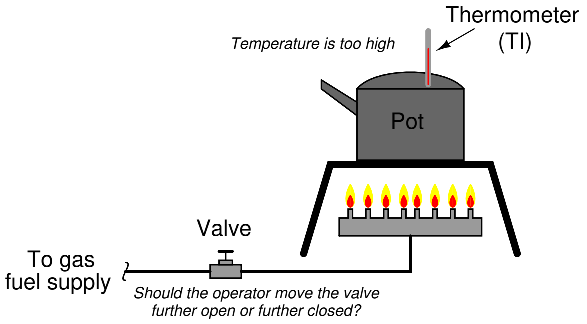
Oppgavesett reguleringsteknikk

Oppgaver

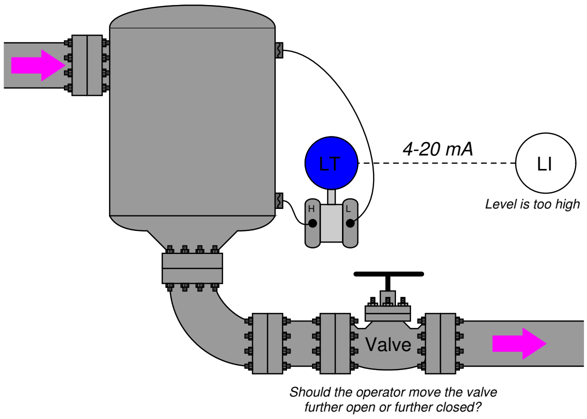
Oppgave 1

Suppose you were giving instructions to a human operator regarding which way to move a hand-operated control valve to maintain a process variable at setpoint. In each of these examples, determine which way the operator should move the valve to *counteract* an increase in the process variable resulting from some independent change in the process:

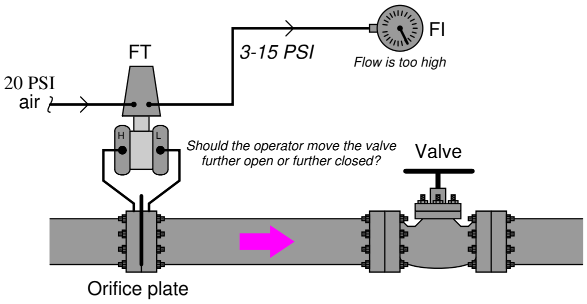
Example 1: Temperature control application



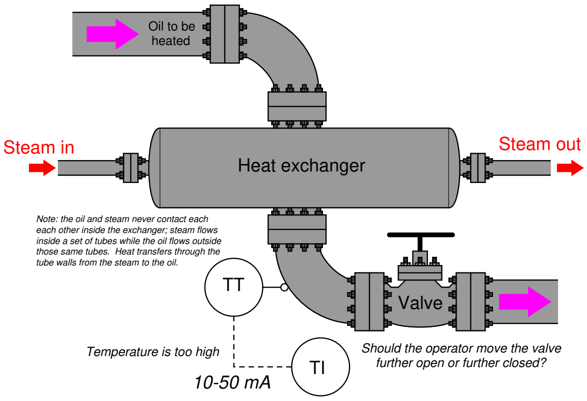
Example 2: Level control application



Example 3: Flow control application



Example 4: Temperature control application



Suggestions for Socratic discussion

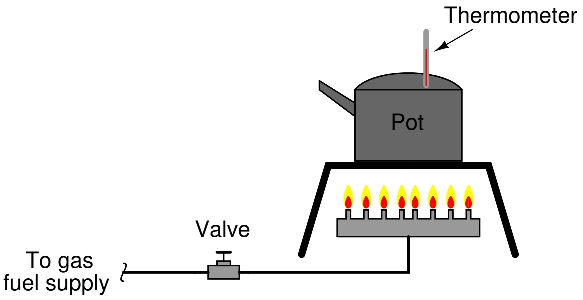
- Follow-up question: in which of these examples is the operator functioning as a *direct-action controller* and in which of these examples is the operator functioning as a *reverse-action controller*?

file i00109

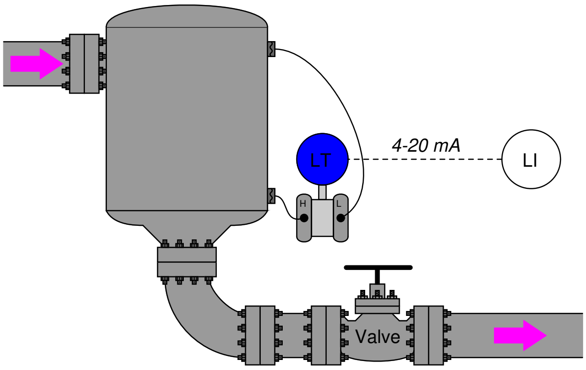
Oppgave 2

In any automated (controlled) system, there is a *process variable*, a *setpoint*, and a *manipulated variable*. There is also something called a *load*, which influences how well the control system is able to maintain setpoint. Provide a general description for a "load," and then identify the load(s) in each of the following manually-controlled processes:

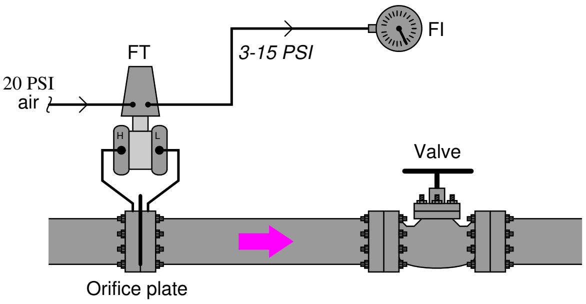
Example 1: Temperature control application



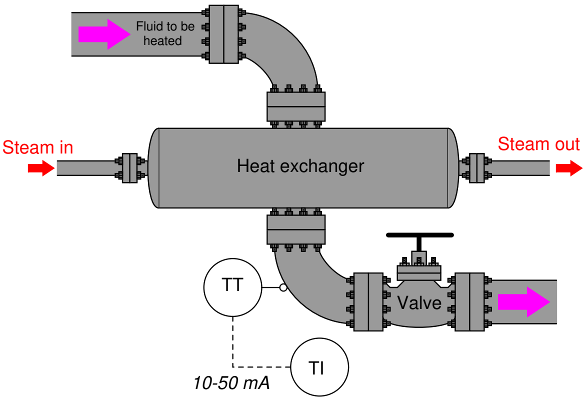
Example 2: Level control application



Example 3: Flow control application



Example 4: Temperature control application



Suggestions for Socratic discussion

- Explain why ambient air temperature is considered a *load* to process example #4, but the insulation thickness on the heat exchanger is not.

file i01453

Oppgave 3

Convert the following controller gain settings into units of proportional band:

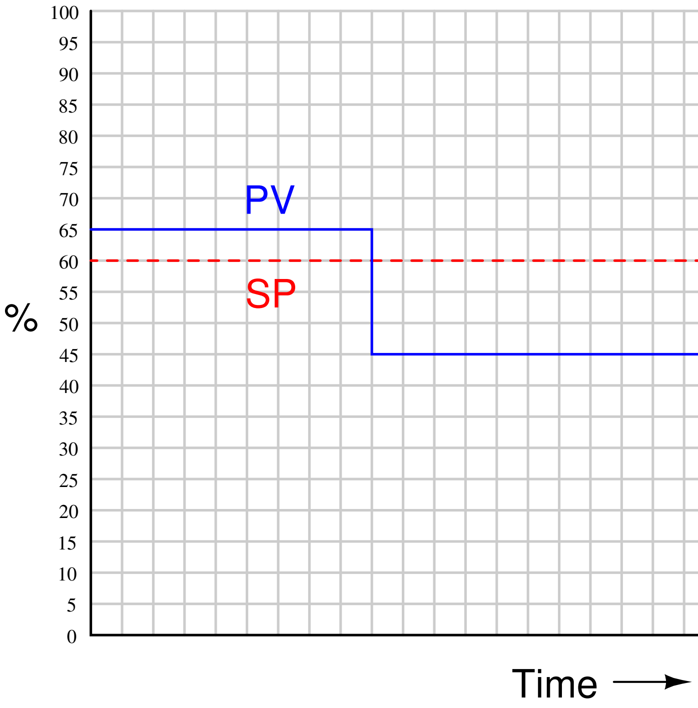
- Gain = 1; P.B. = ________
- Gain = 2; P.B. = ________
- Gain = 3.0; P.B. = ________
- Gain = 0.5; P.B. = ________
- Gain = 0.2; P.B. = ________
- Gain = 0.01; P.B. = ________
- Gain = 5.5; P.B. = ________
- Gain = 10.2; P.B. = ________
- P.B. = 150%; Gain = ________
- P.B. = 300%; Gain = ________
- P.B. = 40%; Gain = ________
- P.B. = 10%; Gain = ________
- P.B. = 730%; Gain = ________
- P.B. = 4%; Gain = ________
- P.B. = 247%; Gain = ________
- P.B. = 9.5%; Gain = ________

Vis formel du bruker for utregningene.

file i01462

Oppgave 4

Graph the output of this proportional-only controller, assuming a gain (K_p) value of 2.0, a bias value of 50%, and a control action that is direct-acting:



Suggestions for Socratic discussion

- Explain why this trend graph of the PV is unrealistic for a real process, but nevertheless useful for learning how a proportional-only controller is designed to respond to changes in PV.
- How do you suppose the PV would *actually* respond in a real process to the conditions shown (or implied) in this trend? Sketch what you would think would be a more realistic response assuming a properly-tuned proportional-only controller running in automatic mode.

file i01468

Oppgave 5

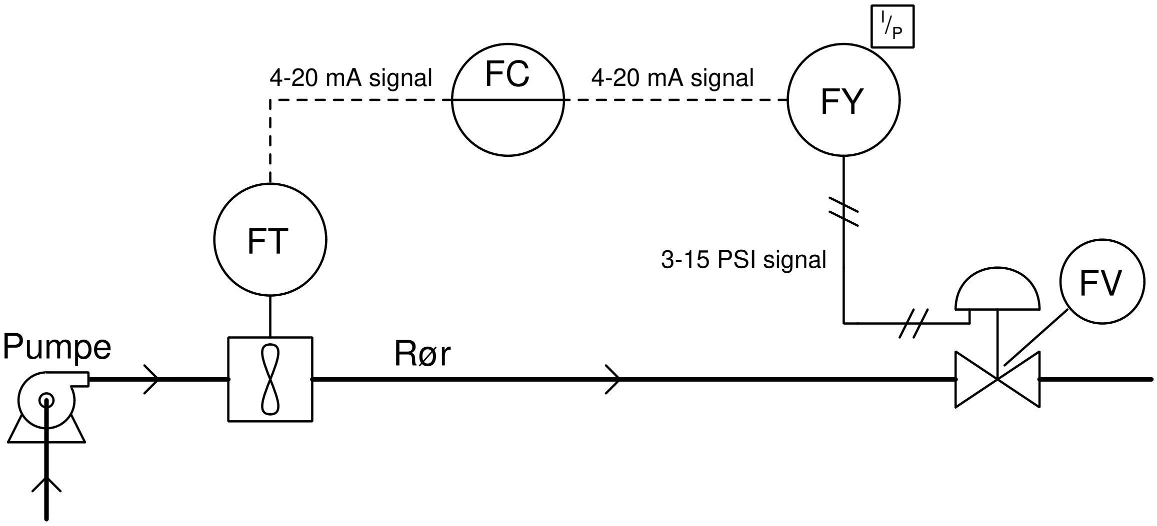
Suppose that a reverse-acting, proportional-only controller has a gain (K_p) setting of 2 and a bias (b) setting of 40%. What will its output be for the following input conditions?

