

1809811

by Gari Davies

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Project

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*Contents list is good
and informative*

1 - Introduction and Background Research

My project is based on a problem at work but completed at collage. *Do not use first person terms*

At work there is a need for a control system to maintain a selected pressure in a chamber for air discharge. The discharge vessels could be variable in size and therefore this is the argument for variable pressure.

The proposed project is to be able to solve the problem of maintaining a set psi pressure in a sealed environment (example 10 psi).

The problem is to maintain air pressure of 10 psi in an enclosed environment which is controlled and monitored from a remote station via a network for safety reasons.

Safety features and remote control will be part of the system

The air will be added to the pressure chamber via a compressor/ hand pump that will pressurise the chamber to the set limits. The chamber will have a pressure sensor attached and an electronic pressure release valve which will be connected to a control unit. The controller will control the process and send the required information to front end visual display. The front end will be used to remotely process the results and control the valves. The safety release valve will be programmed to release the air pressure if it goes above the Safety levels.

The project will be a prototype to demonstrate the control process and monitoring of the system performance at the college and at place of work.

Diagram below shows layout of proposed system.

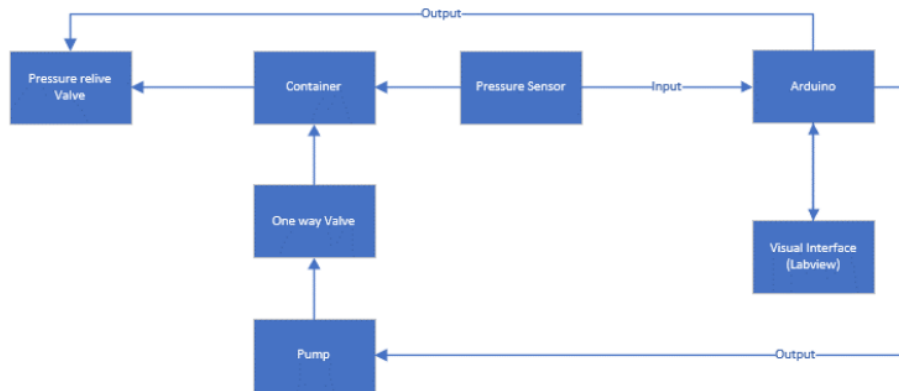


Figure 1 - Layout Plan

Good explanation with a good block diagram.

Research

Research was conducted into different technologies that were readily available on the market and what was used in the college the first component was the Arduino for its simple design



Figure 2 - Arduino board

The Arduino Mega 2560 is a microcontroller board. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; connects to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. (Hub, 2019)

The LCDs have a parallel interface. The interface consists of the following pins:



Figure 3 - LCD Screen

A register select (RS) pin that controls where in the LCD's memory you're writing data to. You can select either the data register, which holds what goes on the screen, or an instruction register, which is where the LCD's controller looks for instructions on what to do next.

A Read/Write (R/W) pin that selects reading mode or writing mode

An Enable pin that enables writing to the registers

8 data pins (D0 -D7). The states of these pins (high or low) are the bits that you're writing to a register when you write, or the values you're reading when you read.

There's also a display contrast pin (Vo), power supply pins (+5V and Gnd) and LED Backlight (Bklt+ and Bklt-) pins that you can use to power the LCD, control the display contrast, and turn on and off the LED backlight, respectively.

(Techie, 2019)

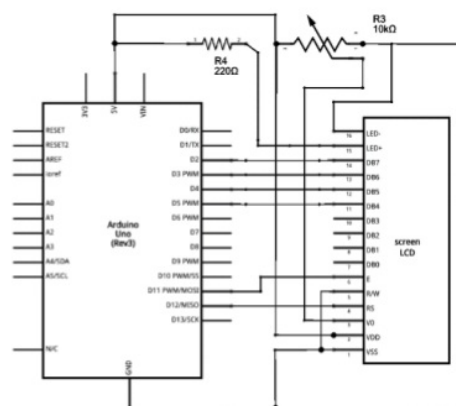


Figure 4 - LCD Pin layout

LabVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a visual programming language by National Instruments. It is very useful for data acquisition instrument control, industry automations, and would work well as a front end for any system. (Deyson, 2020)

PLC

The PLC is a powerful controller that can perform a multitude of applications and complies with future proofing any system with industry 4.0.

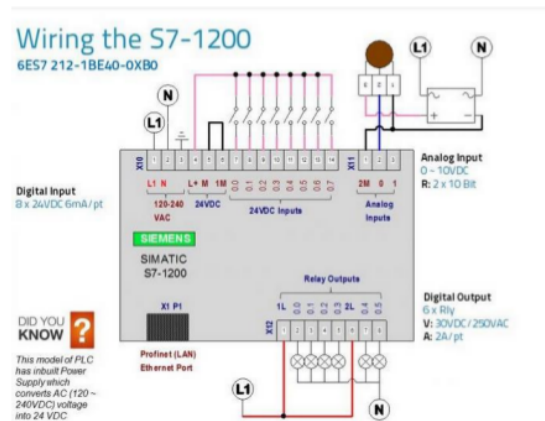


Figure 5 - PLC layout I/O

(Siemens, 2012)

HMI

High-end operator devices for sophisticated HMI applications

SIMATIC HMI Comfort Panels are designed for implementation of high-performance visualization applications on the machine-level. High performance, functionality and numerous integrated interfaces offer the greatest convenience in high-end applications. (Siemens, 2019)

- Ideal entry-level range for simple HMI applications
- Engineered in the TIA Portal
- Mounting compatibility with SIMATIC HMI Comfort Panels and existing SIMATIC HMI Basic Panels 4" and 6"
- Flexible scalability within the HMI range
- High-resolution, dimmable wide-screen displays with 64.000 colours
- Innovative user interface and improved usability thanks to new controls and graphics
- Touch / key functionality for intuitive operation
- Interface for connection with various PLCs
- Versions for PROFIBUS or PROFINET
- Archiving via USB stick

2 – Specification

Customer Needs

This device must be able to maintain a constant pressure and vary the required pressure in the pressure vessel.

There must be a visual display close to the pressure vessel displaying the current pressure that has been set to. The pressure requirements will be set locally by the means of a (pot, switch or encoder) device

There is also a requirement for this system to be monitored and controlled remotely over a network with visual indicators and pressure sensor readings displayed.

Project Reliability

The project reliability will be monitored over time and the pressure sensor will be tested against a calibrated pressure gauge for accuracy and consistency in order to prove the customer requirements are met.

Budget

The budget for the project will be £250.

The budget will be monitored with the use of a spreadsheet listing components and prices. This will ensure that all items are recorded and that the spending can be monitored closely to guarantee no budget overruns.

A Gant chart will be created listing weekly objectives and milestones of the project. This will be used to keep track of project progress and deadline kept. The logbook will be used to monitor weekly project progress and signed by myself, and the tutor.

Health and safety standards

The following standards will be followed during the building and testing of this prototype system.

