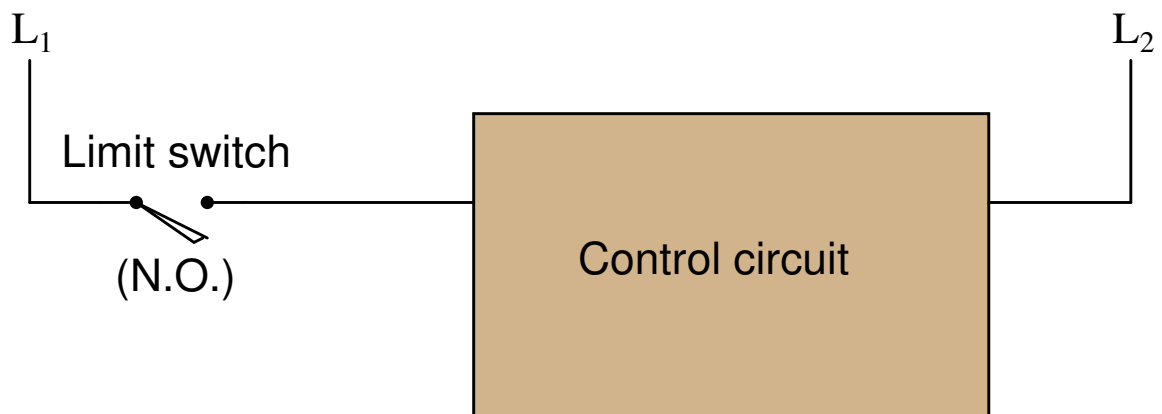
Svar 6

This is an automatic cooling system with high and low temperature alarms.

Svar 7



Svar 8



Svar 9

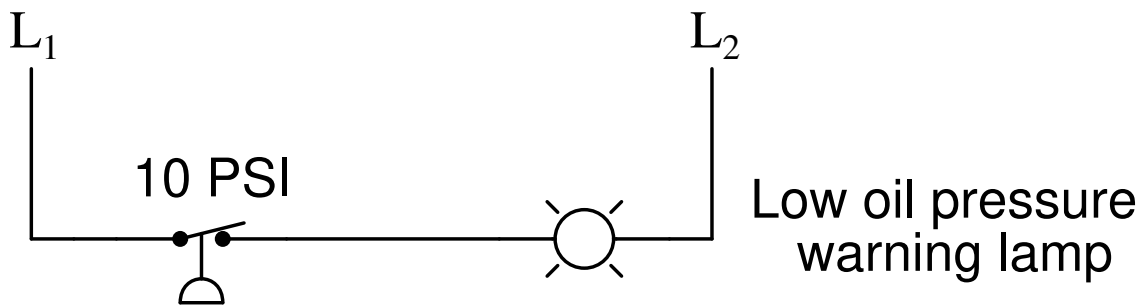
- PSL = Pressure Switch, Low
- PSH = Pressure Switch, High
- PSHH = Pressure Switch, High-High

Both warning lamps should be off when the steam pressure is between 80 and 200 PSI. The boiler will automatically shut down when the shutdown solenoid de-energizes, and this will happen if the steam pressure exceeds 220 PSI for at least 10 seconds.

The difference between a “normally open” process switch and a “normally closed” process switch is vitally important for technicians to understand. The “normal” condition referred to in each label does *not* mean the condition that is typical for the process. Rather, it refers to a condition where the switch is subjected to *minimum stimulus*. In other words, the “normal” condition for each switch is:

- Temperature switch = cold
- Pressure switch = low or no pressure
- Level switch = empty vessel
- Flow switch = low or no flow