- PV = 37%; SP = 50%; Output = ________
- PV = 92%; SP = 80%; Output = ________
- PV = 81%; SP = 75%; Output = ________
- PV = 33%; SP = 42%; Output = ________
- PV = 79%; SP = 76%; Output = ________
- PV = 15%; SP = 20%; Output = ________
- PV = 38%; SP = 38%; Output = ________
- PV = 0%; SP = 0%; Output = ________

file i01489

Oppgave 6

Her vises en P&ID (Prosess og instrumenteringsdiagram) for en væskestrøm reguleringssløyfe. Den består av en strømningsmåler (FT) som registrer strømningen i røret og sender et elektronisk signal på for stor strømning det er. En strømingsregulator (FC) mottar signalet og sammenligner dette med et settpunkt, for så å avgjør hvilken vei reguleringsventilen skal bevege seg. En strøm til luft omformer (*(FY) konverterer strømsignalet fra regulatoren til et lufttrykk som styrer posisjonen til reguleringsventilen(FV), som igjen styrer strømningen i røret.



Retningen på styresignalet for hvert instrument vises her:

- FT: Økende strømning = økende signal
- FC: Økende signal på inngang (PV) = minkende signal på utgang (MV)
- FY: økende strømsignal på inngang = økende pneumatisk signal på utgangen
- FV: økende pneumatisk signal = ventilen åpner mer.

Forklar hva som vil skje med alle signalene i denne reguleringssløyfen med regulatoren i "Auto" modus (Klar for å kompensere for variasjoner i strømningen) hvis pumpen plutselig roterer fortere og øsker strømningen.
Forklar også hva som vil skje med styresignalene i reguleringssløyfen med regulatoren i "manual" modus(styresignalet står fast på det som operatøren har stilt det på) dersom pumpen roterer fortere og forårsaker en økning i strømningen.

Suggestions for Socratic discussion

- Explain the practical benefit of having a "manual" mode in a process loop controller. When might we intentionally use manual mode in an operating process condition?

file i00124

Oppgave 7

The very simplest style of automatic control is known as *on-off* or more whimsically, *bang-bang* control. This is where the automatic controller only has two output signal modes: fully on and fully off. Your home's heating system is most likely of this sort, where a thermostat can either tell the furnace to turn on or to turn off.

Describe the advantages and disadvantages of "on-off" control, as contrasted against more sophisticated control schemes where a final control element such as a control valve may be proportionately positioned anywhere between fully open and fully closed according to the demands of the process.

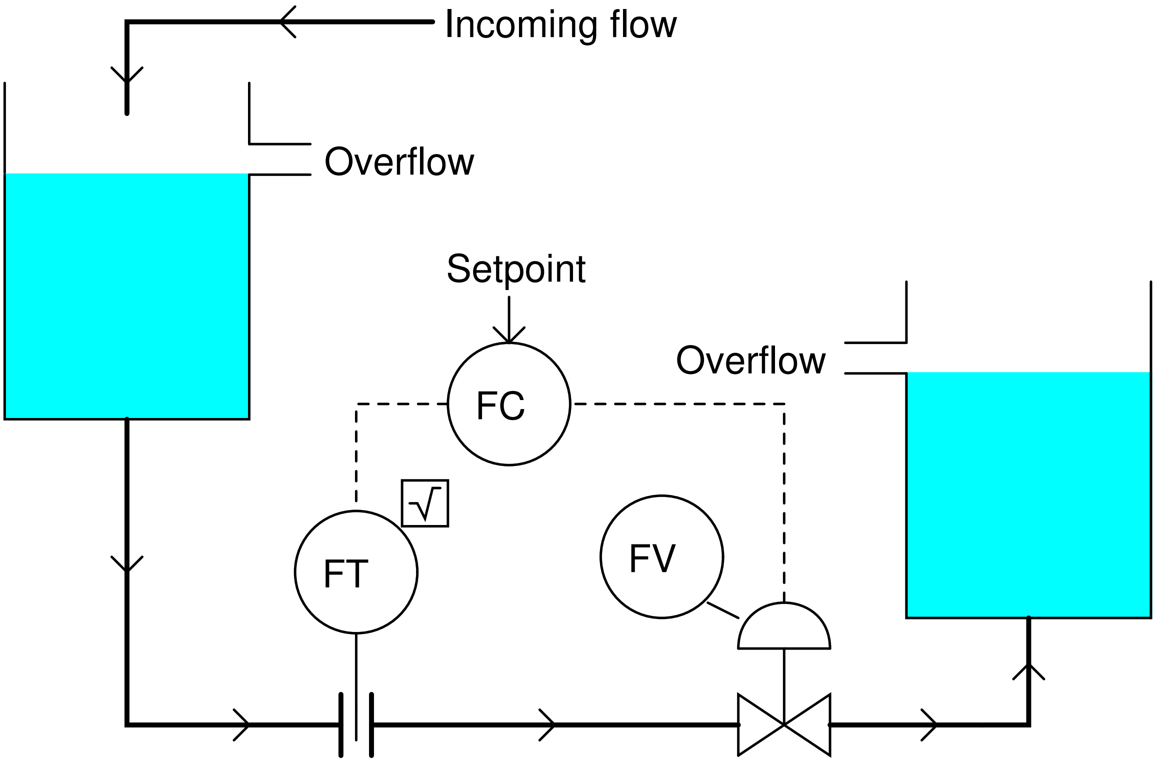
Suggestions for Socratic discussion

- What other control systems in common experience use the "bang-bang" strategy?

file i00125

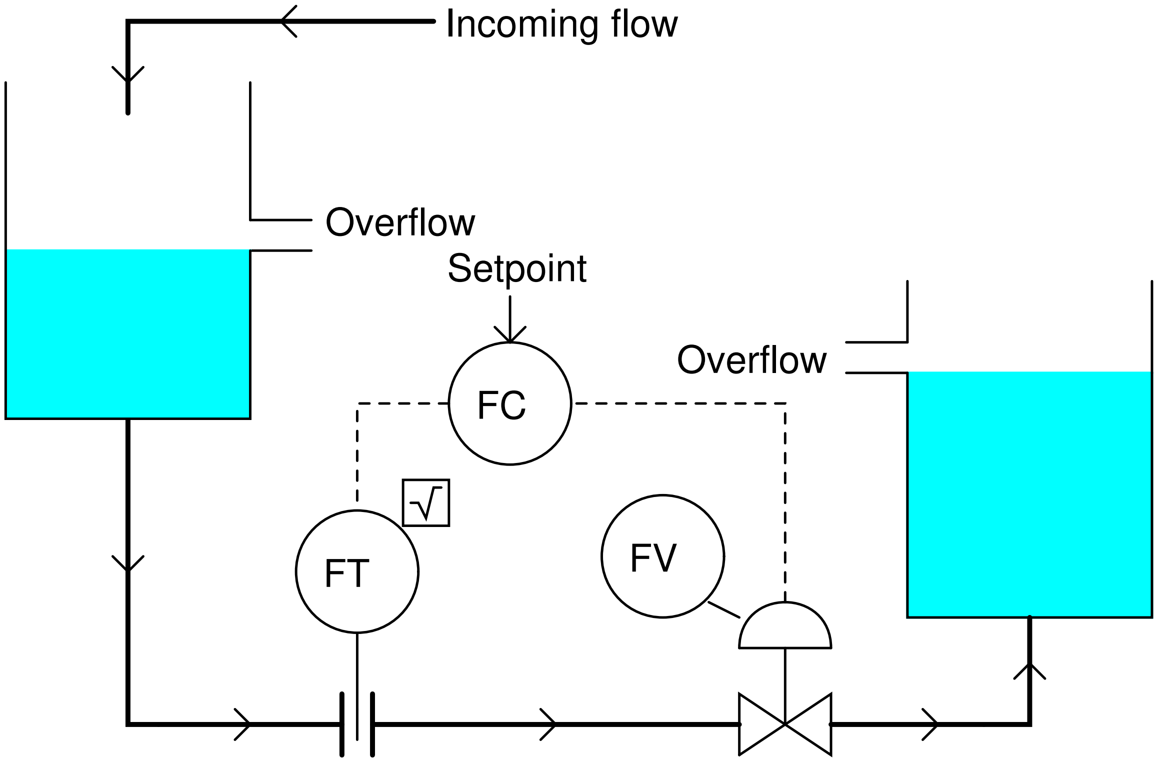
Oppgave 8

Examine this flow control system, where a valve controls the flow rate of liquid between two vessels:



Since each vessel has its liquid level controlled by an overflow pipe, the head pressure at the bottom of each will be constant. This means that the differential pressure across the valve will be constant as well.

Suppose now that the higher vessel has its overflow pipe moved to a lower location, thus reducing the controlled level in that vessel, and consequently the head pressure generated at the bottom:



This change in head pressure, of course, reduces the amount of differential pressure across the valve. How will this affect the process gain, as it relates to flow control? In other words, will the flow rate become more or less sensitive to changes in valve position as a result of decreasing the pressure drop across the valve?

What will happen to the process gain if we then replace the control valve with one having a larger C_v value (a larger opening for fluid flow when fully open)?

Finally, what will happen to the process gain if we re-calibrated the flow transmitter for a smaller span (for example, from 0-120 GPM to 0-75 GPM)?
file i01458

Oppgave 9

Digital proportional controllers generate their output signal values using a microprocessor to repeatedly evaluate the proportional equation:

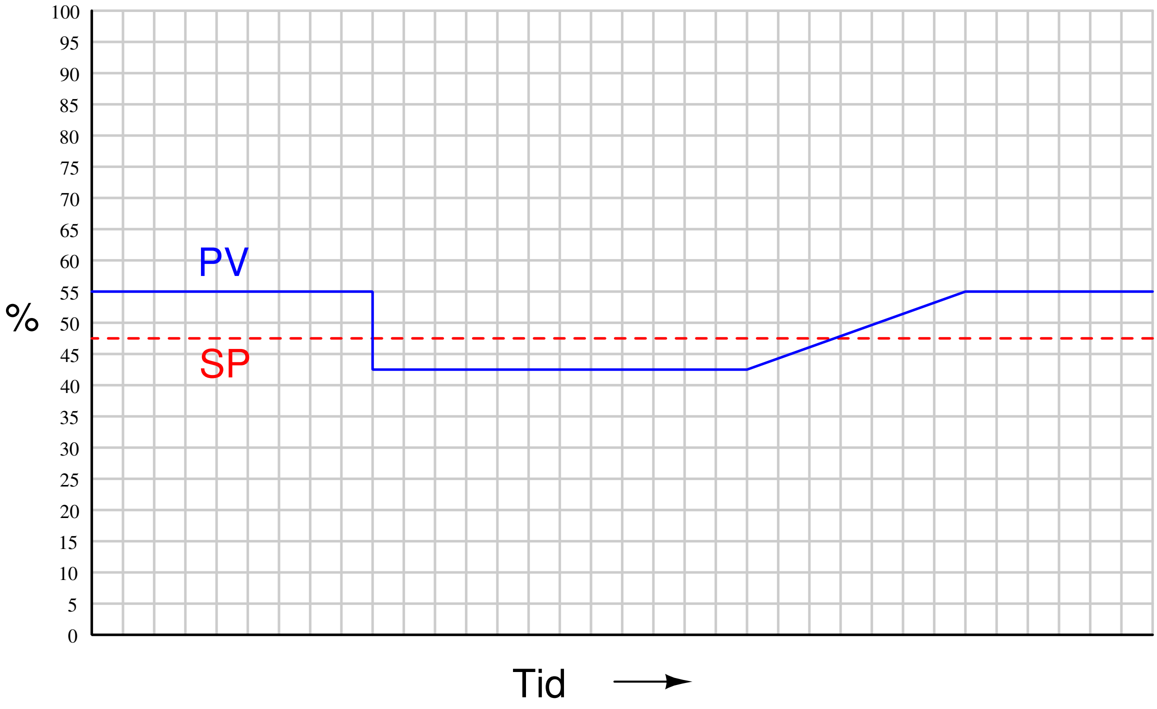
$$m = K_p e + b$$

What would happen if a *negative* value were entered for gain (K_p) into the digital controller's program?
file i01467

