Ministère de l'Enseignement
Supérieur Et de la Recherche Scientifique
*****
Université de Carthage
*****
**Institut National des Sciences
Appliquées et de Technologie**

LABVIEW Project Report

Two-Tank Liquid Level System

Prepared by
Triki Ghaylen
Karoui Nouha
Ben Salah Mehdi Ismail
Boughanmi Hazar

Speciality
Industrial Computing and Automation

Level
4th grade

Master of Labview Courses
Professor Boubaker Olfa

Table of contents

1. Introduction :

Level control is a one of the most basic control strategies in most process plants such as waste water treatment, chemical, petrochemical, pharmaceutical, food, beverages, etc. shown in Fig.1.1.

It's part of the inventory control to prevent accumulation in the systems or tanks. Think about it this way; we often need pumps to drive liquid from one system (tank) to another. A pump will experience cavitation if the liquid level inside the tank falls below a threshold value, which in turn will damage the pump and of course could cause a big problem to the entire plant operation. Another example, the liquid level in a reactor (tank) or bioreactor has a very strong influence on the reactor or bioreactor performance, and thus by controlling the liquid level we can ensure that the reactor/bioreactor involved can run at its optimum condition.

In short, we often need to control liquid levels in tanks not because for the want to keep those levels constants, but such a control is mandatory strategy to ensure that the entire system can run safely (e.g., no tank will dry up or overflow), smoothly (e.g. no pump will break down due to cavitation) and profitably (e.g., a reactor tank will always perform at its optimum condition). Only when we begin to see the many reasons behind the level control, we then will be able to judge whether such control is needed or not - the strategy is never fixed for every single system or plant.