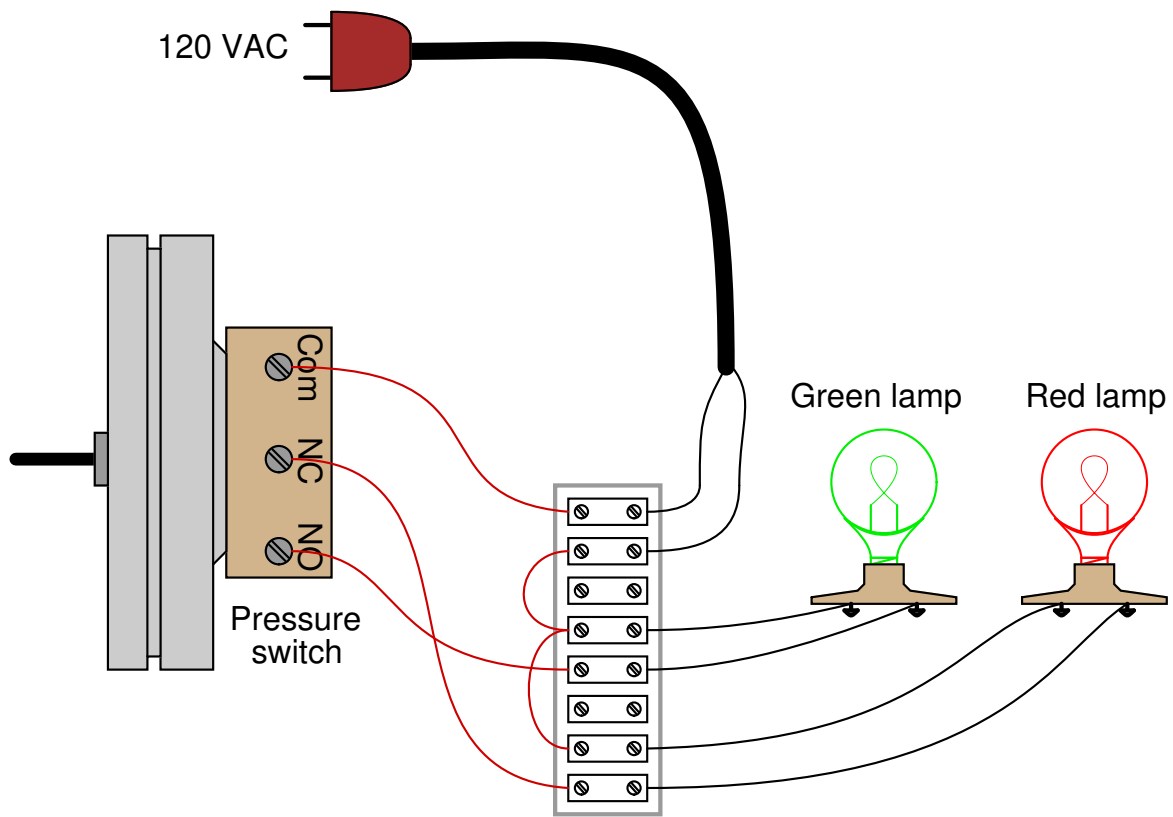
Svar 10



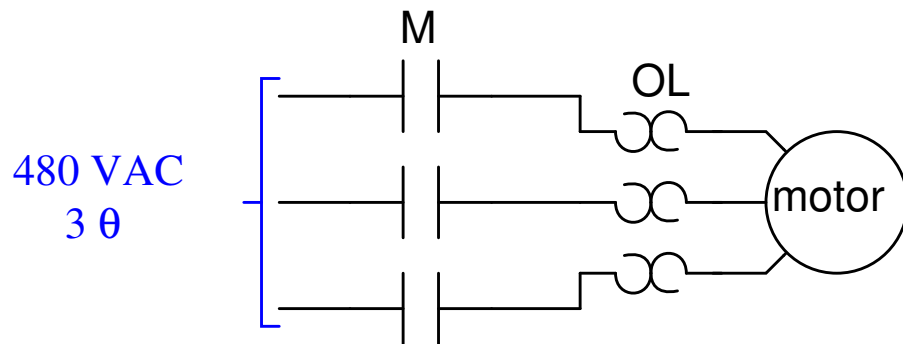
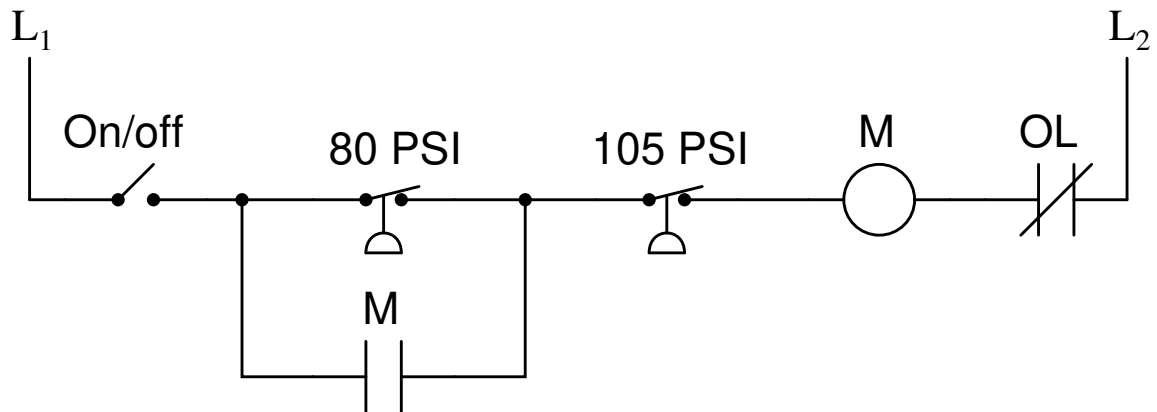
As the diagram shows, this needs to be a **normally-closed** switch.