Oppgave 10

Tegn grafen for utgangen på denne regulatoren med bare p-ledd og direktevirkning. Den er stilt inn med følgende verdier:

- proporsjonalbånd 20%
- bias 50 %



Utregninger:

Suggestions for Socratic discussion

- Explain why this trend graph of the PV is unrealistic for a real process, but nevertheless useful for learning how a proportional-only controller is designed to respond to changes in PV.
- How do you suppose the PV would *actually* respond in a real process to the conditions shown (or implied) in this trend? Sketch what you would think would be

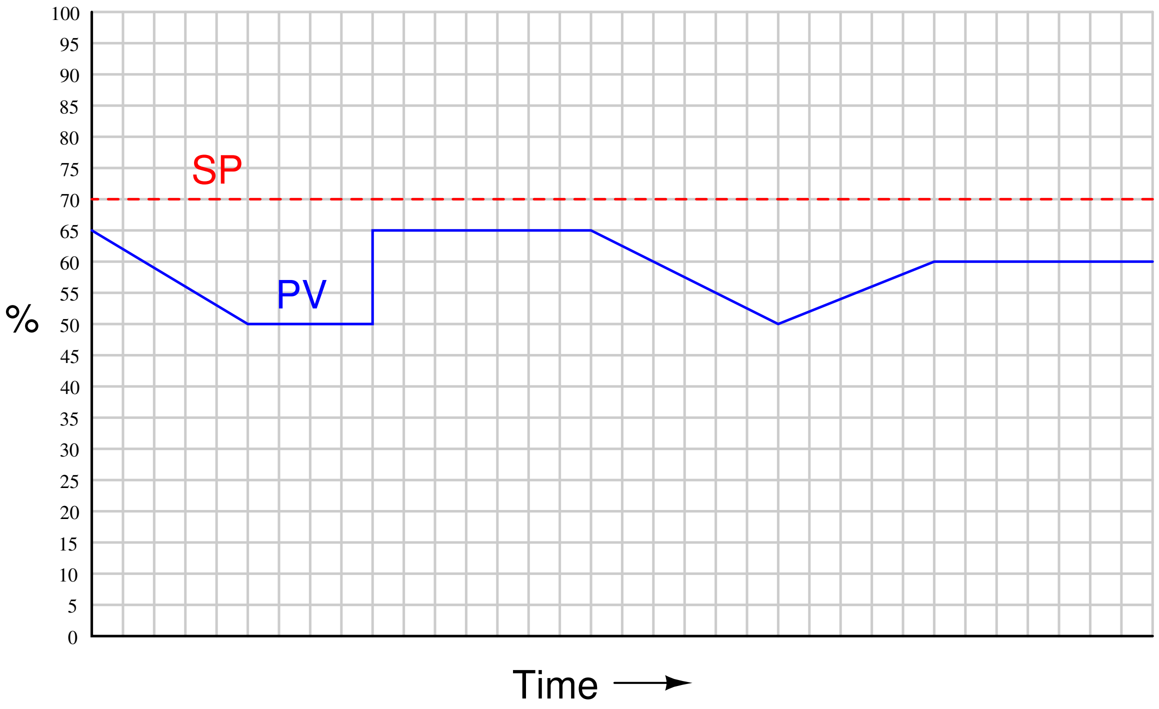
a more realistic response assuming a properly-tuned proportional-only controller running in automatic mode.

- Identify points on the trend where the PV exhibits a positive rate of change.
- Identify points on the trend where the PV exhibits a negative rate of change.
- Identify points on the trend where the PV exhibits zero change.

file i01469

Oppgave 11

Graph the output of this proportional-only controller, assuming a proportional band value of 125%, a bias value of 30%, and a control action that is reverse-acting:



Suggestions for Socratic discussion

- Identify points on the trend where the PV exhibits a positive rate of change.
- Identify points on the trend where the PV exhibits a negative rate of change.
- Identify points on the trend where the PV exhibits zero change.
- How would the output signal trend be altered if the *gain* of this controller were increased?
- How would the output signal trend be altered if the *bias* of this controller were increased?
- How would the output signal trend be altered if the *action* of this controller were switched from reverse to direct?

file i01470

Oppgave 12

A proportional-only controller in automatic mode has the following input and output values:

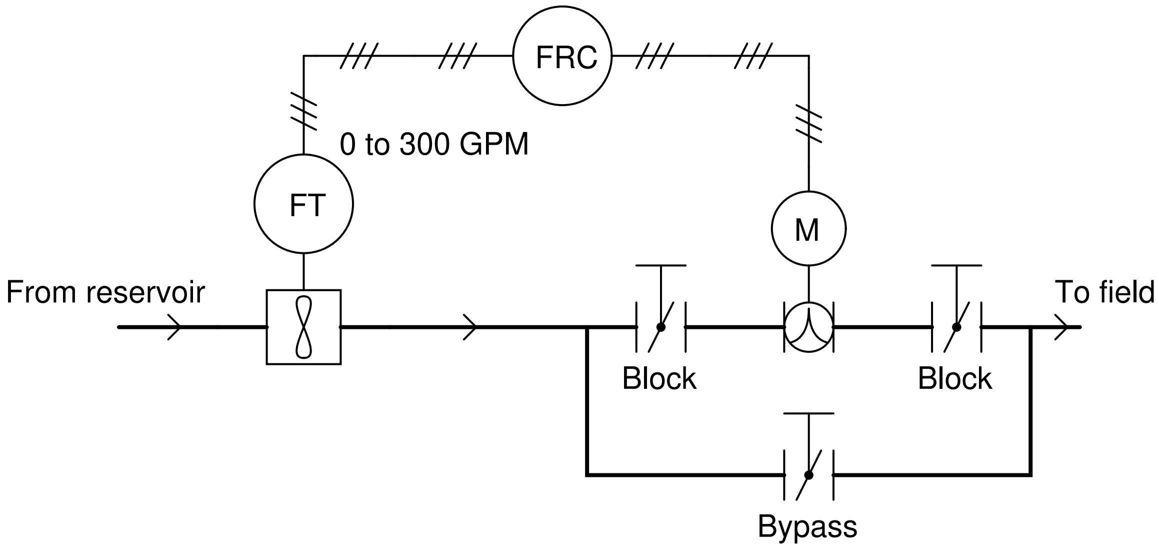
- PV = 65%
- SP = 62%
- Output = 48%

Suddenly, the operator changes the setpoint from a value of 62% to a value of 55%. The controller output immediately goes from 48% to 31%. Calculate the proportional band and the gain for this controller, and show all your work. Also, determine if this controller is *direct* or *reverse* acting.

file i01493

Oppgave 13

Shown here is a simple flow control system for distributing water from an irrigation reservoir to a crop field at a controlled flow rate. The flowmeter is ranged from 0 to 300 gallons per minute:



The flow-recording controller (FRC) is a proportional-only unit with the following algorithm:

$$m = K_p(\text{SP} - \text{PV}) + 50\%$$

Where,
m = Manipulated variable (output)
K_p = Controller gain
SP = Setpoint
PV = Process Variable (water flow)

One day the controller is found to be working perfectly: the setpoint is set to 180 GPM, and the process variable reads exactly the same: 180 GPM. The controller's output is seen to be 50% in this condition. Then, the operator adjusts the setpoint to a new flow rate: 250 GPM. As expected, the controller's output automatically increases and the valve opens up to allow more flow through the pipe. As the flow rate approaches the new setpoint of 250 GPM, the valve begins to close off. This makes the flow rate approach setpoint slower and slower, like a capacitor slowly charging to a new voltage value over time. However, the operator notices something unexpected: the flow rate never makes it all the way to the new setpoint value of 250 GPM. Instead, it stabilizes at about 239 GPM and does not increase beyond that.

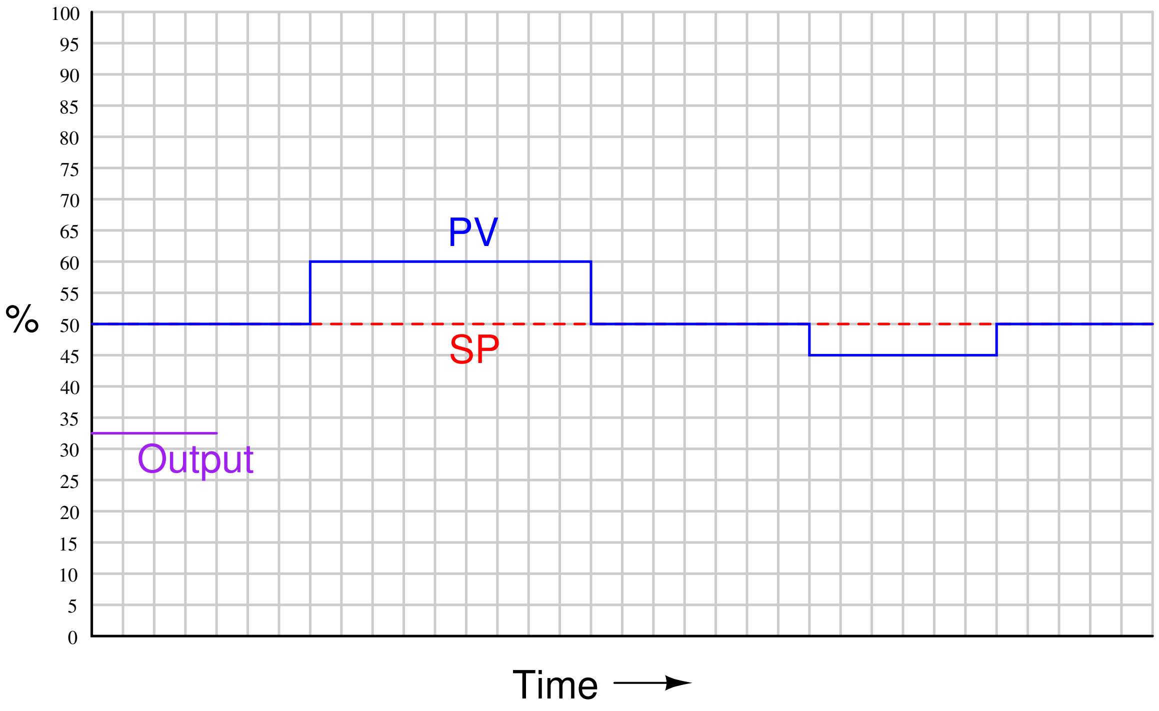
Confused as to why the controller does not reach the new setpoint of 250 GPM like it did the old setpoint of 180 GPM, the operator calls an instrument technician to investigate. "What is wrong with this controller?" the operator asks the technician. "It stops increasing the flow rate shy of its new setpoint." After a moment of investigation, the technician notices that this is a proportional-only controller. Seeing this, the technician just smiles and proceeds to explain to the operator why the controller *never will* reach the new setpoint like it did at 180 GPM. For that matter, it cannot perfectly reach any setpoint less than 180 GPM either! If it perfectly attained setpoint at 180 GPM, then that is the *only* setpoint value it will.