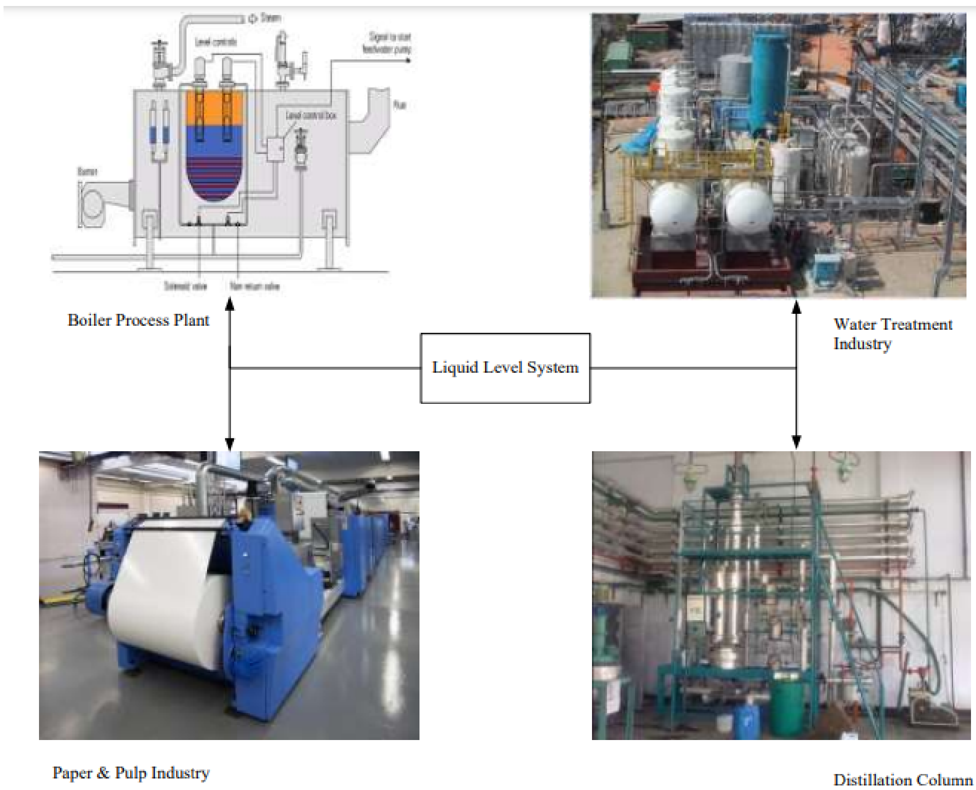


Fig.1.1 : Coupled tank liquid level system examples

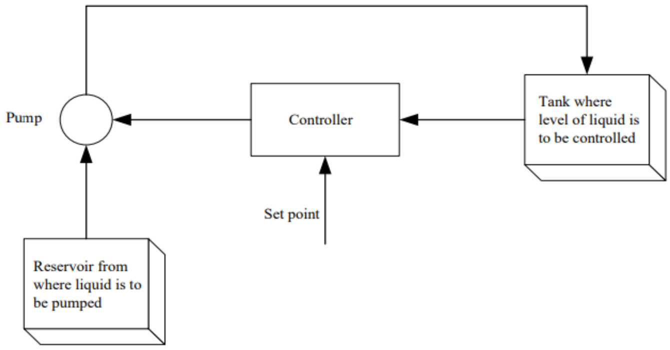


Fig.1.2 : Representation of a typical liquid level system

2. Benchmark Presentation :

This experiment consists of two tanks with orifices and level sensors at the bottom of each tank, a pump, and a water basin (see the picture below). The two tanks have the same diameters and can be fitted with different diameter outflow orifices.

In this laboratory setup, the pump provides infeed to Tank 1 and the outflow of Tank 1 becomes infeed to Tank 2. The outflow of Tank 2 is emptied into the water basin. This is the standard setup that leads to a state-coupled system.

A state- and input-coupled liquid level system is developed by allowing a portion of the pump flow to feed directly Tank 2.

The objective of the experiment is to control the level of liquid in the lower tank and to maintain the water level at the desired setpoint value and also simultaneously ensure robust performances when there is a load disturbance.

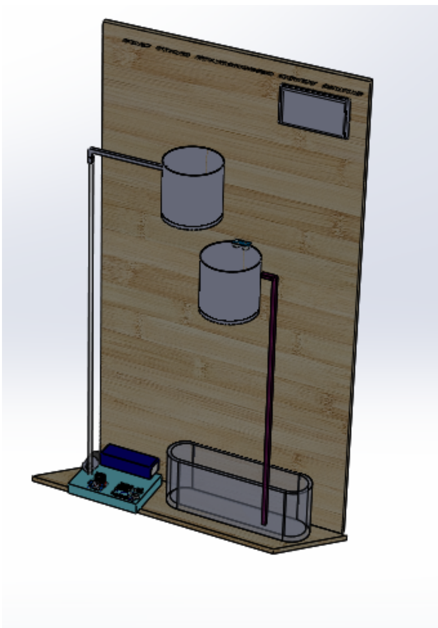


Fig.2 : Design of our Benchmark in Solidworks

3. Theoretical Study :

The simplest nonlinear model of the coupled tank system can be obtained by considering the mass balance principle, which is relating the water level h1, h2 and applied voltage ‘u’ to the pump.

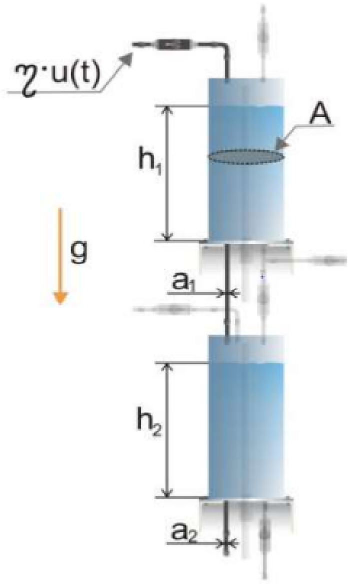


Fig.3 : Representation of Coupled Two Tanks Model

3-1) NonLinear Mathematical Model :

$$A\,\frac{dh1}{dt} = Qvi - Qv1 \qquad (*)$$

$$A\,\frac{dh2}{dt} = Qv1 - Qv0 \qquad (**)$$

where

$h1$**:** water level in tank 1
$h2$**:** water level in tank 1
A : cross-sectional area of tanks
Qvi: the input volume rate
$Qv1$: the volume flow rate from tank 1 to tank 2
$Qv0$: the flow rate of liquid out of tank 2

Qvi= η* u (㎤ / sec) (***)

In addition, using Bernoulli’s law for flow through small orifices the outflow rate for tank 1 is given by :

$$Qv1\,(t) = a_1\sqrt{2gh_1(t)} \qquad (****)$$

Thus, using (*) , (**) ,(***) and (****) the following dynamic equations for the liquid level in the two tanks are obtained:

$$\frac{dh1}{dt} = \frac{-a_1}{A}\sqrt{2gh_1(t)} + \frac{\eta}{A}u(t) \qquad (1.1)$$

$$\frac{dh2}{dt} = \frac{a_1}{A}\sqrt{2gh_1(t)} + \frac{-a2}{A}\sqrt{2gh_2(t)} \qquad (1.2)$$

where

$a1$: outlet area of tank 1

$a2$: outlet area of tank 2

η : Constant relating the control voltage with the water flow from the pump

g : gravitational constant

3-2) Control Objectives :