Svar 11

This is just one possible solution:



Svar 12

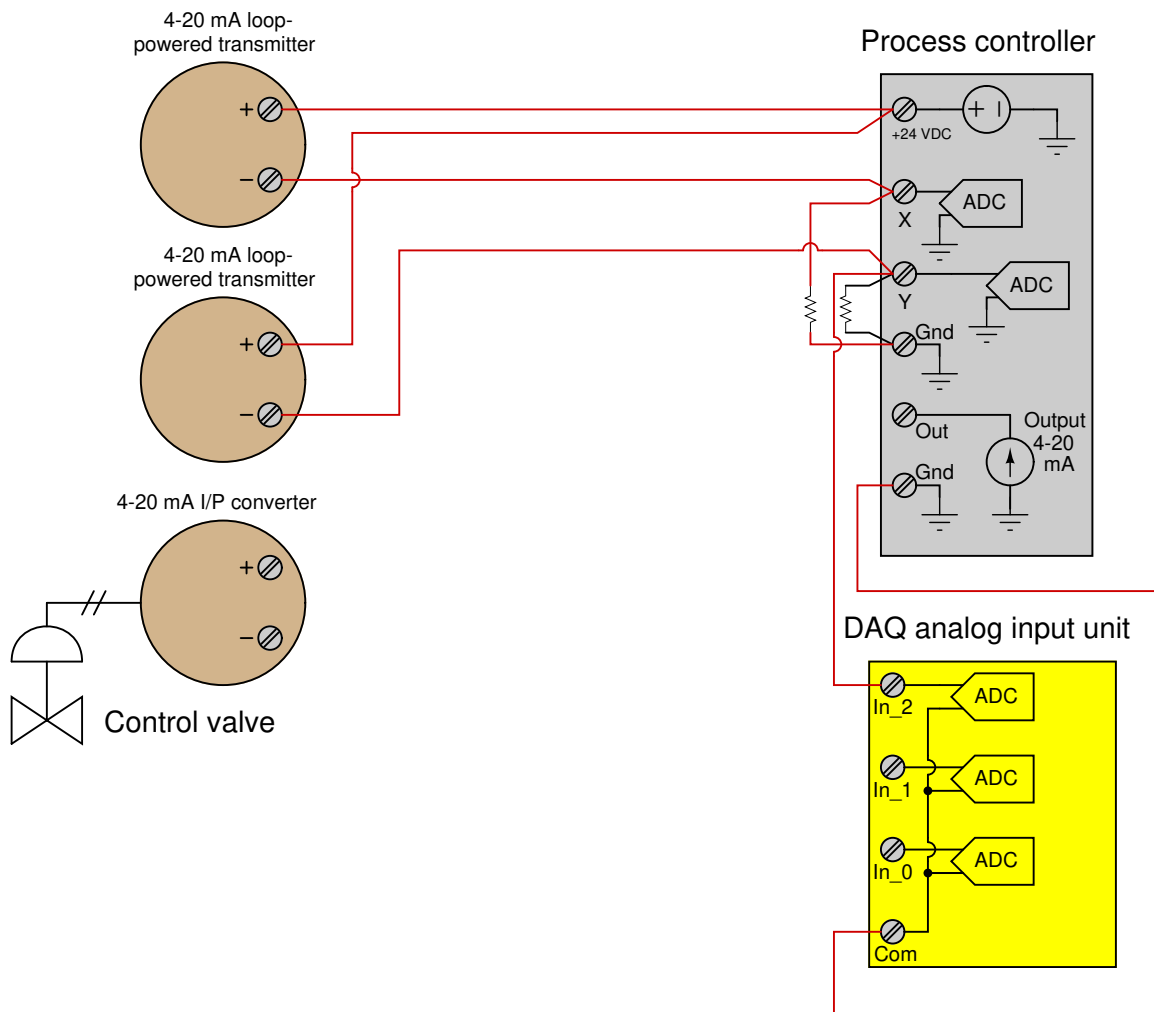


Svar 13

This is a graded question – no answers or hints given!

Svar 14

Partial answer:

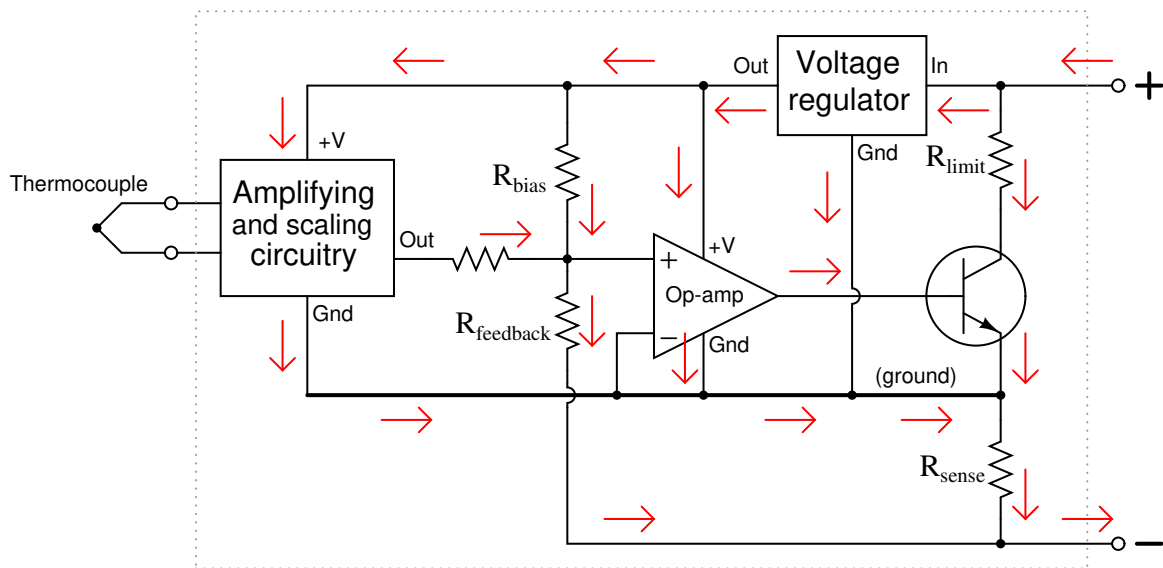


Note that shielded cables and shield grounds are omitted from this diagram for the same of simplicity.

Svar 15

Svar 16

$I_E = 4.3 \text{ mA}$



All arrows drawn in the direction of conventional flow

Follow-up question: how would the transmitter circuit respond to an increase in temperature sensed by the thermocouple? How about a decrease in loop power supply voltage (24 volts \rightarrow 20 volts)?

Challenge question: it is important for instrument accuracy that we make R_{bias} and $R_{feedback}$ resistors rather large in value. Explain why.