Explain, in your own words, why this is true.

file i01584

Oppgave 14

Qualitatively graph the response of a proportional-only controller over time to the following changes in process variable:



Assume *reverse* control action.

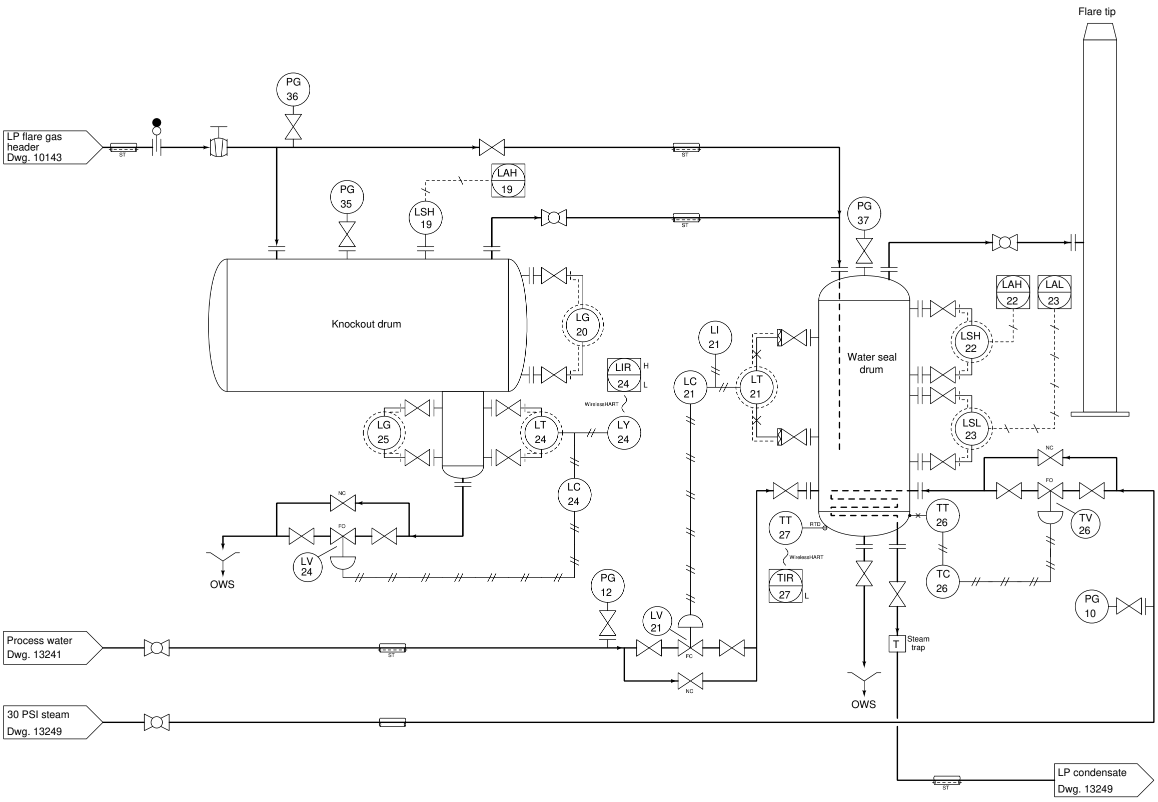
Suggestions for Socratic discussion

- What defines a "reverse" acting controller, in contrast to a "direct" acting controller?
- Explain why it would be highly unusual to see a trend like this in a real, working process loop. Why is this trend unrealistic, assuming a working process where all components are functioning properly?
- Given that this trend is unrealistic, why is it something we're studying? In other words, what value does a "toy" trend like this have for us?

file i01593

Oppgave 15

Examine this process, where the temperature of water sitting at the bottom of a "water seal drum" vessel is regulated by passing hot steam through a heating tube immersed in the water:



Suppose that one day the 30 PSI steam supply boiler shuts down, ceasing the flow of steam to the TV-26. With no supply of steam to heat the seal drum, the water begins to cool down. What will controller TC-26 do in response to this event, assuming it is a proportional+integral (P+I) controller?

Now suppose that the steam "outage" lasts for a very long time. How will the controller's proportional and integral modes respond if left in the automatic mode the entire time? Is there a way to avoid this problem?

Suggestions for Socratic discussion

- Examining the diagram, what do you suppose the function of the water seal drum is, in the larger context of the flare process?
- Which is the worst-case scenario: the water in the seal drum becoming too cold or becoming too hot? How can we tell based on details found in this diagram?
- Suppose operations personnel approached you to install instrumentation to measure the total quantity of substance released to the flare each month, for emissions monitoring purposes. For those who have studied flowmeters, identify at least one practical solution to this problem, including the specific types of technologies used to sense the vapors going to the flare.

file i01608

Oppgave 16

Suppose an aging controller needs to be replaced, and its tuning constants are documented as such:

- Proportional band = 130%
- Reset = 2.7 minutes per repeat

The new controller destined to replace this old unit is also a proportional+integral controller, but its tuning constant units are different. Instead of "proportional band," the K_p constant is labeled as "gain." Instead of "minutes per repeat," the new controller bears the unit of "repeats per second" for its integral constant.
Convert the old tuning constants into the new units, so that when the new controller is installed, it does the same exact job as the old controller. Note: assume the use of the same algorithm type (P+I equation) in both controllers.

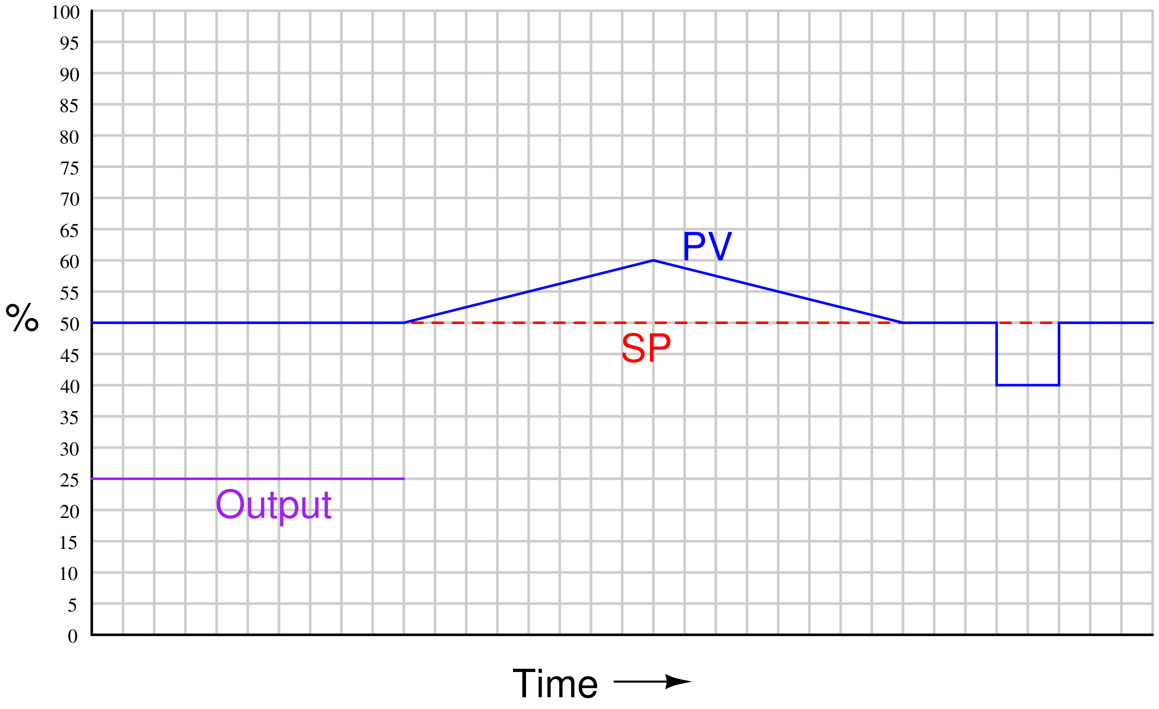
Suggestions for Socratic discussion

- Explain what would happen if the new controller were installed and programmed (by someone who didn't know better) with a gain of 1.30 for proportional action and 2.7 repeats per second for integral action.

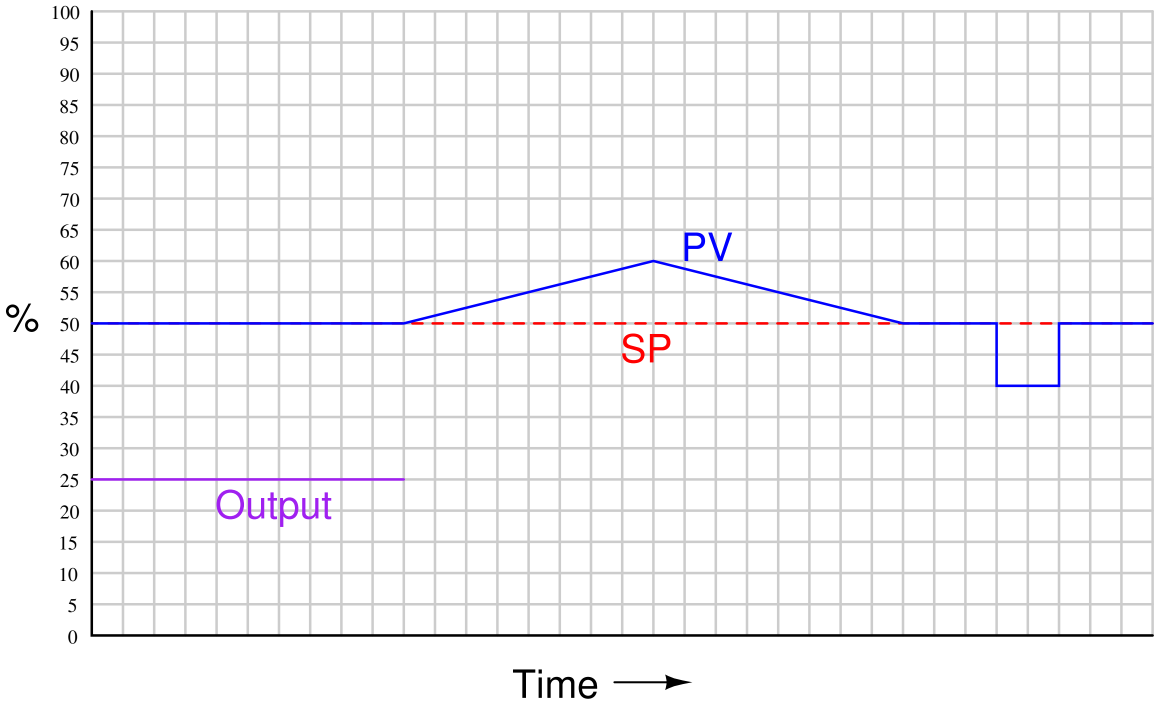
file i01612

Oppgave 17

Qualitatively graph the individual proportional, integral, and derivative responses of a PID controller to the following input conditions, assuming *direct* controller action. Use a solid line for proportional, a dashed line for integral, and a dotted line for derivative:



Then, draw a final graph of the controller's output, showing how the P, I, and D terms would combine to form a composite waveform:



Suggestions for Socratic discussion

- Many students find the task of summing all three control actions together to be much more difficult than plotting any of the three responses separately. Devise a problem-solving strategy to ensure your summation will always be correct!