1. Health and Safety at Work etc. Act 1974.
2. Electricity at work regulations 1989
3. BS7671 amendment 3
4. MOD Regulations JSP 375 electrical and mechanical (pressure systems)

A point of work risk assessment will be carried out to ensure all standards are followed and safety procedures adhered to. The health and safety standards that will be followed are,

- health and safety at work etc. Act 1974 – “An Act to make further provision for securing the health, safety and welfare of persons at work, for protecting others against risks to health or safety in connection with the activities of persons at work, for controlling the keeping and use and preventing the unlawful acquisition, possession and use of dangerous substances, and for controlling certain emissions into the atmosphere;”
I will follow all procedures in this act relevant, governing to my safety and the safety of others, I will wear all appropriate PPE provided and follow all safety guidelines.
- JSP 375 part 2 Vol 3 – these regulations govern the control and safety of working with electricity and pressurised systems on MOD Sites. I will follow all aspects of this regulations governing to health and safety aspects and any electrical and pressure systems worked on Ministry of defence sites and locations.
- electricity at work act 1989 – “The purpose of the Regulations is to require precautions to be taken against the risk of death or personal injury from electricity in work activities.” I will follow all regulations in this act relevant to my workplace and task. The safe use and procedures of working with electricity and safe isolating procedures.
- Provision and Use of Work Equipment Regulations 1998 (PUWER) – “PUWER requires that equipment provided for use at work is: suitable for the intended use, safe for use, maintained in a safe condition and inspected to ensure it is correctly installed and does not subsequently deteriorate used only by people who have received adequate information, instruction and training accompanied by suitable health and safety measures, such as protective devices and controls. These will normally include emergency stop devices, adequate means of isolation from sources of energy, clearly visible markings and warning devices used in accordance with specific requirements, for mobile work equipment and power presses.”

Make sure all equipment used are safe and fit for purpose, calibrated and PAT tested. The PPE required will be safety glasses, composite safety boots, gloves,

Project Risk Assessment						
SEVERITY	Catastrophe	5	5	10	15	20
	Major	4	4	8	12	16
	Moderate	3	3	6	9	12
	Minor	2	2	4	6	8
	Insignificant	1	1	2	3	4
LIKELIHOOD		1	2	3	4	5
		Very Unlikely	Unlikely	Occasional	Likely	Frequent
ID	Risk Item	Likelihood	Severity	Risk Score	Control Measure To Minimise Risk	Risk Score After Control Measure
Action taken						
1	Electric Shock	5	5	25	Isolate Supply as per JSP 375 And lock off and prove dead	5
2	Pressure Systems	5	4	20	Correct isolation of pressurised systems Keep pressure below 10 Bar	4
3	Working with display screen equipment (DSE)	4	1	4	Wear appropriate VDU glasses	1
4	Soldering	3	4	12	Wear appropriate PPE, work in well ventilated designated area	3
5	Use of work equipment (drill)	3	4	12	Wear appropriate PPE, Check equipment safe before use	4
6				0		
				0		

Figure 6 - Risk Assessment

Good
clear
specificat
ion with
environm
ental and
safety
issues
identified

Sustainability

This device is intended to be a device that is future proofed with the ability to add sensors and controls and that ability to link to add further network controls and results. All sensors can be easily replaced with newer and more accurate or more functional sensors which comply with industry 4.0. This prototype could be reconfigured for different sensor and recording capabilities for example (temperature, liquid).

The parts required for the project will be sourced locally, and the project will utilize existing network (internet) to transmit and receive data from the sensors removing the need to install a new network at great expense, this will allow the project to be more flexible using this method as data viewing location could be anywhere in the world if desired.

*Good argument for
sustainability*

Project schedule

The project is scheduled to start on September 2019 with an expected end target date for completion for the start of May 2020.

3 – Planning

To keep the proposed project on schedule a Gantt chart was produced.

This was for the project to be managed in stages by weeks. As can be seen from the Gantt chart below there are 10 stages set for the completion of the project from the initial concept and design stage to gathering the specification and different solutions to the problem, these early stages are planned for completion by week 8 with all materials and components needed ordered and received.

From the Gantt chart it is also clear that the largest amount of time is allocated for the software development and the actual prototype build this is due to the new programming language and tools that will be required for the project.

Weekly progress reports can be seen in the logbooks for each week in the appendix.

During the project progression the actual time taken will be imputed on the Gantt chart to monitor if project is on schedule or falling behind.

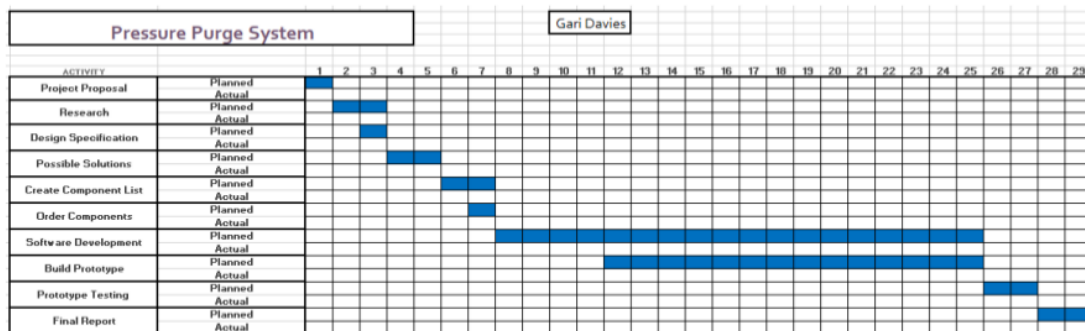


Figure 7 - Gantt Chart

Good
use of
Gantt
chart

Testing

In order to verify that the project has met all the customer requirements a testing table was drawn up from the specifications provided and these tests would be conducted at the conclusion of the project in order to confirm that the outcomes have all been met.

The testing table can be seen in the figure below.

Testing Sequence	Test Carried out	Expected Result	Actual result	Figure	Result
1	Check that LED's light up when program is run	LED's to come on when program starts			
2	Check that Pressure sensor reads correct Pressure when program is run	Pressure sensor to give output on screen every ten seconds			
3	Signal sent to compressor for more air to meet pressure requirements	Compressor starts up			
4	Signal sent to stop compressor as the pressure meets pressure requirements	Compressor stops			
5	Check that sensor keeps Pressure at set point by cutting in and out dependent on Pressure read	Sensor is keeping Pressure at set pressure			
6	Labview Screen shows data	Screen showing correct data from sensor			
7	Control Pressure requirements from remote screen using labview	Pressure set from remote location			

Figure 8 - Testing Table

The use
of a table
for test
analysis
is a good
method

4 – Solutions Considered

Three solutions were considered to complete this project, the same hardware components were used in all three solutions considered these were the (Pressure Sensor, Compressor, Pressure relief valve, one-way valve) these did not change.