Svar 17

Partial answer:

- If a wire breaks loose at TB56-4, creating an “open” fault in the loop circuit, determine what will happen at the alarm unit (AAH, AAL-41) and also where you would expect to measure voltage in the loop circuit and where you would expect to measure *no* voltage in the loop circuit. *The AAL would trip (but not the AAH), and we would expect to measure voltage between the wires of cable 52 but not between the wires of cable 30.*
- If a fire breaks out near the conduit through which cable 52 runs, causing the conductors inside cable 52 to *short* together, what will happen in this system? Where would you expect to measure voltage in the loop circuit, and where would you expect to measure *no* voltage in the loop circuit? Where would you expect to measure current in the loop circuit, and where would you expect to measure *no* current in the loop circuit? *The AAL would trip (but not the AAH), and we would expect to measure no voltage anywhere in the loop circuit. However, we would still have current at the terminals of the AIT-41 transmitter (although no current to the right of the short).*

Svar 18

Switch statuses:

- Switch A = **pressed**
- Switch B = **released**
- Switch C = **released**

The lamp will be de-energized.

Svar 19

Necessary switch statuses:

- Switch A = **released**
- Switch B = **released**
- Switch C = **pressed**

Svar 20

Necessary switch statuses:

- Switch A = **pressed**
- Switch B = **pressed**
- Switch C = **released**

Svar 21

To energize lamp Z: **press** switch B, **release** switch A.

To energize lamp Y: **press** switch A, **release** switch B.

Svar 22

Output Q0.1 will activate to energize lamp Y, but the other output (and lamp) will remain off.

Svar 23

Output Q0.1 will activate to energize lamp Y, but the other output (and lamp) will remain off.

To energize lamp Z, you must release (unpress) both switches.

Svar 24

- Contactor coil failed open
- Wire connecting contactor coil to O:0/2 failed open
- Wire connecting VAC-VDC terminal to DC COM terminal failed open
- Wire connecting input switch “commons” to contactor coil failed open
- Output channel O:0/2 defective on the PLC
- 24 VDC power supply in the PLC is insufficient to power the contactor’s coil

Svar 25

Green lamp is on, red lamp is off.

Svar 26

Green lamp is off, red lamp is on. The PLC inputs are configured here to *sink* current.

Svar 27

The blue lamp will be **off** and the yellow lamp will be **on**.