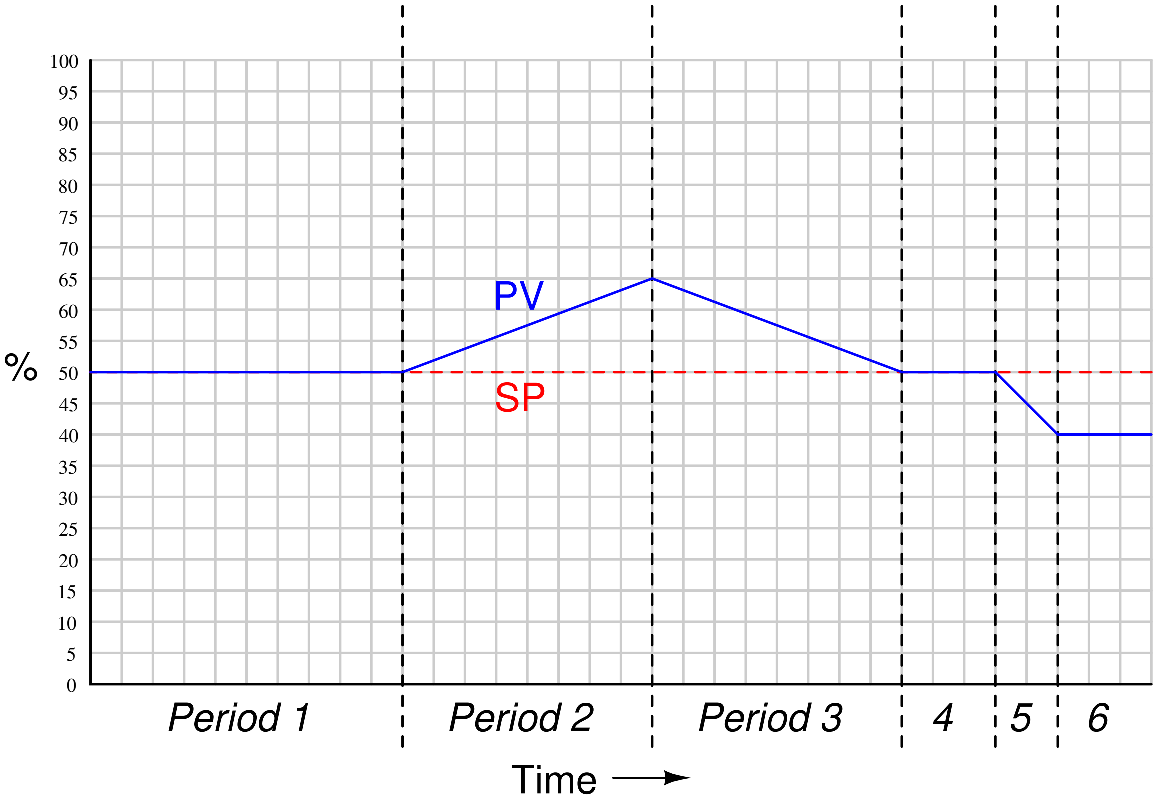
file i01638

Oppgave 18

It is sometimes said that in a PID controller, proportional action works on the *present*, while integral action works on the *past* and derivative action works on the *future*. Explain what this means.
file i01639

Oppgave 19

Determine how each control action (P, I, and D) would react during the periods marked on this process trend by using the symbols ↑ (driving up), ↓ (driving down), + (steady positive), − (steady negative) or 0 (zero), compared to the actions of each at the beginning of the trend. Do this for P, as well as for I and D. Assume *direct action* for the controller.



Suggestions for Socratic discussion

- Identify any good problem-solving strategies you might apply to this problem.
- Sketch a qualitative graph showing the output of a full PID controller given these PV and SP graphs.

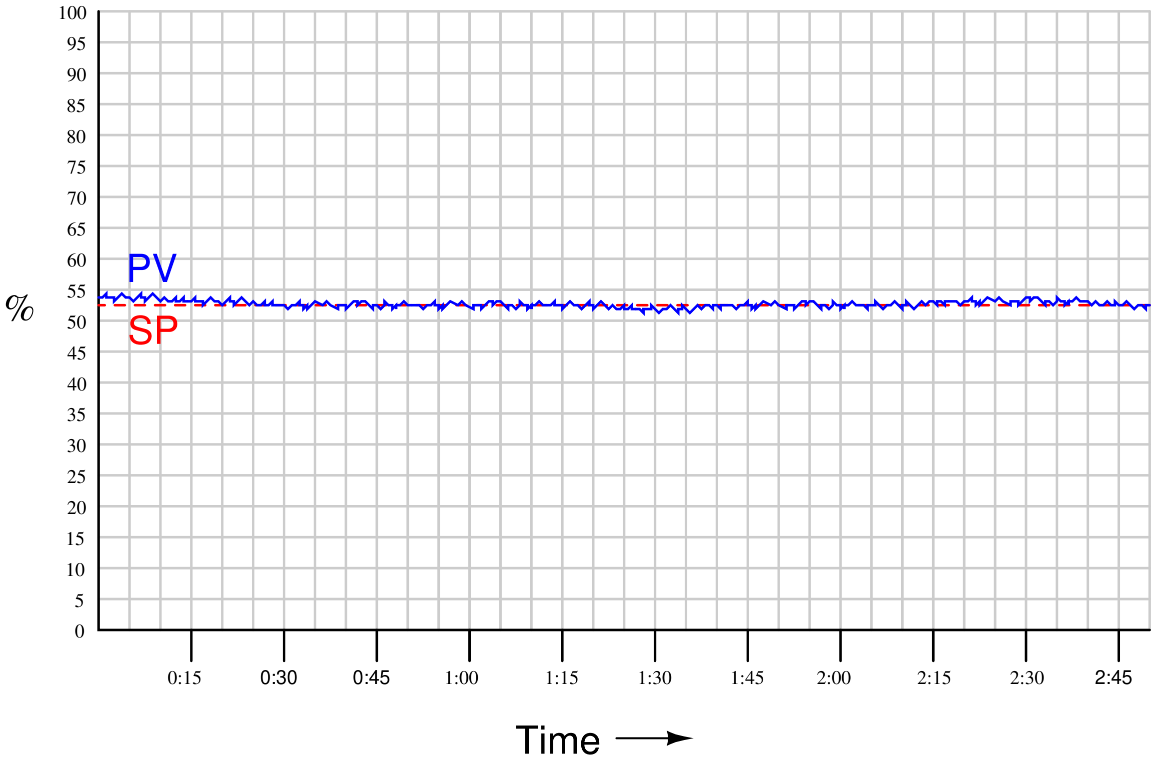
file i01640

Oppgave 20

On some PID controllers, an option is given to allow derivative action to act on process variable (PV) changes only, or act on error (PV − SP) changes like integral action always does. What benefit would it be to have derivative action working on PV changes only and not SP changes?
file i01644

Oppgave 21

Derivative control action is especially useful in processes characterized by slow lag times, especially when the process has a natural tendency to "overshoot" the setpoint due to multiple lags. The purpose of derivative mode control is to make decisions based on how *quickly* the process variable changes over time, taking action in the present to avoid setpoint overshoot in the future.
However, derivative mode control cannot be used in processes where the PV signal is tainted with *noise*, as is the case in this trend:



It does not matter how well-suited the process may be for derivative control in any other regard, so long as the noise is there. Noise and derivative control are simply incompatible – explain why.

Also, identify whether or not *integral* mode control is affected by noise in the PV signal, and explain your answer.

Suggestions for Socratic discussion

- Observing the trend graph shown here, can we tell whether this controller is in manual mode or automatic mode? If so, identify its operating mode.
- Observing the trend graph shown here, can we tell whether this controller is direct-acting or reverse-acting? If so, identify its direction of action.
- Observing the trend graph shown here, can we tell anything about the P, I, and/or D settings of this controller? If so, identify what its dominant control action is (P, I, or D).

file i01671

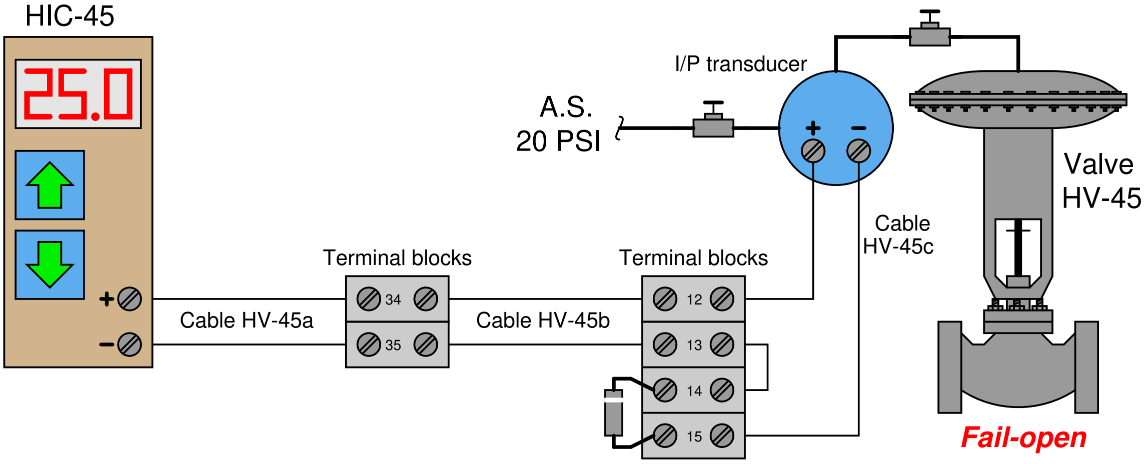
Oppgave 22

What does it mean for a process (such as a temperature-controlled cookie oven) to have a *time constant*? I am referring here to the process itself (oven, heating element, and cookies), not the control system.

file i01678

Oppgave 23

Den manuelle kontrolleren (HIC-45) gjør at den operatør kan kontrollere reguleringsventilen (HV-45) med å trykke pil opp og ned på regulatoren.



Som automatikker må du konfigurere kontrolleren sånn at displayet viser ventilens aktuelle posisjon. 0 på displayet skal tilsvare 0% åpen (helt lukket) og 100 på displayet skal tilsvare 100 % åpen. Dette for at displayet skal være så enkelt som mulig for operatører å betjene. Utfordringen er at ventilen er *air-to-close*, som betyr at den må fullt lufttrykk for å lukkes helt, og det den er helt åpen uten lufttrykk.