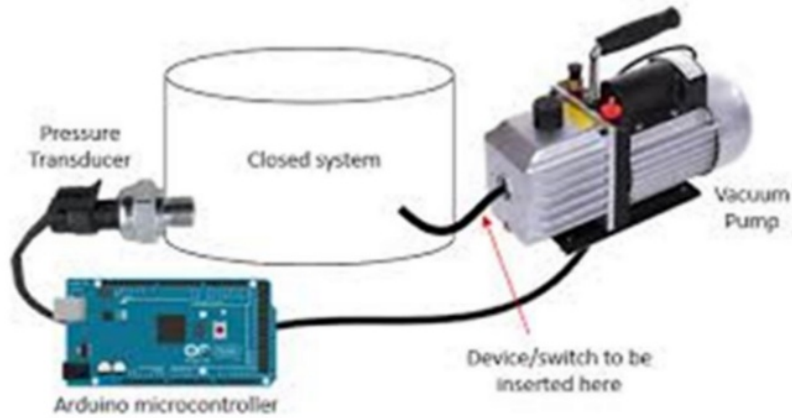


Figure 9 - System Layout

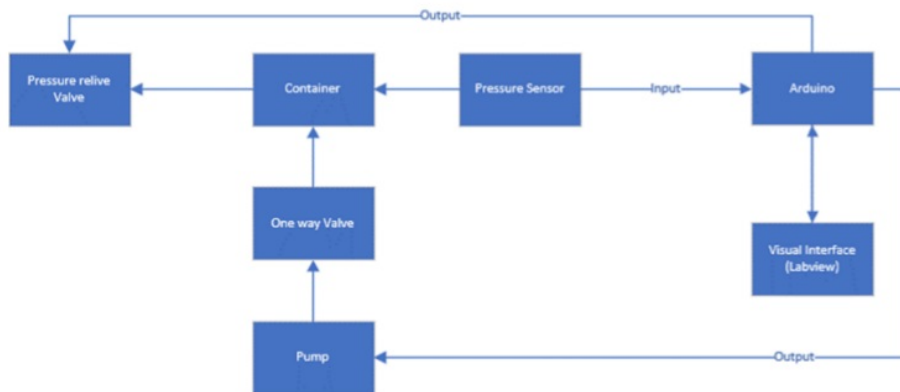


Figure 10 - Layout Diagram



Figure 11 – Compressor

Specifications: Maximum Pressure: 300 PSI, 12v DC



Figure 12 - Pressure transducer

Specifications:

Working Voltage	DC 5.0V
Output Voltage	DC 0.5-4.5 V
Sensor material	Carbon steel alloy
Working Current	≤10 mA
Working Pressure Range	0-1.2 MPa
The Biggest Pressure	2.4 MPa
Cable length	19cm
Destroy Pressure	3.0 MPa
Working TEMP. Range	0-85°C
Storage Temperature Range	0-100°C
Measuring Error	±1.5 %FSO
Temperature Range Error:	±3.5 %FSO
Response Time	≤2.0 ms
Cycle Life	500,000 pcs
Application	non-corrosive gas liquid measurement



Figure 13 - Pressure relief valve

Specifications: Maximum Pressure: 0 - 100 PSI,

First Solution

The first possible solution to this problem would be to use an Arduino board as the controller sending and receiving all data and signals. A small LCD Screen would be wired to the Arduino and pressure results displayed. A potentiometer would be used to control the scaling of the result to the Arduino board. A MOSFET would be connected to the 5v output from the board to control the 12v power supply to the compressor. Remote monitoring will be achieved by using a LabVIEW front end visual display over a network and incorporating visa communication for information sharing between the Arduino board and the LabVIEW front end.

The hardware required for this solution is listed below.

Arduino board, LCD Arduino screen, Potentiometer, PWM, MOSFET 2N700, MOSFET IRF530N.

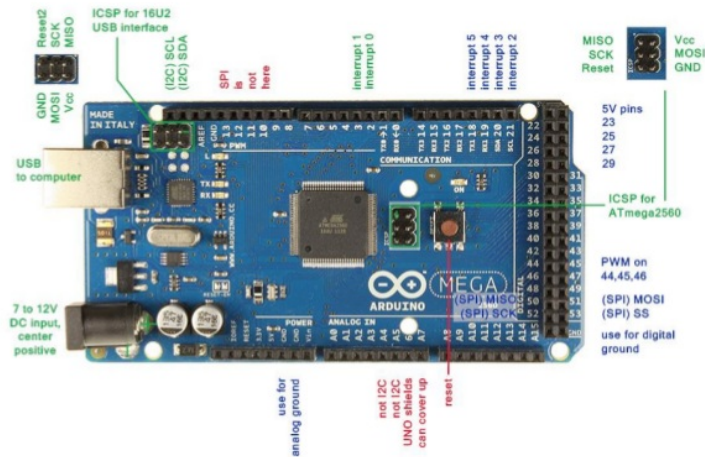


Figure 14 - Arduino board layout pins

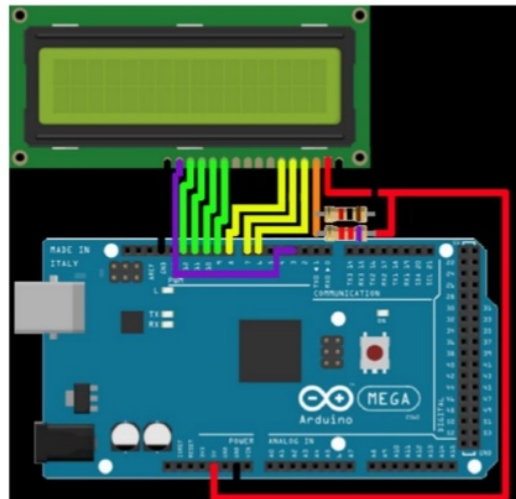


Figure 15 - Arduino LCD screen connected to Arduino

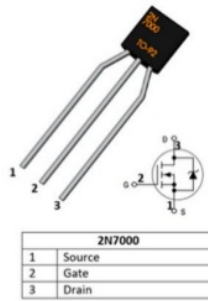


Figure 16 - MOSFET

The software required for this solution are listed below.

Arduino Software IDE (C++ programming), LabVIEW with visa (G Programming) there will no need to purchase any software as licences for these are already available to use.

```

PWM
int led_pin = 6;
int pot_pin = A0;
int output;
int led_value;

// 1 to GND
// 2 to 5V
// 3 to the center pin on the potentiometer
// 4 to Arduino digital pin 12
// 5 to GND
// 6 to Arduino digital pin 11
// 7 (no connection)
// 8 (no connection)
// 9 (no connection)
// 10 (no connection)
// 11 to Arduino digital pin 5
// 12 to Arduino digital pin 4
// 13 to Arduino digital pin 3
// 14 to Arduino digital pin 2
// 15 to 5V
// 16 to GND
#include <LiquidCrystal.h>

LiquidCrystal lcd(12,11,5,4,3,2);
void setup() {
  pinMode(led_pin, OUTPUT);
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
  lcd.begin(16, 2);

  lcd.clear();