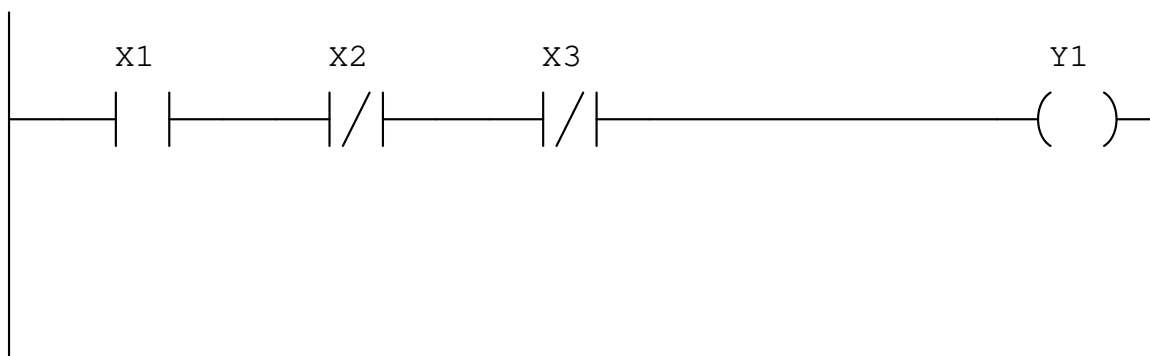
Svar 28

Switch A = **pressed**

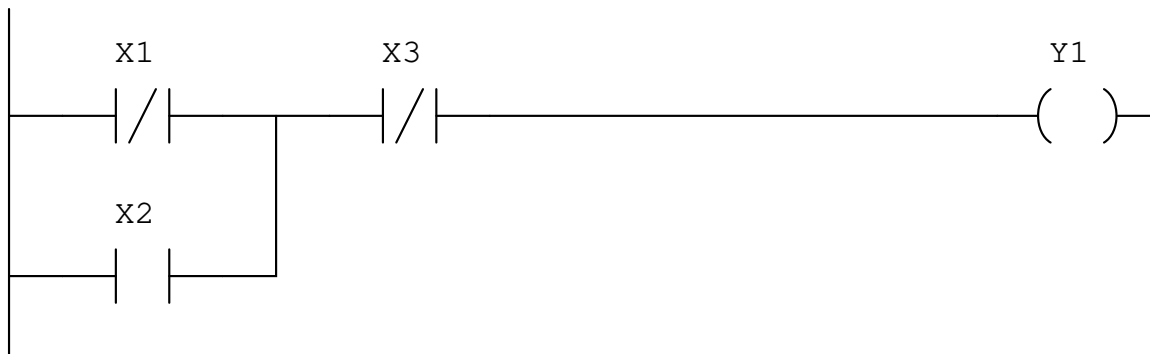
Switch B = **released**

Switch C = **pressed**

Svar 29



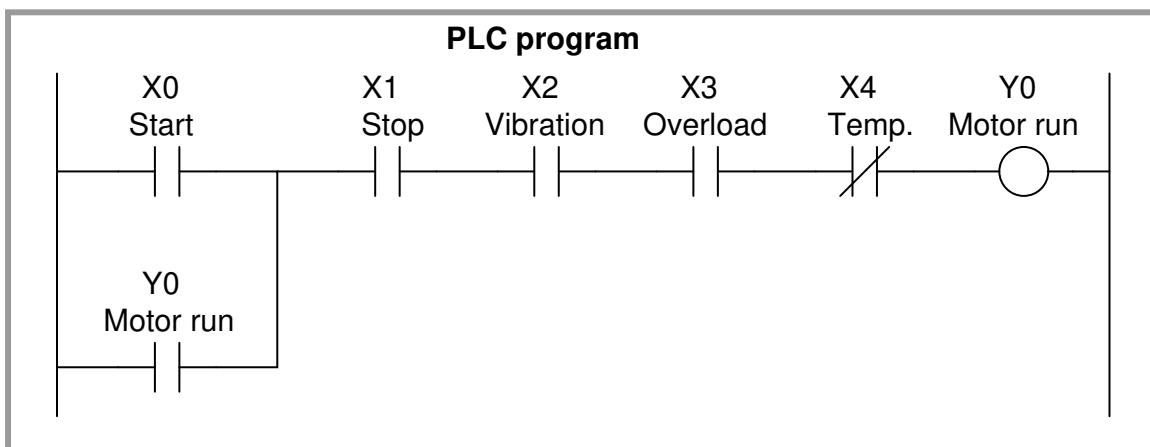
Svar 30



Svar 31

Both pressure switches need their *normally-closed* (NC) contact terminals connected to the respective PLC input terminals.

Svar 32



Svar 33

Partial answer:

- Controller #1 needs to be *reverse-acting*
- Controller #3 needs to be *direct-acting*
- Controller #5 needs to be *direct-acting* (i.e. PV input is "+" and SP input is "-")
- Controller #7 needs to be *reverse-acting* (i.e. PV input is "-" and SP input is "+")

Svar 34

The human operator plays the part of a *reverse-acting* controller, because the valve action must be opposite of any changes in process variable. For example, if the water temperature increases, then the operator should move the control valve further closed.

- PV = water temperature
- SP = ideal (target) water temperature, in operator's mind
- MV = Fuel gas control valve position

Any vapor pressure will be sensed by the transmitter and interpreted as increased liquid level!

Two solutions to this problem:

(1) Use two transmitters (one at top of vessel, one at bottom) and electronically subtract their output signals.

