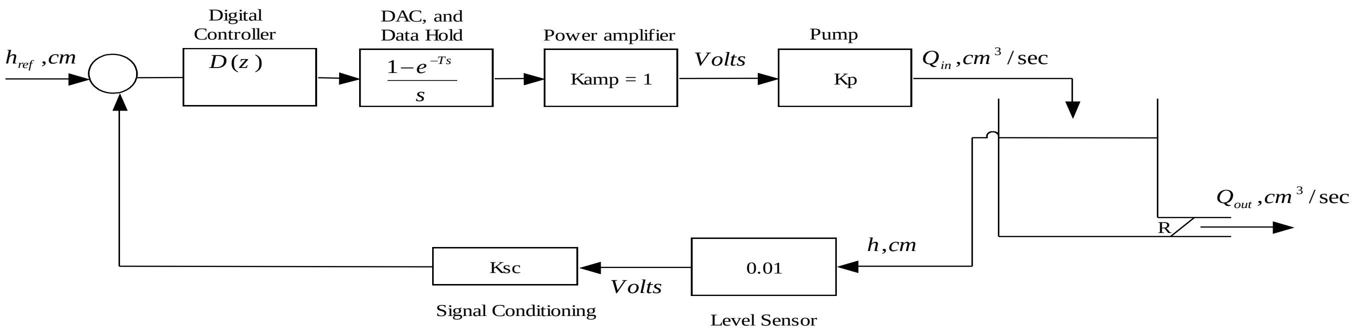
Digital Control Project

Considering the water level control system shown, we applied 10 volts step to the pump. Some readings were taken from the level sensor (10 m volts/cm sensitivity), the sensor reading settles after 10 sec [i] on a value 0.3 volts[ii].

1- Treating the pump as a gain ($K_p \dfrac{cm^3/\sec}{volt}$), determine this gain and the pressure resistance in the outlet pipe.
   $\rho_{water} = 1gm/cm^3, g = 981cm/\sec^2$, Tank Cross section: 15x15 cm^2
2- It's required to design a signal conditioning unit for the level sensor in a level range 0 → 50 cm.
3- To discretize this system with 0.1 sec sampling period, is this sampling period suitable? if not, select a suitable sampling period.
4- Design a digital controller to achieve 5 sec settling time, 5 % over shoot, and 5 % steady state error.
5- Write a program on Arduino to perform the digital controller function.
6- By using Matlab, get the sampling frequency that could be used to analyze the system and design the controller continuous.



Design Your microcontroller program such that, it'll receive two analog signals coming from the signal conditioning unit (A3) and the input h_ref (A4), and it'll output the digital value calculated from the digital controller difference equation [from D(z)] on (PORT D).

The 10 sec, open loop settling time, and the 0.3 volts, final sensor output value, vary by group:

a- Group 1	(B.no.1 to 25)	10 + (B.no. /10) sec	0.3 volts
b- Group 2	(B.no.26 to 50)	15 + ((B.no. -25)/10) sec	0.4 volts
c- Group 3	(B.no.51 to 75)	15 + (B.no. /10) sec	0.5 volts
d- Group 4	(B.no.76 to 100)	20 + ((B.no. -25)/10) sec	0.6 volts

[i] 10 sec open loop settling time varies by group
[ii] 0.3 volts, final sensor output value, varies by group

Tips for the Project

1- Derive a mathematical, continuous model for the system (pump + tank). It should be a 1^{st} order one.
2- From the sensor readings, the first order system-parameters (dc gain and time constant) can be calculated.
3- Compare the transfer function coefficients of the derived model with those calculated in step 2, getting the pump gain and the outlet pipe flow-resistance.
4- Design a signal conditioning unit to convert the sensor output voltage range (level range * sensitivity in volts) into a range accepted to the A/D unit in the microcontroller.
5- Get the combined, system and data hold, digital transfer function G(z).
6- Derive a formula for the digital controller transfer function D(z) in terms of the desired closed loop transfer function F(z), the forward transfer function G(z), and the feed back gain H.
7- Calculate the appropriate desired closed loop transfer function F(z) from the requirements specified.
8- Calculate the required controller transfer function D(z) using the formula of step 6 and the calculated F(z) in step 7.
9- To implement D(z), you must get the degree of D(z) denominator higher than the degree of D(z) numerator with at least one. You can get it by either decrease the degree of F(z) numerator or increase the number of poles of the desired closed loop transfer function F(z).
10- Write a program on Arduino to perform the function of the digital controller transfer function D(z), then do the necessary definitions and adjustments.

<u>Very Important Note:</u> During the system running, the digital controller may be required to output a large value that couldn't be outputted practically. So you have to know the digital controller output range during running, and if it's higher than the practical limit (0→255:0→5volts), you can manipulate this by dividing the controller output by a certain value and then multiply it again out of the controller by using an amplifier gain.

You can know the digital controller output range during running using Matlab or Simulink when you apply the maximum input (maximum tank level).