```

Figure 17 - C++ programming

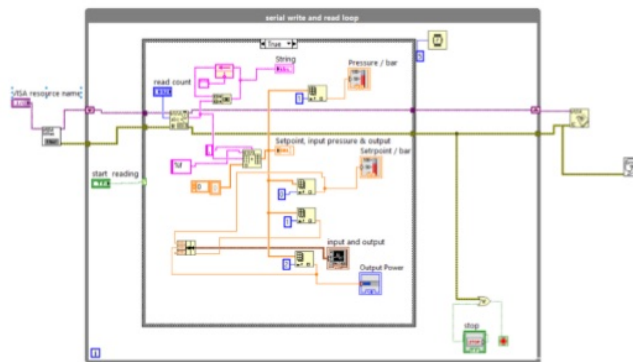


Figure 18 - LabVIEW programming

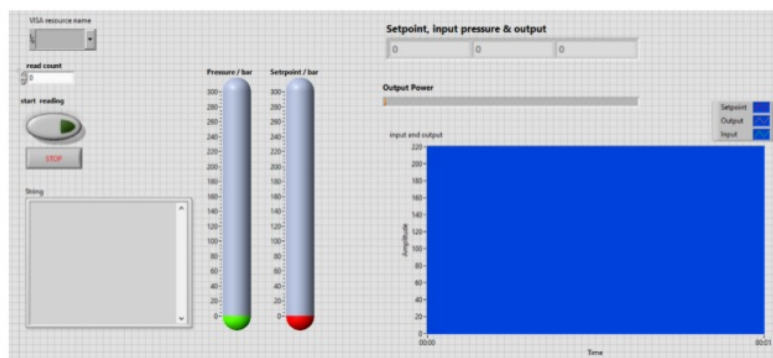


Figure 19 - LabVIEW front end

Advantages:

- Solves the problem and allows operator control.
- Easier to change components.
- Easier to adapt.
- Low cost of parts if destroyed.

Disadvantages

- Expensive software.
- Limited I/O

Description	Cost each	Qty	
Arduino Board	£35.00	1	£35.00
LabVIEW Software (No cost as in college)	£2,920.00	1	£0.00
LCD Screen	£25.00	1	£25.00
MOSFET	£4.98	2	£9.96
Heat sink	£4.79	1	£4.79
Compressor	£6.99	1	£6.99
230v to 12v power supply	£26.99	1	£26.99
One way valve	£9.09	1	£9.09
Pressure Sensor	£8.99	1	£8.99
Total			£126.81

Figure 20 - Cost

This
is a
good
method

Second Solution

The second solution considered is to use a PLC controller as seen in the figure below. The PLC is small computer and only requires inputs and outputs to control the circuit. The PLC will remove the need for a lot of wiring and separate parts, it takes away all the physical cables and replaces them with a computer program which will perform the same job. Most of the components in solution 1 can be programmed in the PLC.

The HMI (Human machine interface) is a touch-controlled display screen which is programmable device that is controlled via the network. This display in conjunction with the PLC Program will control all data and scaling required for the circuit design.

The hardware is readily available in college for this prototype but implementation on work site would incur costs.

The hardware required for this solution are below.



Figure 21 – Siemens PLC



Figure 22 – Siemens HMI Screen

The software required for this solution are Step 7 programming

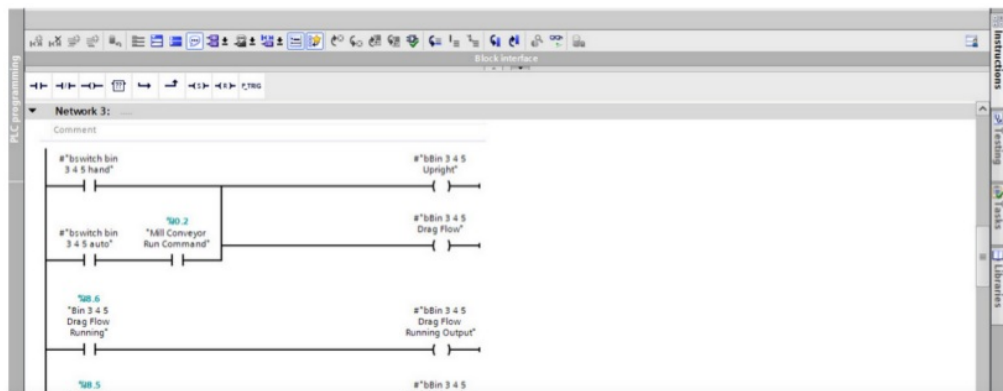


Figure 23 - Ladder program

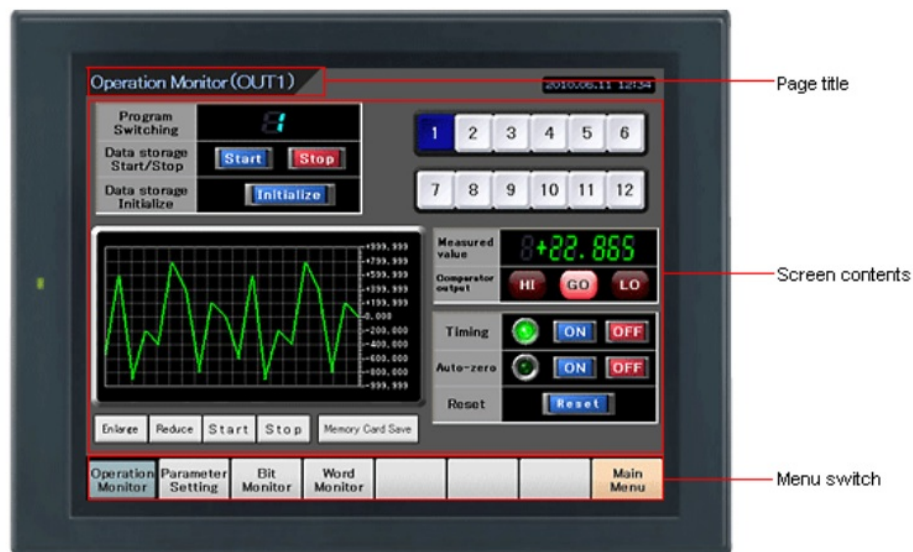


Figure 24 - HMI Screen

Advantages:

- Solves the problem and allows operator control.
- Easier to fault find on.
- More modern industry 4.0 and will take up less space.
- Easy to expand I/O with modules

Disadvantages

- Expensive if fails and to buy.
- Need to write complex PLC program.

Description	Cost each	Qty	
PLC (No cost as in college)	£145.00	1	£0.00
HMI Screen (No cost as in college)	£646.00	1	£0.00
Step 7 software (No cost as in college)	£138.00	1	£0.00
Compressor	£6.99	1	£6.99
230v to 12v power supply	£26.99	1	£26.99
One way valve	£9.09	1	£9.09
Pressure Sensor	£8.99	1	£8.99
Total			£52.06

Figure 25 - Cost 2

A
good
possible
solution

Third Solution

The third solution would be to use a PLC as solution 2 but using the built-in web server on the PLC and construct a web page that all the required information can be retrieved and sent from the PLC. (Siemens, 2017)

The figures below show example of the JavaScript required and possible visual html display.

```
<!DOCTYPE html>
<html>
  <head>
    <meta charset="utf-8">
    <title>DMC Gage Demo</title>
    <script src="js/jquery-2.0.2.min.js"></script>
    <script src="js/raphael.2.1.0.min.js"></script>
    <script src="js/justgage.1.0.1.min.js"></script>
  </head>

  <body>
    <div id="g1"></div>
    <div id="g2"></div>

    <script type="text/javascript">
      $(document).ready(function(){
        var g1, g2;
        var g1 = new JustGage({
```

Figure 26 - JavaScript



Figure 27 - HTML Page

Advantages:

- Solves the problem and allows operator control.
- Easier to fault find on.
- More modern industry 4.0 and will take up less space.
- Easy to expand I/O with modules

Disadvantages

- Expensive if fails and to buy.
- Need to write complex PLC program and JavaScript front end.