Det er to måter å oppnå dette målet på. Den første er å kalibrere I/P transduceren til å være reverserende (4 mA = 15 PSI : 20 mA = 3 PSI). Den andre måten krever at vi konfigurerer den manuelle kontrolleren til å være reverserende. (4 mA = 100% display ; 20 mA = 0% display). Anta du velger den andre metoden, der I/P kalibreringen er normal. (e.g. 4 mA = 3 PSI) og kontrolleren er reverserende. (e.g. 100% display = 4 mA). Gitt denne konfigurasjonen fullfør tabellen:

Controller display	**Controller current**	**I/P pressure**	**Valve stem position**
77.5%			
	17.9 mA		
		4.29 PSI	
			64% open

Suggestions for Socratic discussion

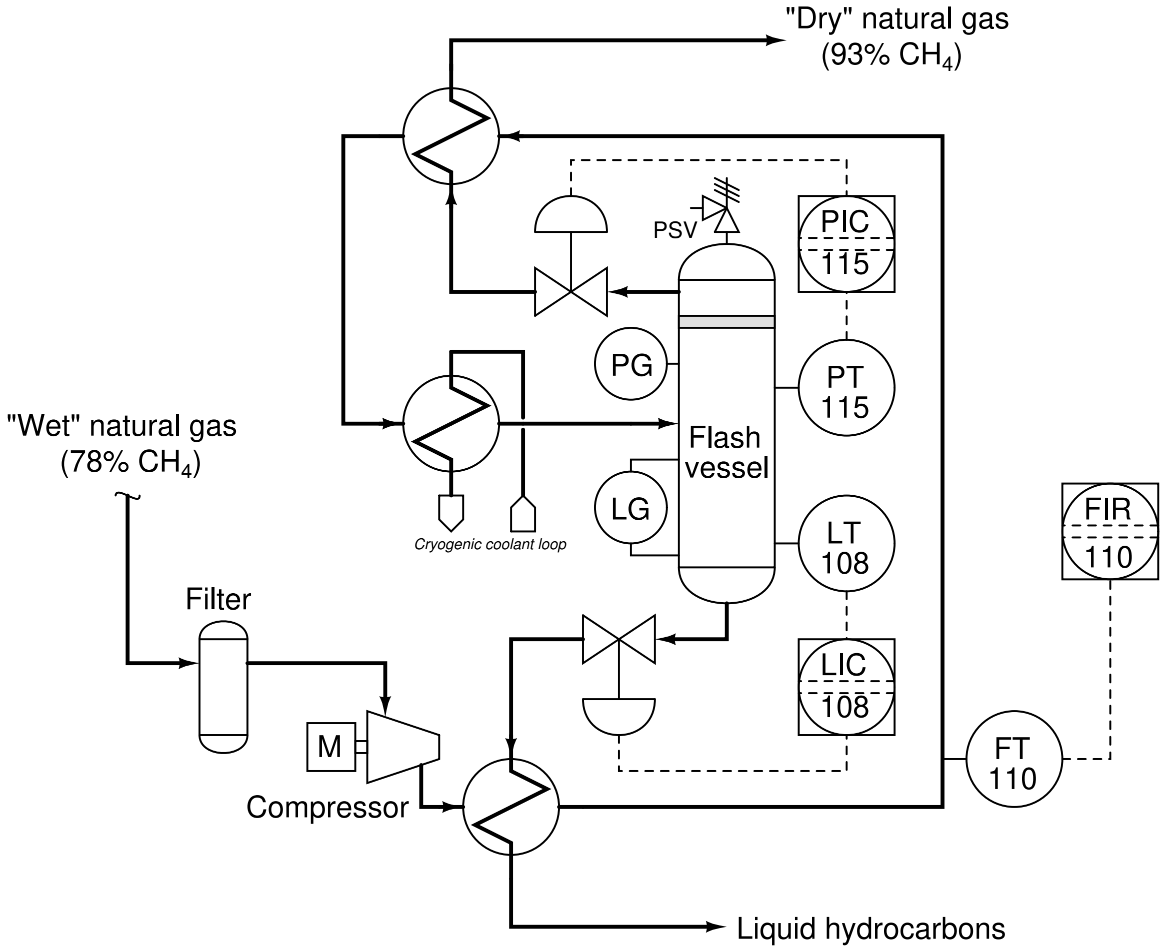
- Explain why anyone would choose to use an air-to-close (fail open) control valve.
- Explain why choosing to use a reverse-acting I/P might not be a good idea, considering fail-safe requirements of the system.
- Write a linear equation in the form $y = mx + b$ to describe the current signal output from the controller (y) in terms of its displayed percentage (x).
- Explain the distinction between a loop controller that is *reverse-acting* versus one that is merely *reverse-indicating*.

- Explain the purpose of the diode in the circuit.

file i02325

Oppgave 24

“Wet” natural gas is mostly methane (CH_4) mixed with significant amounts of heavier hydrocarbon species such as ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and pentane (C_5H_{12}). A process for separating these heavier hydrocarbons from the chief component (methane) using compression and cooling is shown here:



Chilled gases enter the flash vessel, where methane rises and escapes in gaseous form, while all the other (heavier) hydrocarbon molecules condense into liquid and exit out the bottom.

Suppose PT-115 is mis-calibrated, such that it falsely indicates a pressure lower than what is actually inside the flash vessel. How will this mis-calibration affect the control of flash vessel pressure? Will the operator be able to know anything is wrong by observing the DCS monitor screens for this process?

Suggestions for Socratic discussion

- Explain the purpose of the heat exchangers in this P&ID, especially the two exchanging heat between the incoming (compressed) gas and the products coming off the top and bottom of the flash vessel.
- Identify and explain the purpose of the “PSV” valve in this diagram.

- Assuming air-to-open control valves, identify the correct actions for each loop controller (direct or reverse).
- Identify the effect(s) of LV-108 failing shut.
- Identify the effect(s) of PV-115 failing shut.

file i03084

Svar 1

- Example 1: increasing temperature, operator should close the valve more
- Example 2: increasing level, operator should open the valve more
- Example 3: increasing flow, operator should close the valve more
- Example 4: increasing temperature, operator should open the valve more

The goal with these questions is to think like an operator, in order to have a clear understanding of the process's needs. Only when one recognizes the required direction of valve operation to correct for an upset (off-setpoint) condition is it possible to properly and confidently configure an automatic controller to do the same. This is something every instrument professional needs to consider when designing and/or commissioning a control system: *which way does the final control element need to go, in order to stabilize the process variable if it deviates too high?*

In the first example, we would need to move the fuel gas valve further closed (toward the shutoff position) if ever the temperature got too high.

In the second example, we would need to move the drain valve further open to correct for a too-high liquid level in the vessel.

In the third example, we would need to move the flow control valve further closed (toward shutoff) if ever the flow rate measured too high.

In the fourth example, we would need to open the control valve further in order to reduce a too-high oil temperature exiting the heat exchanger. The rationale for this direction of valve motion is to increase the flow rate of the oil so that each molecule spends less time in the heat exchanger absorbing heat from steam and increasing in temperature.

Svar 2

A *load* is any variable in a process (besides the manipulated variable) that has influence over the process variable being controlled.

Note: the following answers are not exhaustive. In other words, there may be more loads than what is listed here for each process!

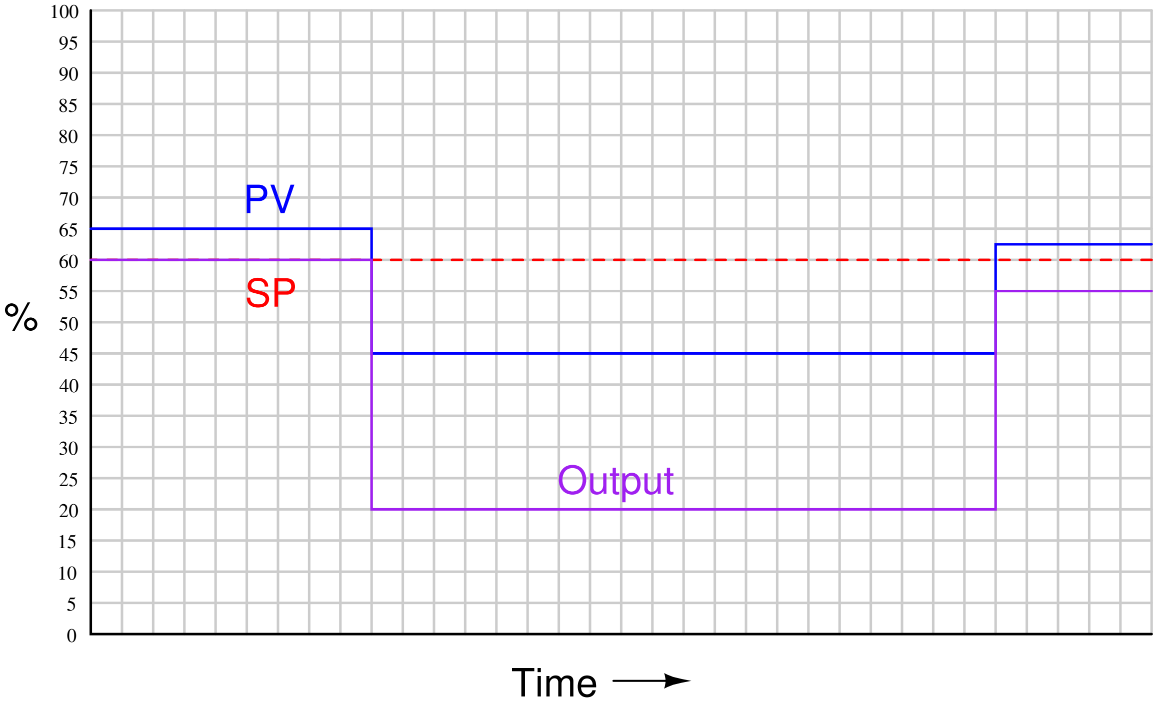
- Example 1: ambient air temperature
- Example 2: incoming flow rate
- Example 3: upstream and downstream pressures
- Example 4: steam flow rate, steam temperature

Svar 3

- Gain = 1; P.B. = 100%
- Gain = 2; P.B. = 50%
- Gain = 3.0; P.B. = 33.3%
- Gain = 0.5; P.B. = 200%
- Gain = 0.2; P.B. = 500%
- Gain = 0.01; P.B. = 10,000%
- Gain = 5.5; P.B. = 18.18%
- Gain = 10.2; P.B. = 9.804%

- P.B. = 150%; Gain = 0.667
- P.B. = 300%; Gain = 0.333
- P.B. = 40%; Gain = 2.5
- P.B. = 10%; Gain = 10
- P.B. = 730%; Gain = 0.137
- P.B. = 4%; Gain = 25
- P.B. = 247%; Gain = 0.4049
- P.B. = 9.5%; Gain = 10.53

Svar 4



Svar 5

- PV = 37%; SP = 50%; Output = **<u>66%</u>**
- PV = 92%; SP = 80%; Output = **<u>16%</u>**
- PV = 81%; SP = 75%; Output = **<u>28%</u>**
- PV = 33%; SP = 42%; Output = **<u>58%</u>**
- PV = 79%; SP = 76%; Output = **<u>34%</u>**
- PV = 15%; SP = 20%; Output = **<u>50%</u>**
- PV = 38%; SP = 38%; Output = **<u>40%</u>**
- PV = 0%; SP = 0%; Output = **<u>40%</u>**

Svar 6

In automatic mode:
Process flow rate (increase) → FT output signal (increase milliamps) → FC output signal (decrease milliamps) → FY output signal (decrease PSI) → FV position (moves further closed, pinching off liquid flow).