Given a desired, constant, liquid level for Tank 2, denoted as , h_{2_d} design a control input u_0 such that $\lim_{t \to \infty} h_2(t) = h_{2_d}$

. Note that using (1.1), we can compute the steady-state pump voltage u_0 that produces the desired steady-state constant level h_{1d} in Tank 1. Specifically, setting $\dot{h}_1(t) = 0$ in (1.1) yields

$$u_0 = \frac{a1}{\eta}\sqrt{2gh_{1d}} \qquad (1.3)$$

In a similar manner, we can compute the steady-state level h_{1d} in Tank 1 that produces the desired steady-state constant level h_{2d} In Tank 2. Specifically, setting $\dot{h}_2(t) = 0$ in (1.2) yields

$$h_{2d} = \left(\frac{a1}{a2}\right)^2 h_{1d} \qquad (1.4)$$

Now, theoretically one can use (1.3) , (1.4) to regulate the water level in Tank 2. However, external disturbances, system parameter uncertainty/variation, etc., necessitate a feedback controller to improve the level control system performance.

To quantify this control objective, we define the liquid level tracking error for Tanks 1 and 2, i.e.,$\Delta h_1(t)$ and $\Delta h_2(t)$ as follows:

$$\Delta h_1(t) = h_1(t) - h_{1d} \qquad (1.5)$$

$$\Delta h_2(t) = h_2(t) - h_{2d} \qquad (1.6)$$

$$\Delta u(t) = u(t) - u_0 \qquad (1.7)$$

On performing Taylor's series expansion of equation (1.1) and equation (1.2) we can obtain a linear mathematical model for the coupled tank system.

$$\Delta \dot{h}_1(t) = -\frac{a1}{A}\sqrt{\frac{g}{2h_{1d}}}\,\Delta h_1(t) + \frac{\eta}{A}\Delta u(t) \quad (1.8)$$

$$\Delta \dot{h}_2(t) = \frac{a1}{A}\sqrt{\frac{g}{2h_{1d}}}\,\Delta h_1(t) - \frac{a2}{A}\sqrt{\frac{g}{2h_{2d}}}\,\Delta h_2(t) \quad (1.9)$$

Next, we develop the transfer function models for the linearized error system of (1.8) and (1.9) by taking the Laplace transform of (1.8) and (1.9) and rearranging terms to

$$G_1(s) = \frac{\Delta h_1(s)}{\Delta u(s)} = \frac{\frac{\eta}{A}}{s + \frac{a1}{A}\sqrt{\frac{g}{2.h_{1d}}}} \quad (1.10)$$

$$G_2(s) = \frac{\Delta h_2(s)}{\Delta h_1(s)} = \frac{\frac{a1}{A}\sqrt{\frac{g}{2.h_{1d}}}}{s + \frac{a2}{A}\sqrt{\frac{g}{2.h_{2d}}}} \quad (1.11)$$

Table.1 : Parameter values for the coupled-tank system

Description	Symbol	Values	Unit
Outlet area of tank 1	a1	0.785	cm²
Outlet area of tank 2	a2	0.3925	cm²
Cross-sectional area of tanks	A	113.04	cm²
Gravitational constant	g	9.8	m/sec
Constant relating the control voltage with the water flow from the pump	η	0.1194	-
Water level in tank 1	h1	-	cm
Water level in tank 2	h2	-	cm
Voltage of the pump	u	-	V

4. Experimental Study :

4-1) Software design :

In the software part, we used :

- **Labview** to control the entire system (like data acquisition and data processing, management of the pump speed, controlling the system with PID)
- **Arduino** as an input output interface between labview and the physical system
- **Solidworks** to design our 2 tank system model
- **Tinkercad** to design the electrical wiring
- **ThingSpeak** to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.