Description	Cost each	Qty	
PLC (No cost as in college)	£145.00	1	£0.00
Step 7 software (No cost as in college)	£138.00	1	£0.00
Compressor	£6.99	1	£6.99
230v to 12v power supply	£26.99	1	£26.99
One way valve	£9.09	1	£9.09
Pressure Sensor	£8.99	1	£8.99
Total			£52.06

Figure 28 - Cost 3

Comparison

	Cost	Connectivity	Pressure Change	Efficiency	Reliability	Parts Cost
Option 1	£126.81	ethernet /USB	Manual/program	No	yes	Cheap parts to replace
Option 2	£52.06	ethernet	Programed	yes/computer required	yes	Expensive if PLC OR HMI stops working
Option 3	£52.06	ethernet	Programed	yes/computer required	Yes	Expensive if PLC stops working

Figure 29 - Comparison Table

This is a good option which ties in with IIOT 4.0 and most

Solution chosen

The solution chosen for this project is solution number 1. This is due in large parts to cost and ease of programming. Solution 1 in the comparison is the most expensive to buy since college has the parts already this is not a true reflection of real-world costs. If this prototype was to be implemented in my work place then solution 1 is the best due to the work carried out and risk of catastrophic damage to the equipment during normal working operation.

Costs is probably the main driver here

5 - Final Solution and Implementation

The first stage of implementing the project was to assemble all the required parts and components ready to start.

A system diagram was created showing the location and connection of all components and their prospective layout in the system.

The bullet point list shows the basic operation of the intended system.

- Setpoint set
- PWM triggers MOSFET
- MOSFET triggers Compressor to Start
- Setpoint nearly reached PWM slows down compressor
- Setpoint Reached PWM stops compressor
- Pressure dropping slowly below setpoint PWM starts compressor slowly
- Pressure dropping rapidly PWM starts compressor at full duty to meet demand and reach setpoint

The construction of the system was broken down into stages, this enabled each part to be tested for functionality before adding further components to the system and moving on.

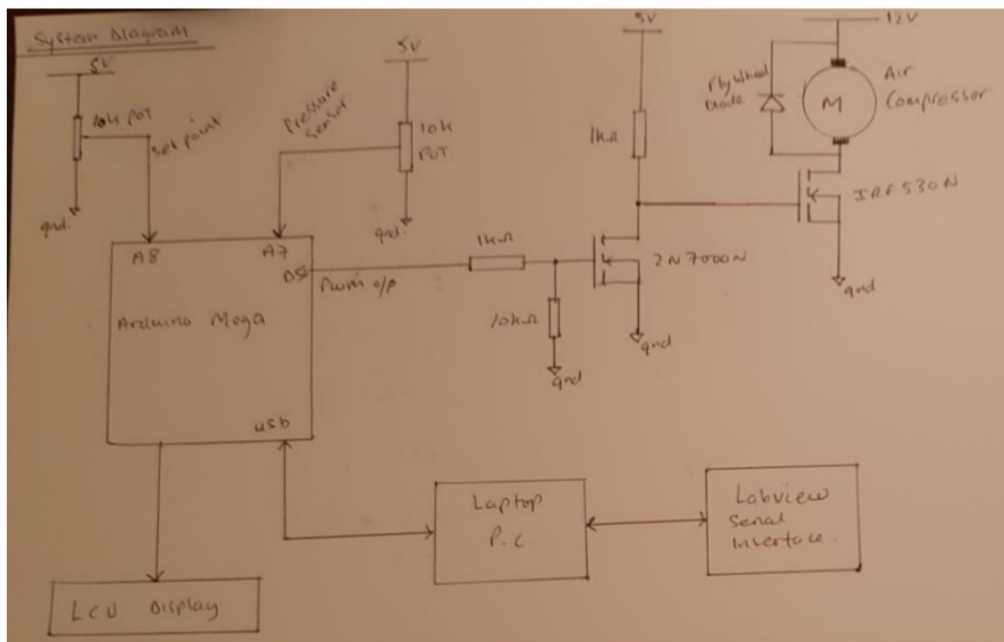


Figure 30 - Final System diagram

Good
diagram
showing
the system
connections

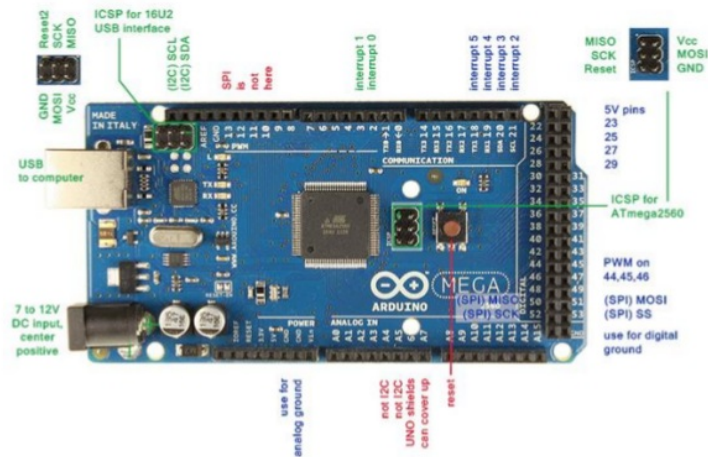


Figure 31 - Arduino pin layout

Stage 1 was to get the Arduino board and connected the pressure sensor to the Arduino using a breadboard for connections a 5v supply and ground was connected and signal connected to pin A7 the pot was also fitted in line with the sensor to adjust the sensor scaling. The Program was written to initialize pin A7 and the program was run. The results recorded can be seen in the figure below.

The test looks successful

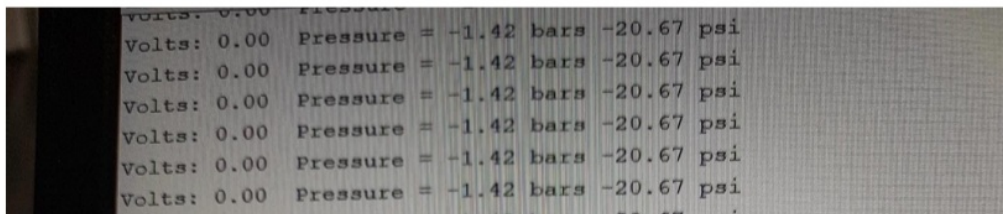


Figure 32 - Sensor results

Stage 2 in this stage the second pot was connected to the breadboard power supply and the signal to the Arduino to port A8 this was to set the desired setpoint. The Program was written to initialize pin A8 and the pot and the program was run again. The results recorded can be seen in the figure below.