In manual mode:
Process flow rate (increase) → FT output signal (increase milliamps) → FC output signal (remains steady) → FY output signal (remains steady) → FV position (holds position).

The important part of this question is the difference in response between "automatic" and "manual" controller modes. In automatic control mode, the controller takes action to bring the process back to setpoint. In manual control mode, the controller just lets the process drift and takes no action to stop it.

At first, having a "manual" mode in a control system seems pointless. However, giving human operators the ability to manually override the otherwise automatic actions of a control system is important for start-up, shut-down, and handling emergency (unusual) conditions in a process system.

Manual mode is also a very important diagnostic tool for instrument technicians and operators alike. Being able to "turn off the brain" of an automatic control system and watch process response to manual changes in manipulated variable (final control element) signals gives technical personnel opportunity to test for unusual control valve behavior, process quirks, and other behaviors in a system that can lead to poor automatic control.

Svar 7

Svar 8

Reducing the differential pressure drop across the valve will result in less flow when the valve is fully open. Of course, the flow rate will still be zero when the valve is fully closed. This means that the controllable flow *range* has been decreased as a result of decreased pressure drop across the valve.

With less of a controllable flow range, the flow will not change as much as it did before given the same change in valve position. That is to say, the process variable in this control system will be less sensitive to changes in valve position than before. In other words, we are faced with a *decreased* process gain.

Given a larger valve, the process gain will *increase*, because greater changes in flow rate will result from the same changes in valve position with a valve of greater size.

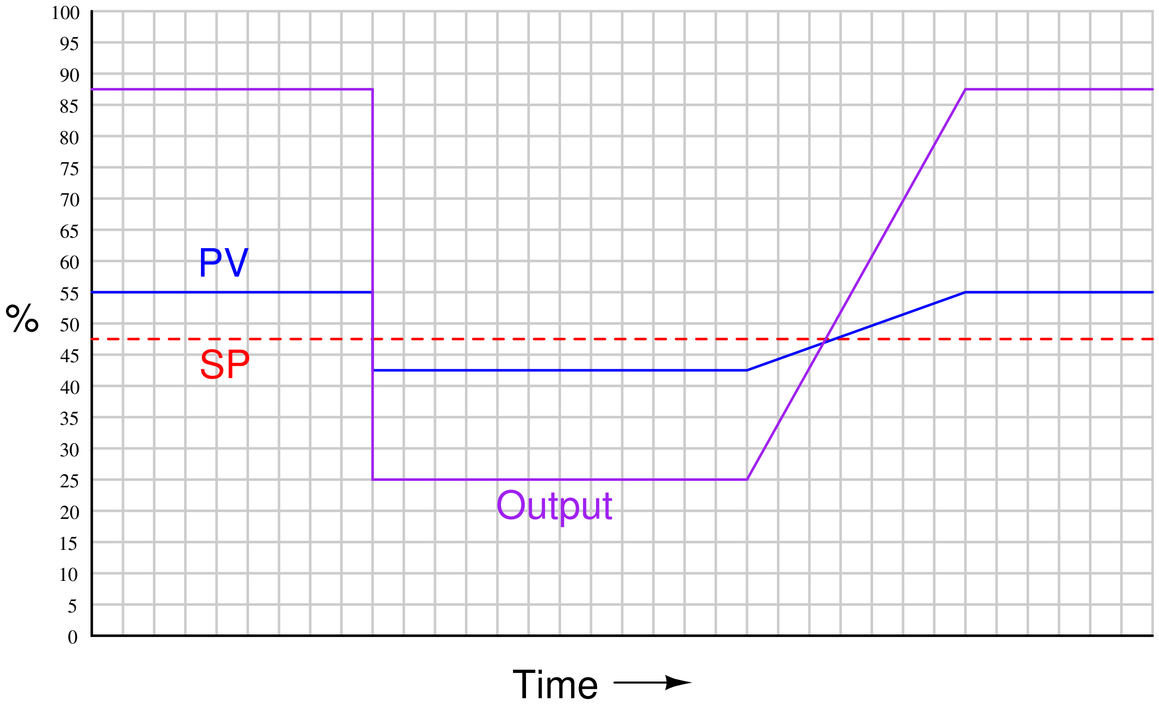
Technically speaking, the gain of the valve (ratio of valve coefficient, or C_v, versus position change) is a separate variable from the gain of the process itself (ratio of flow rate versus valve coefficient), and this is separate from the gain of the sensor (ratio of transmitter output percentage versus flow rate). However, here I use the term "process gain" to refer to the sensitivity of the whole control system, except the controller (the process vessels and piping, control valve, and flow transmitter).

Given a flow transmitter with a smaller range, the process gain will *increase*, because the same changes in valve position will now result in greater *percentage* changes in the transmitter output.

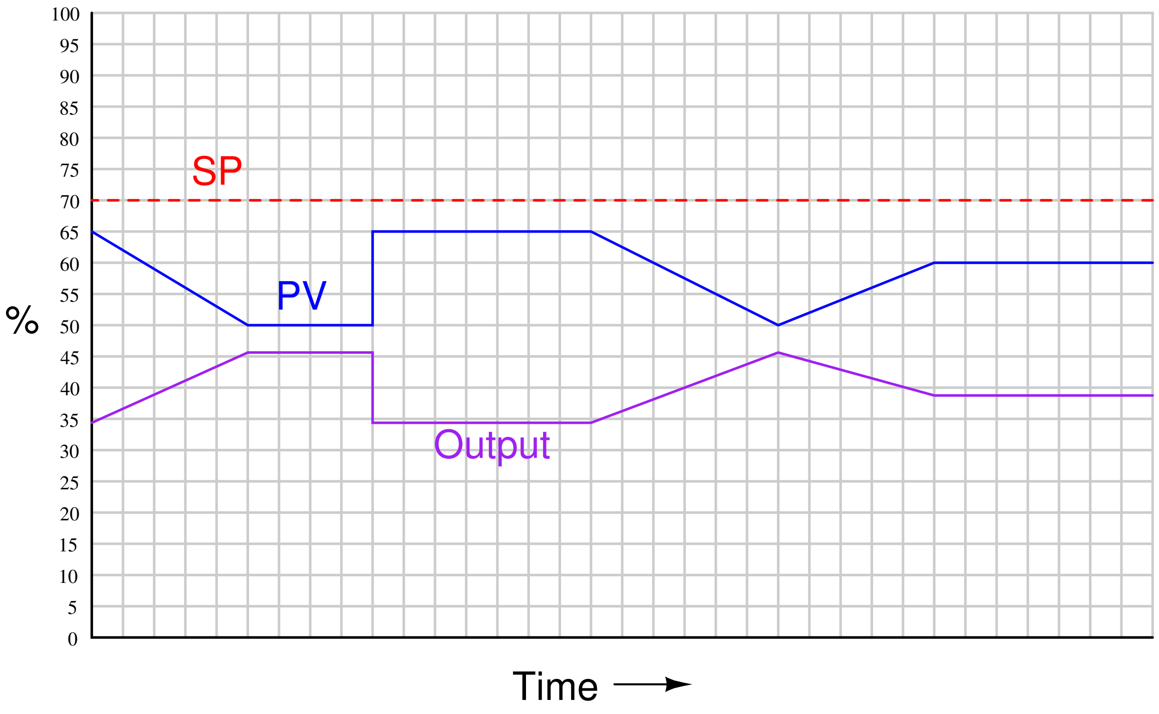
Svar 9

The effect of a negative K_p value in a digital controller's algorithm would be to reverse the control action (from reverse-acting to direct-acting, or from direct-acting to reverse-acting), because a positive error would *decrease* the output, and vice-versa. This is assuming, of course, that the controller is programmed to accept such values. A wise programmer might make it impossible to enter negative tuning constant values, to avoid confusion from someone accidently entering one and unintentionally reversing the control action.

Svar 10



Svar 11



With a proportional band value of 125%, the gain will be equal to 0.8.

$$m = 0.8(\mathrm{SP} - \mathrm{PV}) + 30$$

PV	**SP**	**Output**
65%	70%	34%
50%	70%	46%
60%	70%	38%

Svar 12

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

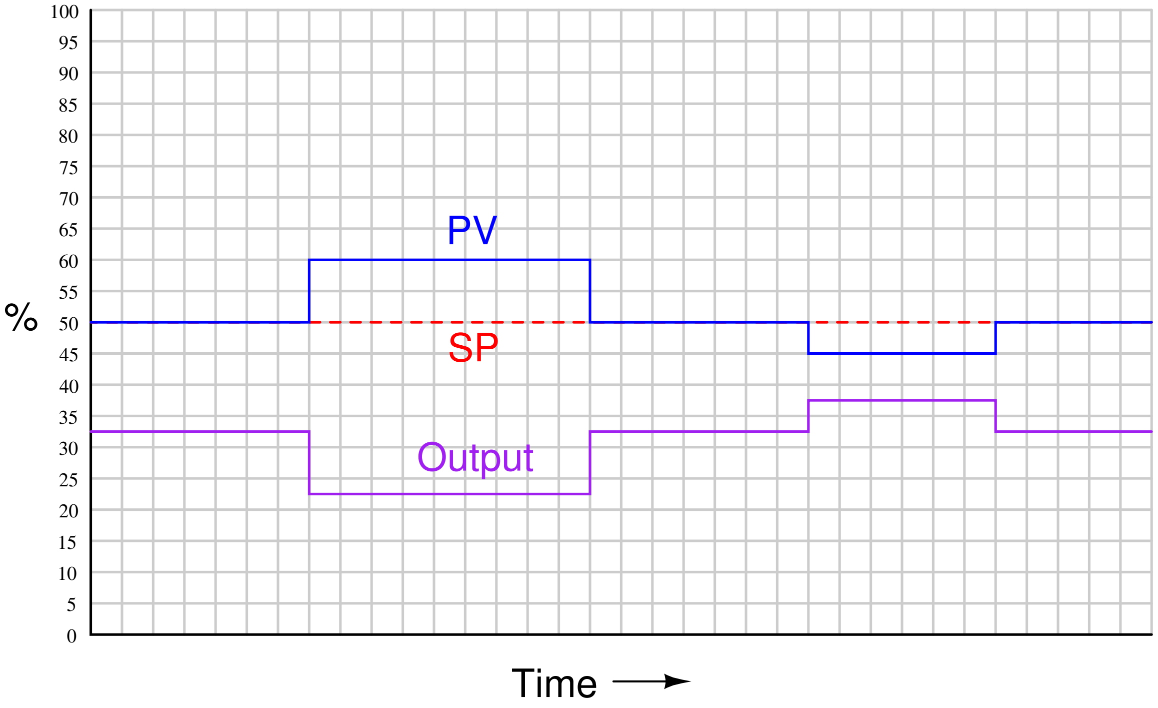
Svar 13

I will answer this question with another question: imagine if the controller actually *did* attain the new setpoint value of 250 GPM. If it did, what would the valve position be in this condition of equilibrium where both SP and PV are equal to 250 GPM? Now, compare this with the valve position when both SP and PV were equal to 180 GPM. Do you see now why PV = SP = 250 GPM is impossible?