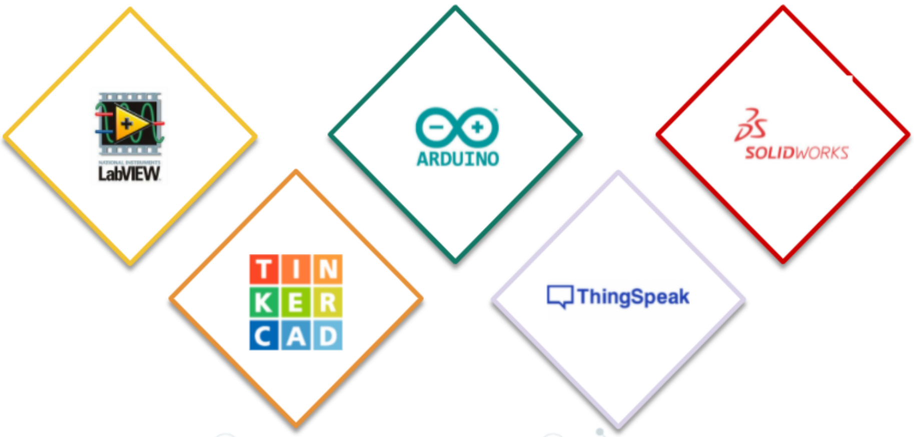


Fig.4.0 : Set of softwares that we used for conception and design

4-2) Components :

And in the hardware part, several available components have been offered in the market
We had the choice between different :

- Microcontroller boards

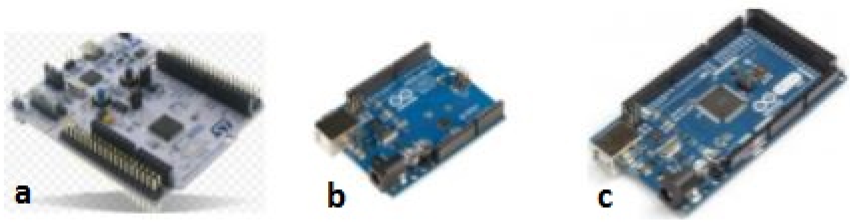


Fig.4.1 : (a) stm32 nucleo, (b) arduino uno, (c) arduino mega

- Pumps

Fig.4.2 : Different available pumps in the market

- <u>Sensors :</u>

Fig.4.3 : (a) magnetic float level switches, (b) magnetic float level transmitters, (c) ultrasonic level transmitters, (d) radar level transmitters

- <u>Batteries :</u>

Fig.4.4 : (a) Lipo 12v 4s, (b) Lead Acid Battery, (c) Electric Battery

And this is what we chose :

- **Arduino uno:** because it’s an open source, cheap, linx supported device
- **Ultrasonic sensor:** because it has accurate results, easy to use and low price
- **Pump DC365 :** because it's one of the cheapest pump and we don't need a big pump for a small model
- **Lipo :** because it doesn't heat up and slowly discharges

we added also a motor driver controller board to control the direction and the speed of the pump

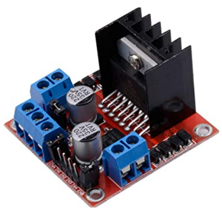


Fig.4.5 : Motor Driver Controller Board

4-3) Electrical wiring :

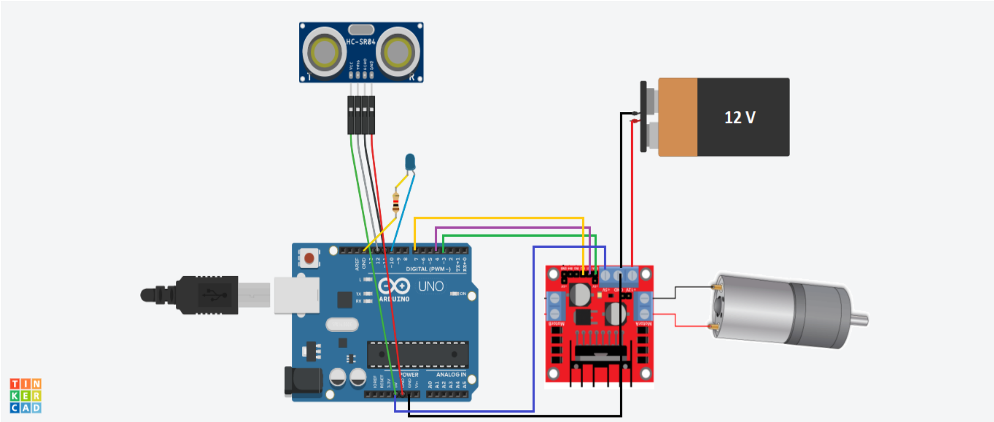


Fig.4.6 : Electrical wiring designed by Tinkercad

4-4) Benchmark montage :