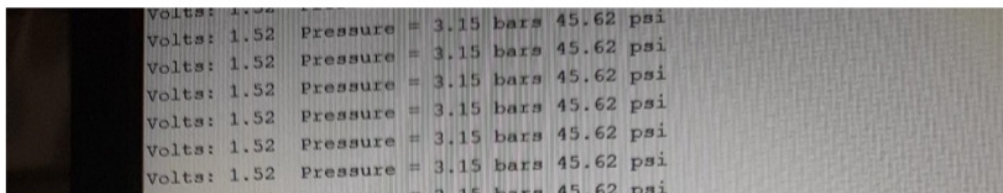


Figure 33 - Sensor results with POT

Set point values look correct

Stage 3 in this stage the LCD screen is connected to the Arduino using connection 4-13 and 5v and ground as seen in the figure below. The program for the LCD screen was added to the original program and the resultant program run again adjusting the pot to show the results changing on the screen match the program readouts. (Techie, 2019)

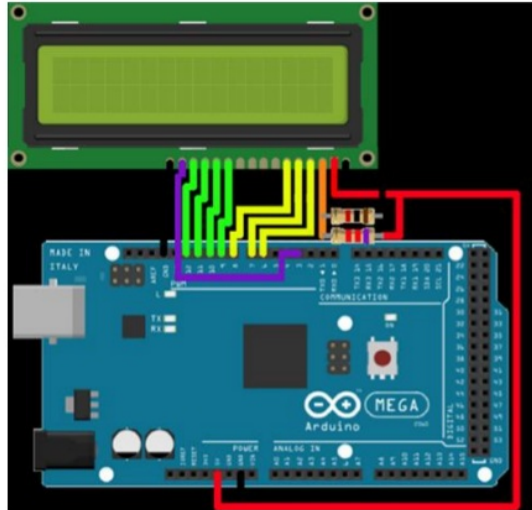


Figure 34 - LCD screen pins

The figures below show the two different reading taken.



Figure 35 - LCD Reading 1



Figure 36 - LCD Reading 2

The test looks successful with the values changing

Stage 4 the two MOSFETS were added to the breadboard as per the drawing and the program changed with the PID loops initialised and all the limits for these set on the program. There are two MOSFETs used the first is a 2N7000 (RS, 2019) which takes 5v is connected to the output pin of the Arduino and the second an IRF540 (transistors, 2019) which takes a maximum of 24v but for the project 12v will be supplied for the compressor. The first MOSFET will switch the second which controls the actual load. The second MOSFET will need a large heatsink due to the high temperatures generated from the component through the current loading needed.

The Circuit was connected to a small motor for testing the MOSFETS and PID loops with a 12v power supply connected, a Pico scope was connected to verify that the output signal did operate as intended for this basic test.

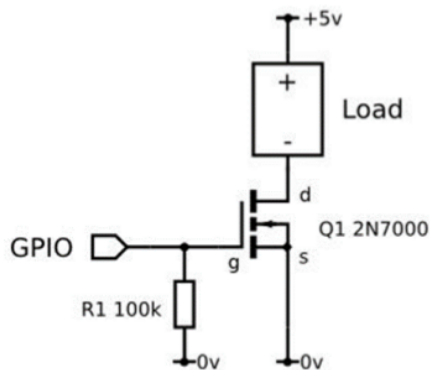


Figure 37 - 2N7000 MOSFET

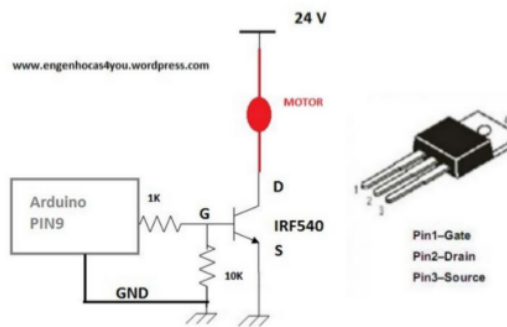


Figure 38 - IRF540 MOSFET

Circuit looks correct

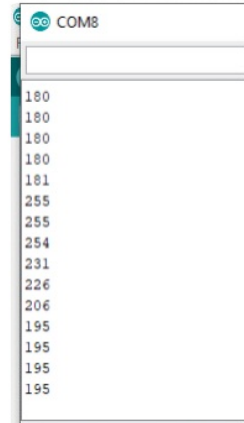
The C++ code below entered the program will enable the analogue input to control the PWM power output. The pins on the Arduino Mega for PWM have been identified and pin 46 is the PWM pin used. The analogue input is controlled using a potentiometer which is scaled to 0 – 255 (8 bit). The output values can be monitored on the serial monitor within Arduino IDE.

```
int led_pin = 45;
int pot_pin = A7;
int output;
int led_value;
void setup() {
  pinMode(led_pin, OUTPUT);
  Serial.begin(9600);
}
void loop() {
  //Reading from potentiometer
  output = analogRead(pot_pin);
  //Mapping the Values between 0 to 255 because we can give output
  //from 0 -255 using the analogwrite funtion
  led_value = map(output, 0, 1023, 0, 255);
  int display_value = 255 - led_value;
  analogWrite(led_pin, led_value);
  Serial.println(display_value);
}
```

```
delay(100);
}
```

Test results:

The value of PWM follows the value of the analogue input.



This test looks good. This obviously shows the PWM function is working.

Figure 39 - PWM Analogue input

The figures below show the circuit being tested and results Pico scope results.