Challenge question: what effect does gain (K_p) have on the controller's inability to attain setpoint values other than 180 GPM?

Svar 14

The controller output graph shown here is *qualitative* only. Although drawn to scale (i.e. all changes in the output are properly scaled relative to each other), the scale itself is arbitrary and therefore may not match the scale of your sketch:



Svar 15

The controller will decrease its output signal as it tries to open the air-to-close valve. Both the proportional and integral terms of the controller will work to open the steam valve as the reactor temperature decreases. If there is no steam supply for an extended period of time, the controller's integral action will *wind* to a condition of saturation (3 PSI or less output signal pressure).

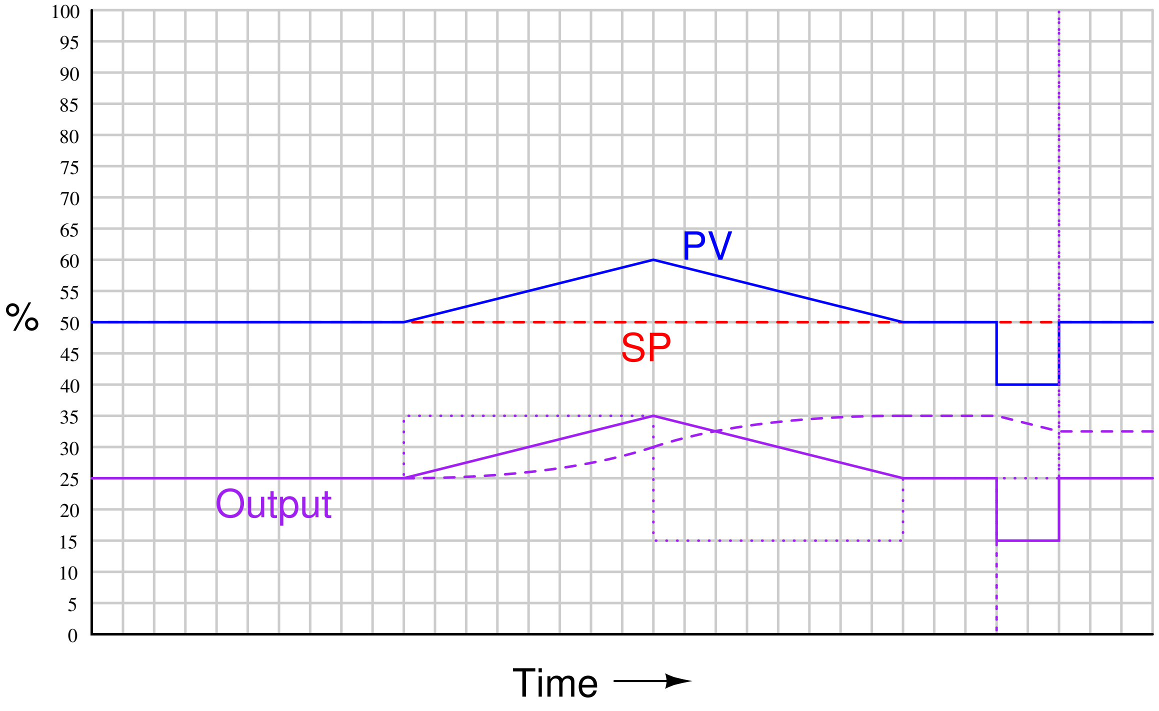
Svar 16

- Gain = 0.769
- Reset = 0.00617 repeats per second

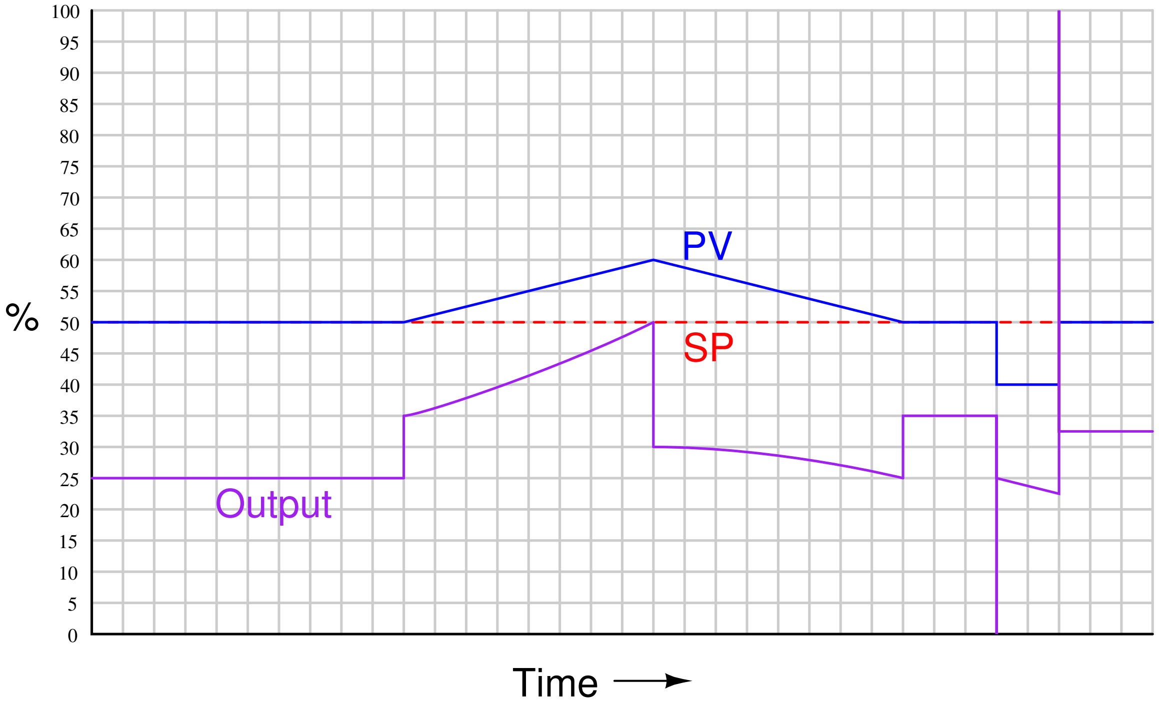
Svar 17

The controller output graph shown here is *qualitative* only. Although drawn to scale (i.e. all changes in the output are properly scaled relative to each other), the scale itself is arbitrary and therefore may not match the scale of your sketch:

Individual P, I, and D responses graphed:



Final output signal graph:



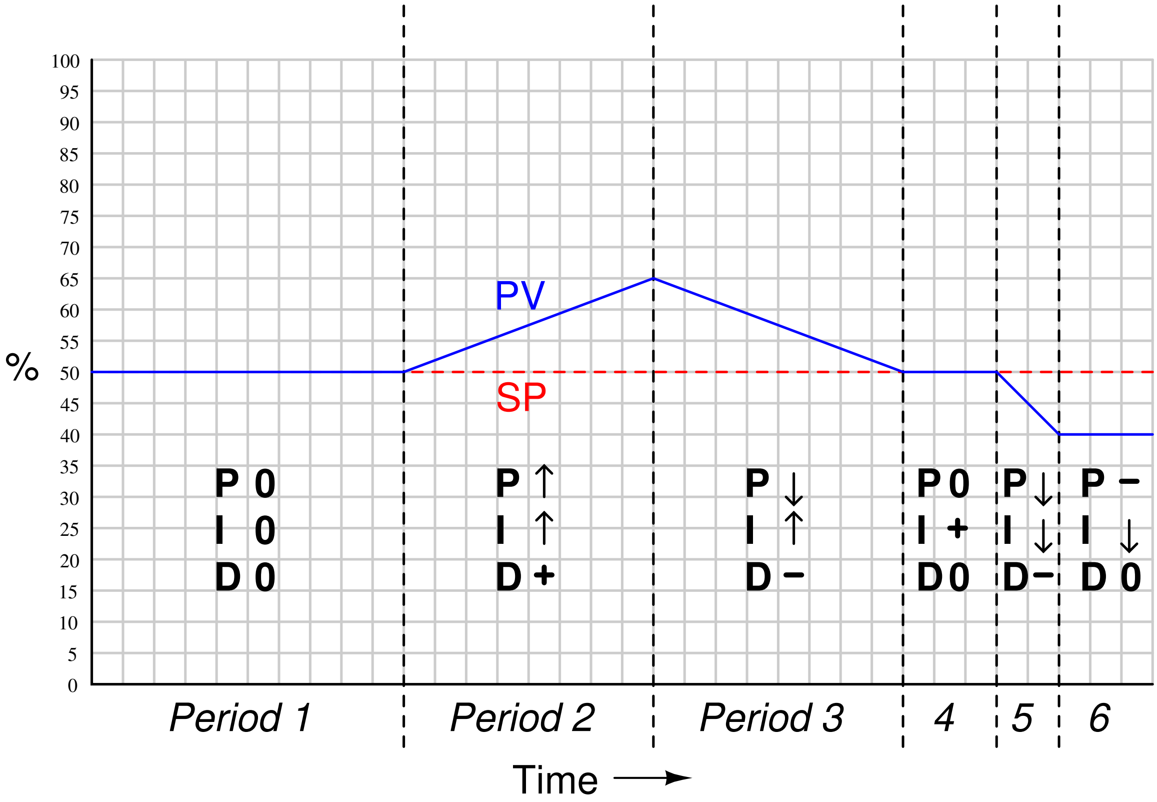
Svar 18

Proportional action is said to work on the present because its action is instantaneous and does not depend on time. The value of the proportional term in a PID controller is strictly a function of PV, SP, and gain, without any reference to time.

Integral action is said to work on the past, because its action is based on the amount of error (PV − SP) *accumulated over time*. Thus, the value of a PID controller's integral term is a function of past (accumulated) error.

Derivative action is said to work on the future, because its action is based on the rate-of-change over time of the PV, which is a good predictor of overshoot. This is why derivative action is sometimes called *preact*, because it preemptively acts to avoid overshoot of setpoint. This is analogous to a passenger in a fast-moving automobile, who can "predict" that the car's high speed will likely lead to "overshoot" of an intersection.

Svar 19



Svar 20

When derivative action works on the *error* signal, it responds to changes in setpoint (SP) and process variable (PV) equally. This will result in the controller output saturating (100% or 0%) upon step changes in setpoint, which can be a bad thing. That is why some controllers provide the option of having derivative action work only on PV changes only and not SP changes.

Svar 21

Svar 22

The time constant of a process is the amount of time it takes for the process variable to change by 63.2% from its initial value to its ultimate value, following a "step-change" in the final control element or any "load" in the process affecting the measured variable.

Svar 23

Controller display	**Controller current**	**I/P pressure**	**Valve stem position**
77.5%	7.6 mA	5.7 PSI	77.5% open
13.1%	17.9 mA	13.43 PSI	13.1% open
89.3%	5.72 mA	4.29 PSI	89.3% open
64%	9.76 mA	7.32 PSI	64% open

Svar 24