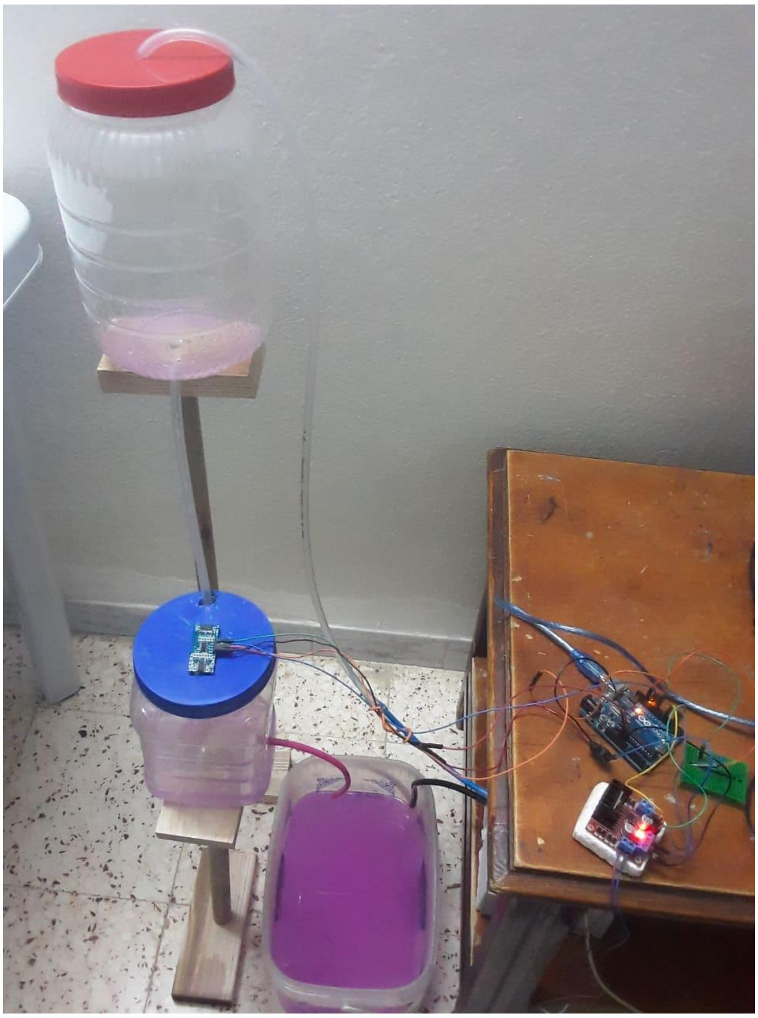


Fig.4.7 : Our montage

4-5) Technical sales study :

Table.2 : Costs of each component that we bought

Components	Costs
Pump	28.5 dt
Arduino Uno	40 dt
Ultrasonic Level Transmitters	11 dt
Pipe	2.5 dt
12V Battery	35 dt
Motor Driver Controller Board L298N	15 dt
2 Tanks	4.5 dt
TOTAL	136.5 dt

5. System regulation :

Controllers may be classified by the type of control action or the variable used for the control signal.

Presently, most of the controllers used in industry are based on PID control. It is often very difficult to obtain an exact mathematical model of a nonlinear dynamical process.Therefore, the fact that PID controllers utilize the error, the integral and the derivative of the error rather than an explicit mode of the process has made them quite popular. However, the proportional, integral and derivative gain constants determined by tuning the controller* heavily depend on system parameters.

An alternative to conventional control is fuzzy logic control. Fuzzy logic control is based on the fact that an experienced human operator can control a process without knowledge of its dynamics (King and Mamdani, 1977).

Another Controller is Linear quadratic regulator or LQR is a commonly used technique to find the state feedback gain for a closed loop system. This is the optimal regulator, by which the open-loop poles can be relocated to get a stable system with optimal control and minimum cost for given weighting matrices of the cost function.

Tuning a control loop is the adjustment of its control parameters (proportional band/gain, integral gain/reset, derivative gain/rate) to the optimum values for the desired control response.

Here is a simplified comparative table between the 3 different regulations

Table.4 : comparative table between PID, LQR and fuzzy

	Adaptability	Performance	Robustness	Mathematical model requirement	Less human expertise
PID	+++	++	++	+	+++
Fuzzy	+	+++	+++	+++	+
LQR	++	+	+	++	++

So as the mathematical model exist and due to less data to applied FLC we have chosen pid algorithm, but we want to try fuzzy algorithm in the future

6. Software study :

6-1) Flowchart :

At the start, the system receives the water level position from the ultrasonic sensor and compares it with the desired setpoint. If they are equal then the system maintains the speed of the pump to control the water level in the lower tank. Otherwise the system have to acquire data from the sensor, filtering it then computing the error and applying the PID control signal to change the pump speed until we obtain the equilibrium level of the water.