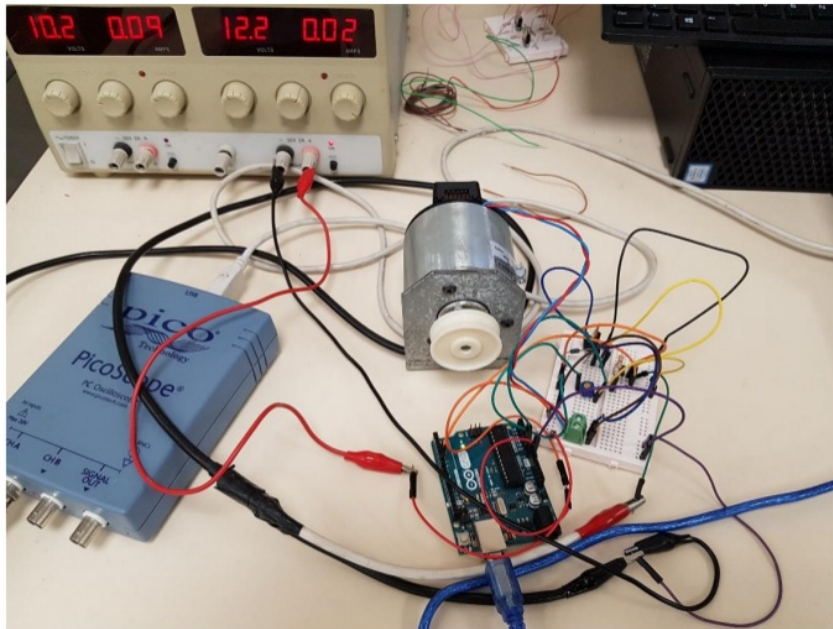


Figure 40 - Testing MOSFET

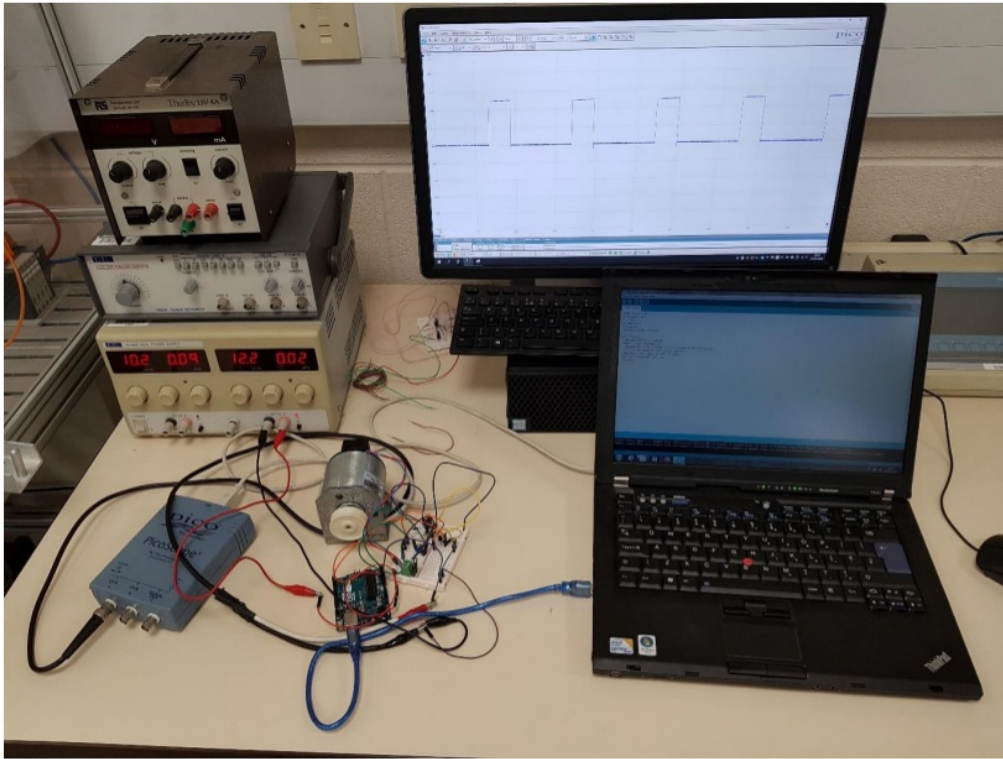


Figure 41 - Pico scope results on screen

Good test
setup

PWM output with duty cycle at 16%.

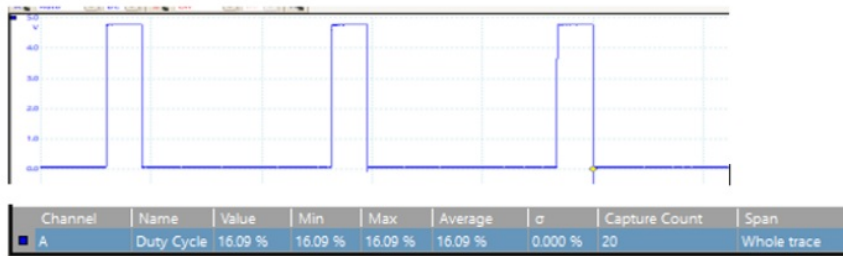


Figure 42 - PWM 16%

PWM with duty cycle at 54%.



Figure 43 - PWM 54%

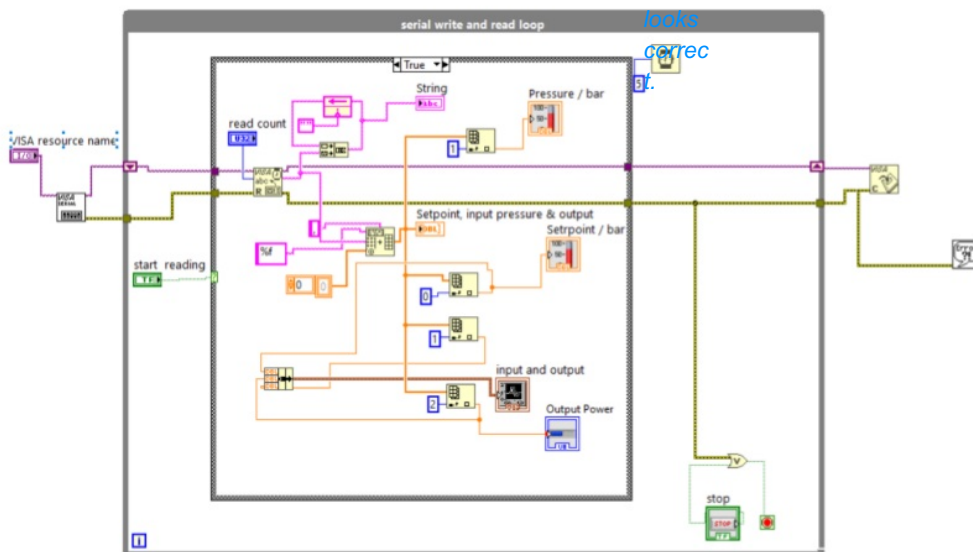
PWM with duty cycle at 93%.



Figure 44 - PWM 93%

Duty
cycle
of
PWM
control
/

Stage 5 was to program the LabVIEW front end and set up the communications between the Arduino and the visual display this was achieved using the visa add on to LabVIEW.



looks
correct
st.

Figure 45 - LabVIEW Program

This labVIEW
program looks
correct but it
must be
connected to the
Arduino to test.

Stage 6 was to construct the visual part of LabVIEW showing the set point and the current pressure giving all the information to the operator they require for example how hard the compressor is working to get the pressure to the setpoint. This information can be seen in the figure below.

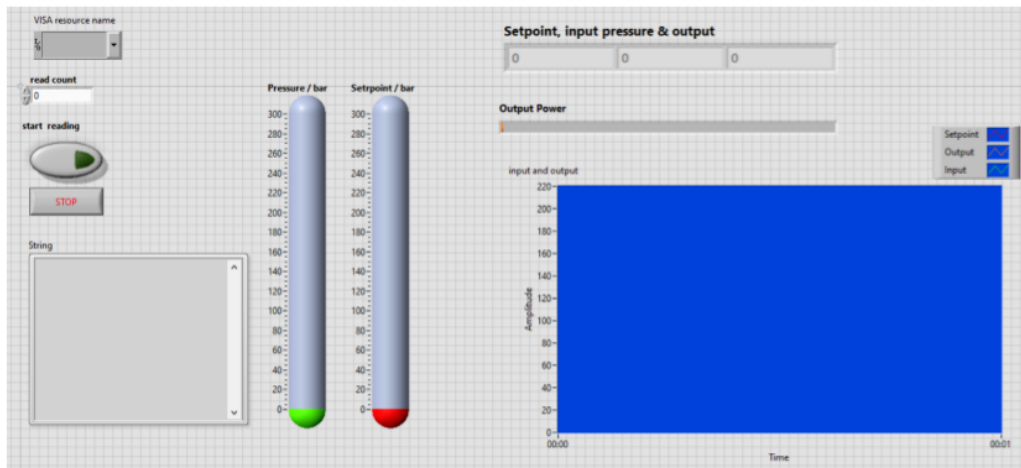


Figure 46 - LabVIEW front end

Stage 7 was to incorporate all the program together and set all the values and LCD display information required for the project. When this was achieved the program was ready to be fully tested against the set outcomes.

