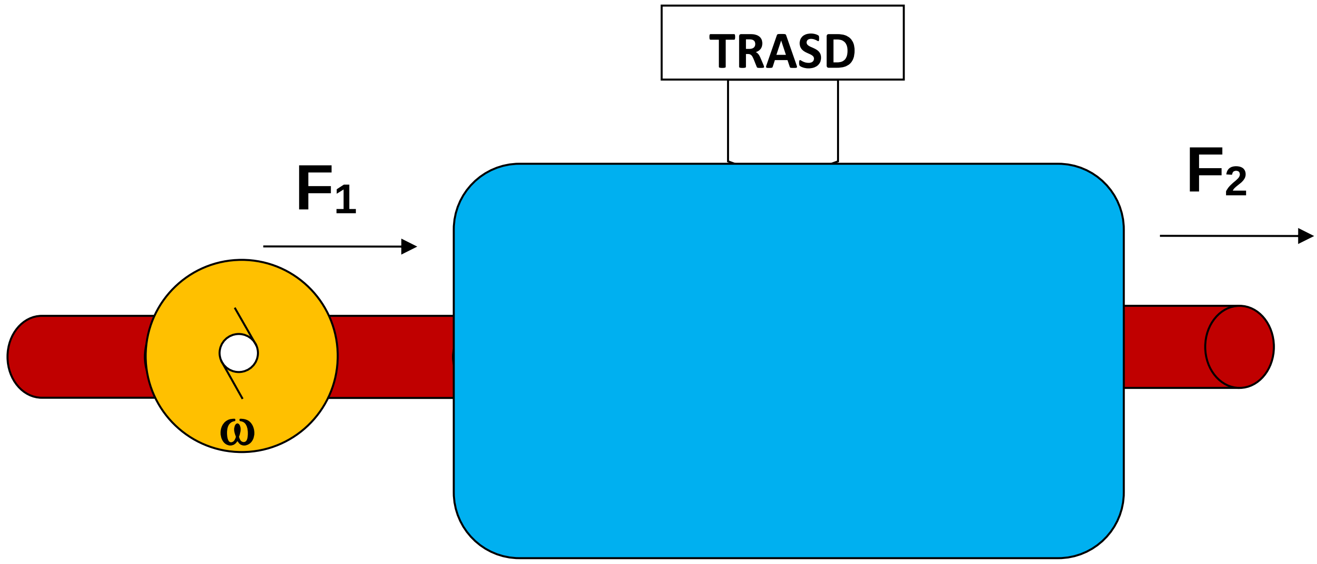
MECHATRONICS – EXAM JULY 16th 2010

Candidate Name and Surname …………………………………………………………………..

Registration N° ………………………………………………………………………………



A tank is filled with an incompressible fluid and the internal pressure must be controlled so as to avoid any possibility of explosion. The tank is filled by means of a tube crossed by a fluid with a flow rate F_1 determined by a turbine (motorized).

The fluid, supposed at a constant temperature, exits from the tank with a flow-rate F_2.

Considering the amount of fluid present into the tank and that the moles number is given by the ratio between the mass and its molecular weight (supposed known together with the density of the fluid) design the regulation system of the internal pressure.

1. Draw the block scheme of the acquisition/regulation chain identifying the input and output variables in every block and in particular the process variable.
2. Calculate the transfer function of the process highlighting what variables must be known.
3. Plot the Bode diagram of the loop function (process + actuator) discussing the eventual problems in terms of stability/instability.
4. Describe what kind of regulators can be introduced to eliminate the sources of instability and their numerical implementation.
5. Choose and describe accurately an ultrasound transducer to allow to detect the PV with its own conditioning network so as to maintain a measurement precision in the order of 5%.

Solution

1) PV = internal pressure in the tank

   Vm = F1 (input flow rate), v /velocity of the turbine, ω (angular velocity of the motor)

   Vc =Vps (power supply of the motor)

2-3) Let's suppose that the motor is a DC motor

Moreover the M (mass) is given by the integral function of the flow-rate

If the fluid is a gas like the air for example the ideal gas law says that PV=nRT and for not big pressures it describes well also the behavior of real gases.

The fluid is injected in the tank with constant pressure clearly but the volume V will augment depending on the amount of fluid entered and this volume will be directly related to the internal pressure that we want to keep under control.

Therefore from the previous law we obtain that n= PV/RT or n = kV

n is the number of moles that is given as the text says by M/Mol. Weight.