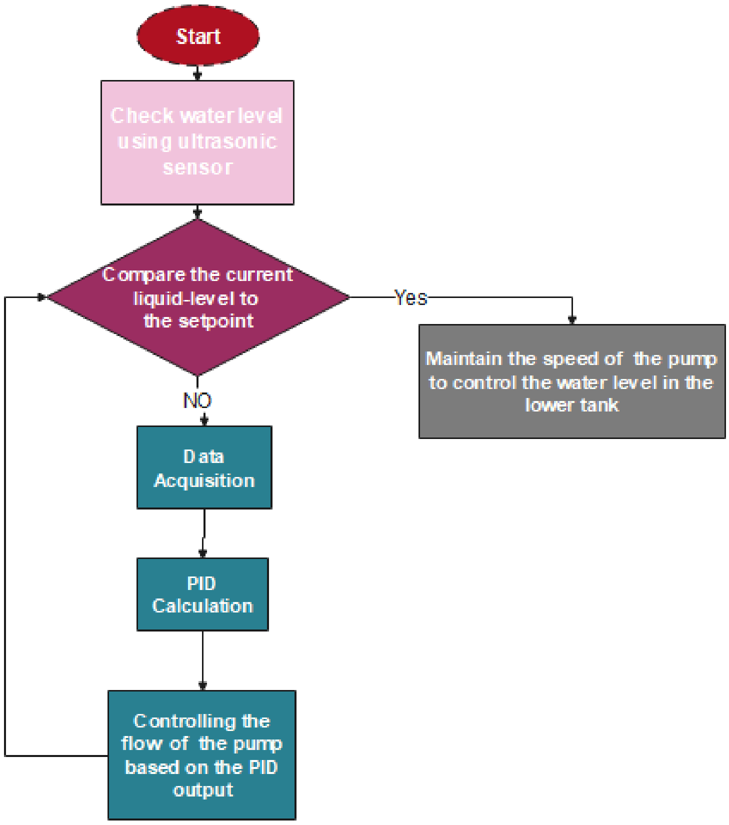


Fig.6.1 : Flowchart

6-2) Labview programming :

6-2-1) Front panel :

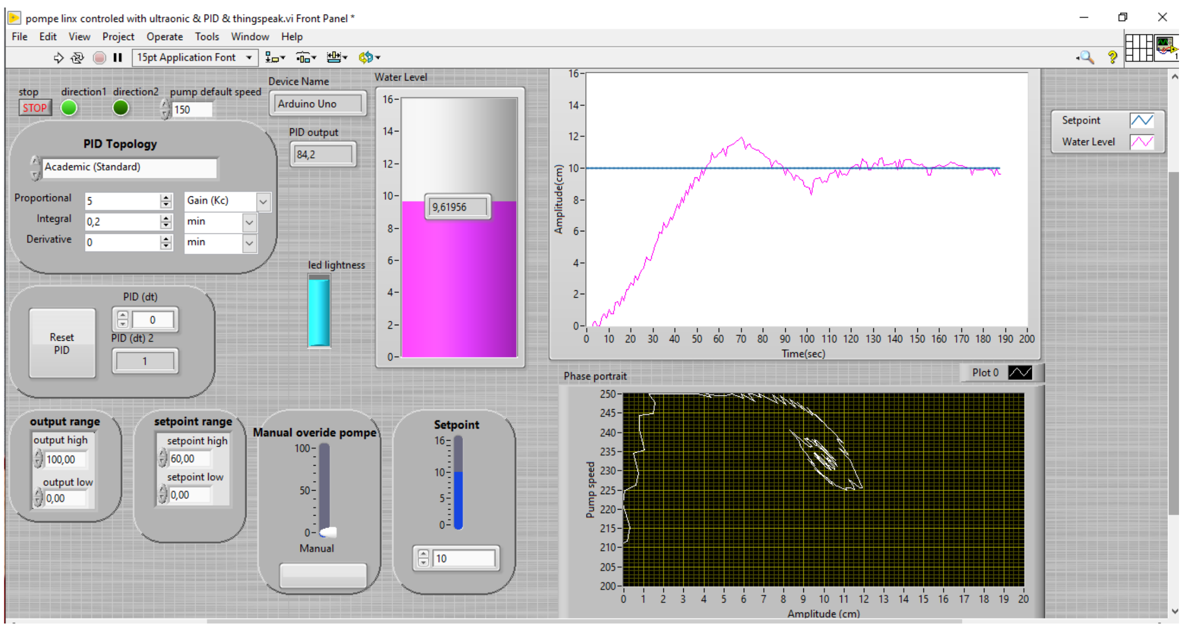


Fig.6.2 : Front panel

6-2-2) Block diagram :