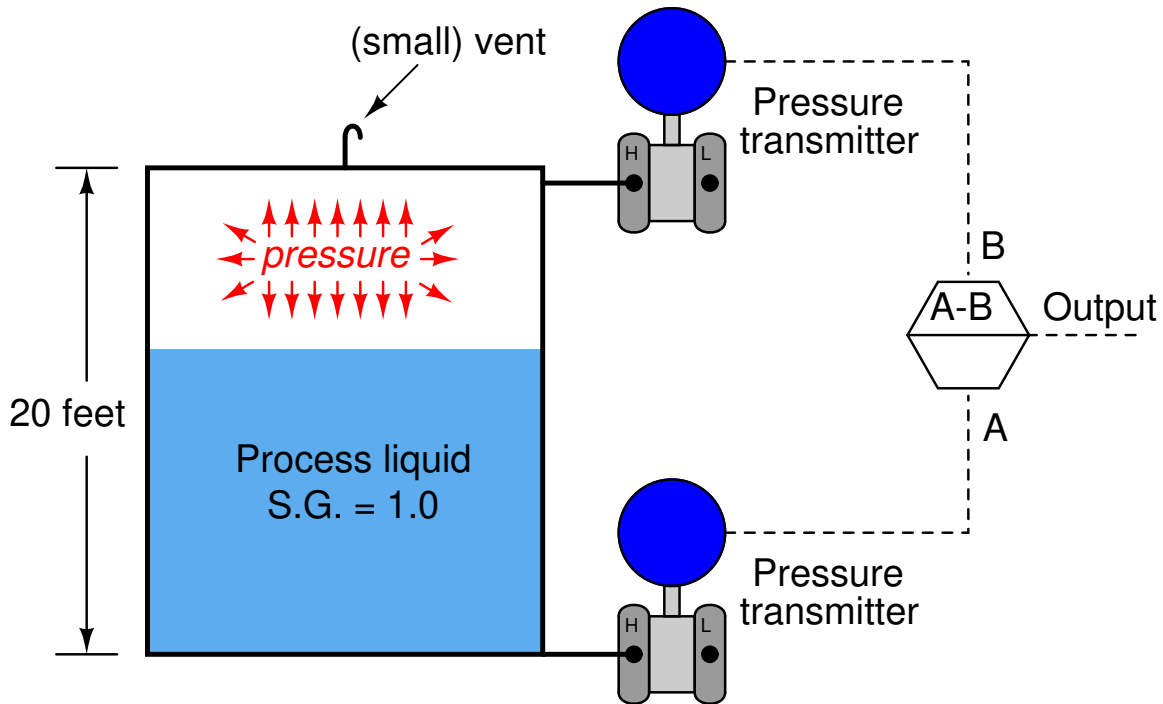
(2) Connect the “Low” side of the one ΔP transmitter to the top of the vessel to naturally compensate for vapor pressure.

Since the transmitter infers level from the amount of pressure sensed at the bottom of the vessel, any vapor pressure buildup inside the vessel will be falsely interpreted as additional liquid level, since the transmitter senses the *sum total* of hydrostatic pressure plus any vapor pressure trapped inside the vessel.