This means that M = n*Mol. Weight = k * V * Mol. Weight = k'* V

On the other hand M = (F1−F2)/s

F2 can be considered as a disturbance and can be eliminated by means of a Feed-Forward compensation. The value of the FF transfer function is –α/β*Factuator and the actuator is the motorized turbine.

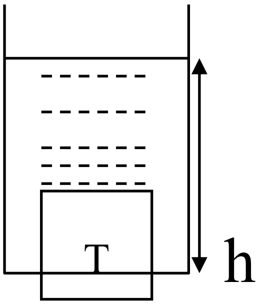
Finally the transfer function of the regulation chain is:

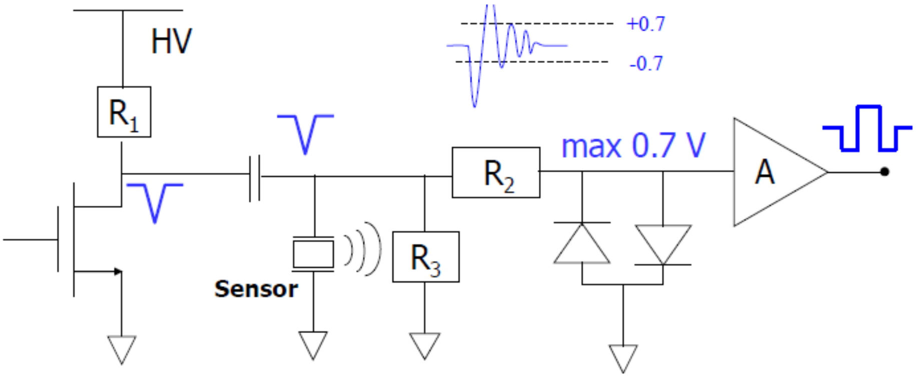
PV/Vc = (PV/Vm)*(Vm/Vc)=(internal pressure/ω)*(k''/(1+sτ))=(F1/(k*s* ω))*(k''/(1+sτ))

And since F1∝ω, we have that G= k'/(k*s*(1+sτ))

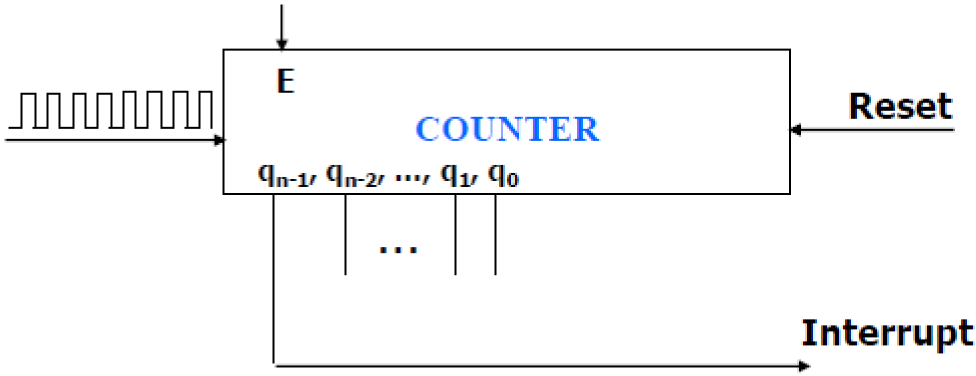
4) Once more we can have a potential instability but with a dynamic compensation the bandwidth can be extended.

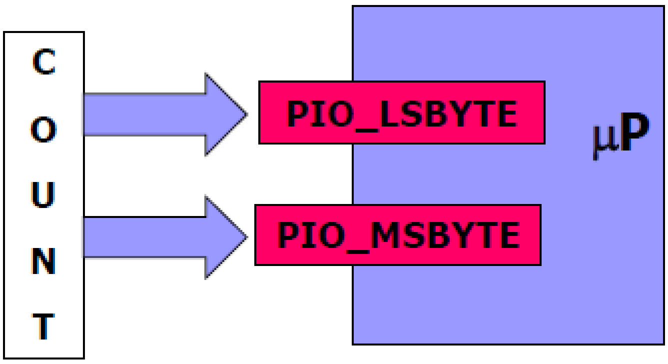
5) The PV is the internal pressure but since the request is to use the ultrasounds we can measure the volume of the filled part of the tank using a ultrasound transducer detecting the level of the fluid injected.





N of bits of the timer that measures the time between the ultrasound beam generation and the reception of the echo





N = $\log_2(100/2) = 6$