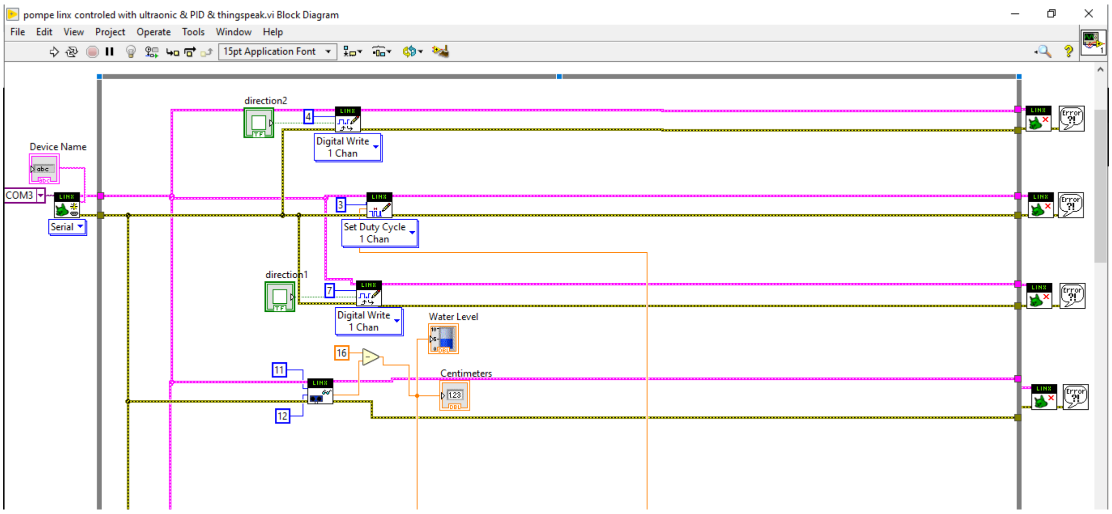


Fig.6.3.1 : Block diagram (1)

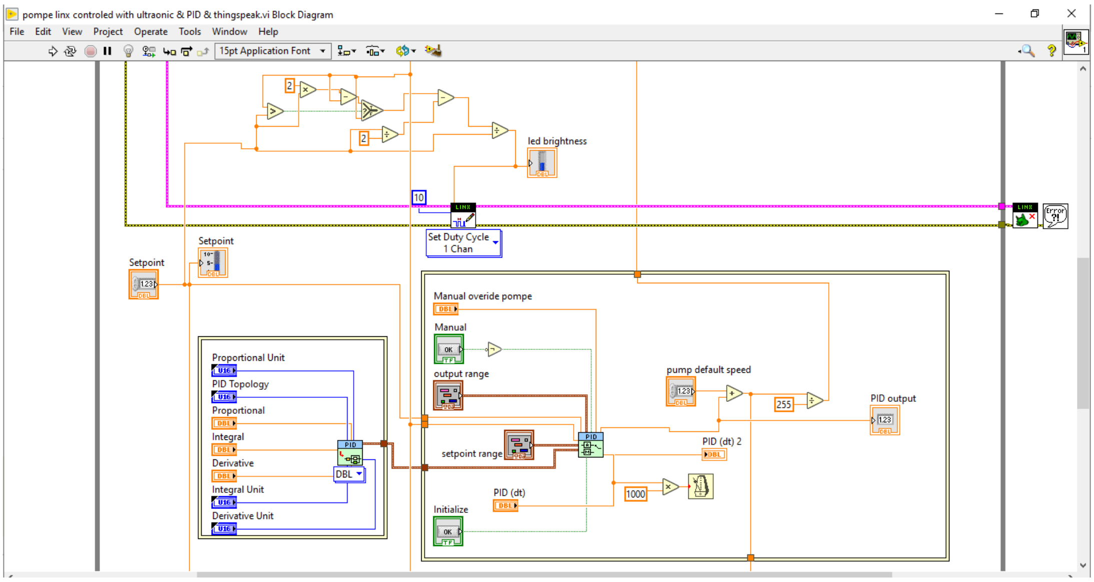


Fig.6.3.2 : Block diagram (2)