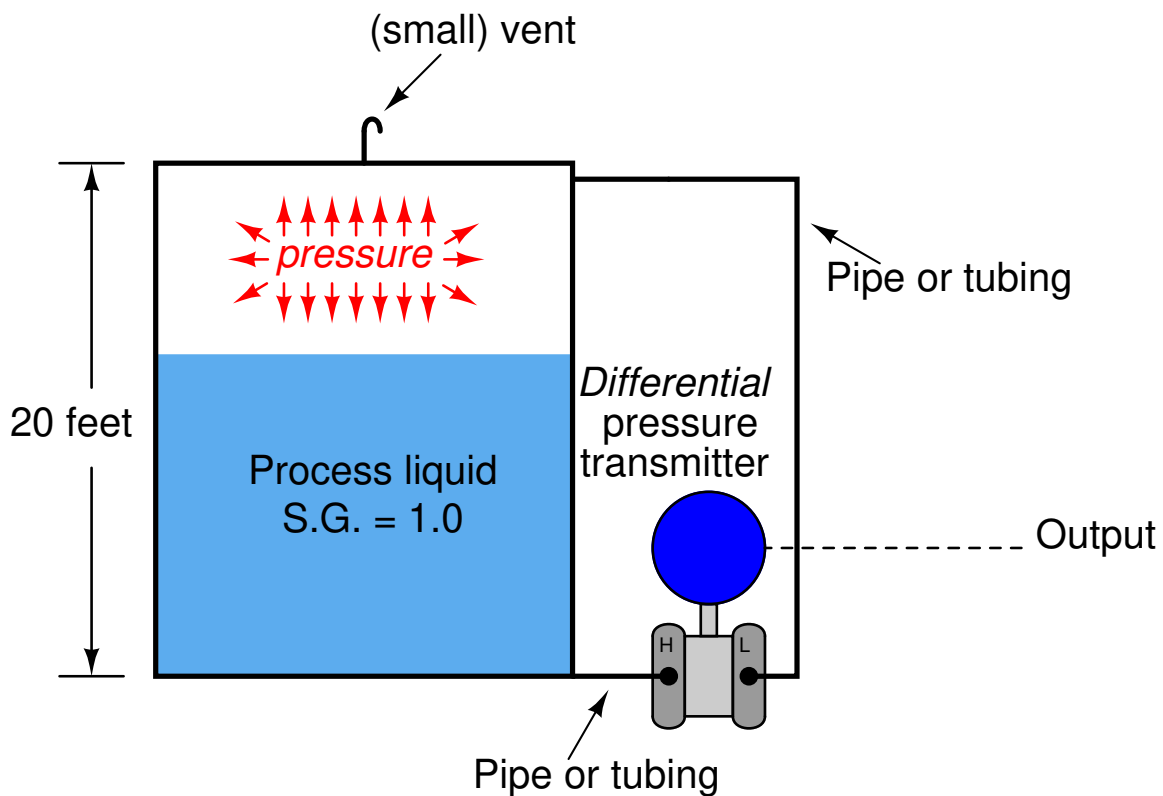
For example, if the process liquid level were at 10 feet (50% of range), the hydrostatic pressure generated by the liquid column would be 120 inches W.C., assuming a specific gravity of 1.0, equal to water. If, however, the vessel contained a vapor pressure equal to 15 inches W.C., this pressure would add with the 120 inches W.C. of pressure generated by liquid head to create 135 inches W.C. of total pressure sensed by the transmitter. As a result, the transmitter would “think” it was detecting a liquid level of 11.25 feet (135 inches high) instead of the true level of 10 feet (120 inches high). Essentially, any vapor pressure in the vessel results in a “zero” shift of the transmitter’s indication.

In many applications, the gas pressure inside a vessel far exceeds the hydrostatic pressure generated by the column of liquid inside of it, so this problem can be a very serious one in level measurement. We need to fully understand the nature of the problem and how to solve it in order to successfully measure liquid level in many industrial applications.

The solution to this dilemma is to measure the *difference* in pressure between the top and bottom of the vessel. We could do this by using two pressure transmitters, one at the top and one at the bottom, and detect hydrostatic pressure by subtracting the top transmitter’s measurement from the bottom transmitter’s measurement. A computer may be used to perform the mathematical subtraction of signals:



Another, more elegant method, incorporates a *differential* pressure transmitter with pipe connections to both ends of the vessel. This solution performs the subtraction mechanically, by directly exposing the transmitter's sensing element to the *difference* of two applied pressures:



Because the differential pressure transmitter solution requires only one sensing instrument rather than two, and results in better accuracy because we are only dealing with

the inaccuracies of a single instrument rather than the compounded inaccuracies of two instruments (three, if you include the subtraction unit), the differential, or “d/p” solution is the one more widely used.

In this particular level measurement application, a differential pressure instrument would have the exact same calibration points (lower and upper range-values) as a “normal” pressure transmitter connected to an open vessel.

Svar 36

Process level (ft)	Percent of span (%)	Δ pressure sensed ("W.C)	Output signal ideal (mA)	Output signal min. (mA)	Output signal max. (mA)
8	0	156	3	2.88	3.12
8.4	10	160.8	4.2	4.08	4.32
9	25	168	6	5.88	6.12
10	50	180	9	8.88	9.12
11	75	192	12	11.88	12.12
11.6	90	199.2	13.8	13.68	13.92
12	100	204	15	14.88	15.12

Svar 37

Hydrostatic pressure when completely full of water = 1.065 bar

Hydrostatic pressure when completely full of gasoline = 0.717 bar

Hydrostatic pressure when water-gasoline interface is at the 50% level = 0.891 bar

Svar 38

- (6 points) Transmitter ΔP at 0% water level = **-38.832** "W.C.
- (6 points) Transmitter ΔP at 50% water level = **-31.864** "W.C.
- (6 points) Transmitter ΔP at 100% water level = **-24.896** "W.C.