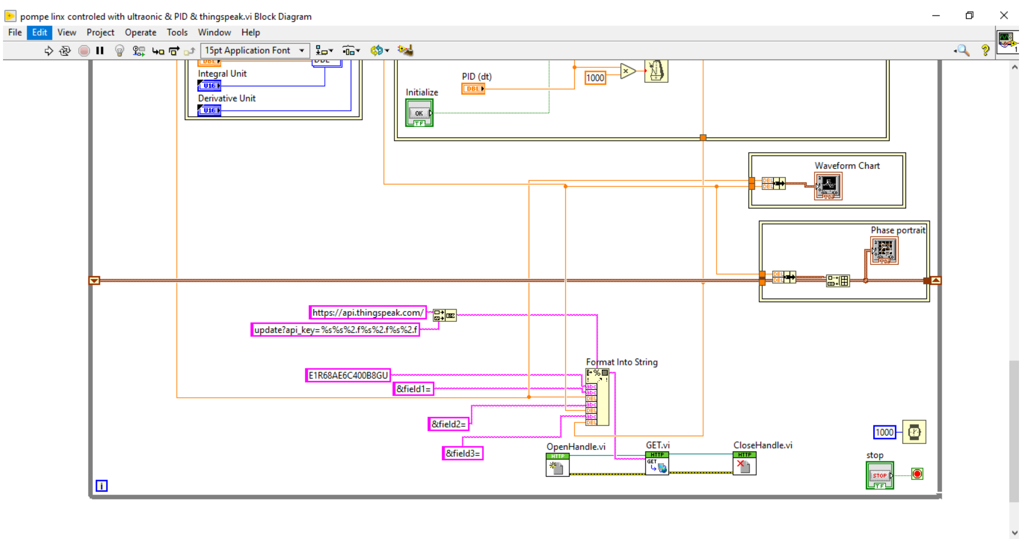
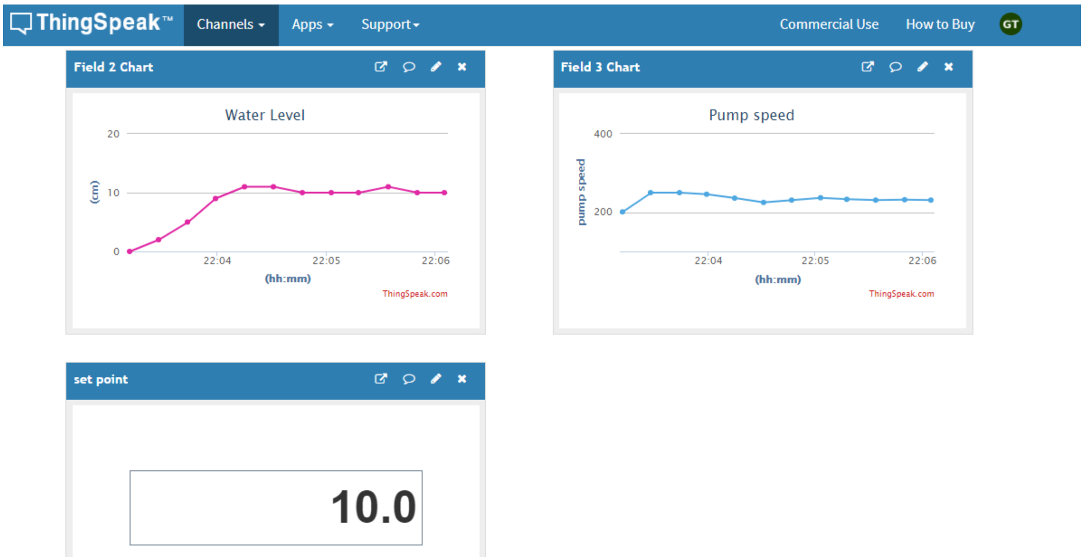


Fig.6.3.3 : Block diagram (3)

6-3) ThingSpeak :



7. Conclusion and perspectives :

The Two tanks benchmark is a nonlinear system used in different areas : to ensure that the entire system can run safely, smoothly and profitably.
Starting from the theoretical idea then we proceed to do the mechanical conception and the electrical wiring then we programmed the model with labview software with an iot addition.

We could improving it by :

- Using Fuzzy algorithm instead of pid to control the benchmark
- Using protocol i2c to work with lcd instead of cabling lcd directly to the arduino
- Using the site Thing speak to visualize the output charts instead of labview
- Work on how to control the two tanks in a wireless way using iot and esp32 instead of arduino