The figures below show the C++ program in its entirety.

```
Gary_pressure_PID_v3$
#include <PID_v1.h>
#include <LiquidCrystal.h>

//Definitions
#define FAN 45 // Output pin for fan

int analogInPin2 = A8;
const int analogInPin = A7; // Analog input pin that the potentiometer is attached to
//volatile unsigned int encoderPos = 0; //Encoder value for ISR
int sensorValue = 0; // value read from the pot
int sensorValue2 = 0;
LiquidCrystal lcd(8, 9, 4, 5, 6, 7); //set up LCD

//Setup PID
double Setpoint, Input, Output; //t/o for PID
double aggFp=20, aggKi=2, aggKd=3; //original: aggFp=4, aggKi=0.2, aggKd=1, Aggressive Turning,50,20,20
double consFp=5, consKi=0.5, consKd=3; //original consFp=1, consKi=0.05, consKd=0.25, Conservative Turning,20,10,10
PID myPID(&Input, &Output, &Setpoint, consFp, consKi, consKd, REVERSE); //Initialize PID

//interface
//int timeCounter;
void setup()
{
    // start serial port for temperature readings
    Serial.begin(9600);
    Serial.println("Start");

    // read the analog in value:
    sensorValue = analogRead(analogInPin);
    sensorValue2 = analogRead(analogInPin2);
    sensorValue = map(sensorValue, 0, 1023, 255, 0);
    sensorValue2 = map(sensorValue2, 0, 1023, 255, 0);
    Output = map(Output, 0, 1023, 255, 0);
}
```

Figure 47 - Program part 1

```

Gary_pressure_PID_v3$
//PID Setup
myPID.SetMode(AUTOMATIC);
//TCCR2B = TCCR2B & 0b11111000 | 0x01; //adjust the PWM Frequency, note: this changes timing like delay()

//Setup Pins
pinMode(FAN, OUTPUT); // Output for fan speed, 0 to 255

//Setup LCD 16x2 and display startup message
lcd.begin(16, 2);
lcd.setCursor(0,1);
lcd.print(" Starting Up");
delay(3000);
lcd.clear();
}

void loop()
{
    delay(200);
    //Get temperature and give it to the PID input
    sensorValue = analogRead(analogInPin);
    sensorValue2 = analogRead(analogInPin2);
    sensorValue = map(sensorValue, 0, 1023, 255, 0);
    sensorValue2 = map(sensorValue2, 0, 1023, 255, 0);
    Setpoint=sensorValue2;
    Input = (sensorValue);

    //print out info to LCD
    lcd.setCursor(0,0);
    lcd.print("P:");

    lcd.print((int)Input);
    lcd.print(" ");
    lcd.setCursor(7,0);
    lcd.print("PWM:");
}

```

Figure 48 - Program Part 2

```

    lcd.print(255 - Output); //This us because it is inveted by using 2 MOSFET drivers. This scales it the right way
    lcd.print(" ");
    lcd.setCursor(1,1);
    lcd.print("Set:");
    lcd.print((int)Setpoint);
    lcd.print(" ");
    //Compute PID value
    double gap = abs(Setpoint-Input); //distance away from setpoint
    if(gap<2)
    {
        //Close to Setpoint, be conservative
        myPID.SetTunings(consKp, consKi, consKd);
        analogWrite(FAN,Output);
    }
    else
    {
        //Far from Setpoint, be aggressive
        myPID.SetTunings(aggKp, aggKi, aggKd);
        analogWrite(FAN,Output);
    }
    myPID.Compute();
    Serial.print(Setpoint);
    Serial.print(",");
    Serial.print(Input);
    Serial.print(",");
    Serial.println(255 - Output);
} //end loop

```

Figure 49 - Program Part 3

The program could have been put in an appendix and referenced from the main report.

6 - Testing and Results

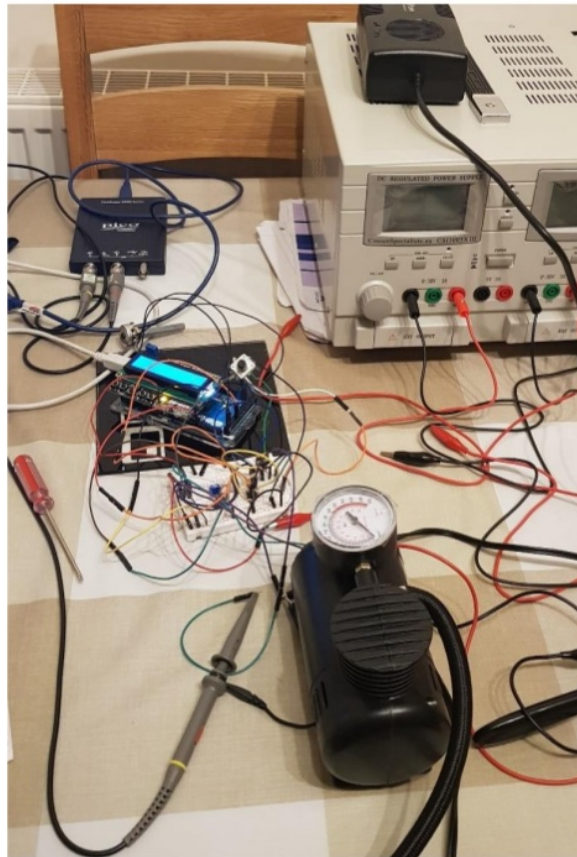
The testing of the completed project design was carried out in accordance with the customer specifications and outcomes these objectives where compiled into a testing table as seen in the figure below.

Testing Sequence	Test Carried out	Expected Result	Actual result	Result
1	Check that LED's light up when program is run	LED's to come on when program starts	LED Come on	PASS
2	Check that Pressure sensor reads correct Pressure when program is run	Pressure sensor to give output on screen every ten seconds	Pressure readout on LCD	PASS
3	Signal sent to compressor for more air to meet pressure requirements	Compressor starts up	Compressor stars pressureising vessel	PASS
4	Signal sent to stop compressor as the pressure meets pressure requirements	Compressor stops	Compressor stops pressureising vessel	PASS
5	Check that sensor keeps Pressure at set point by cutting in and out dependent on Pressure read	Sensor is keeping Pressure at set pressure	Pressure maintaind by system	PASS
6	Labview Screen shows data	Screen showing correct data from sensor	LabVIEW data displayed on front end	PASS
7	Control Pressure requirements from remote screen using labview	Pressure set from remote location	LabVIEW frontend control of system	PASS

Figure 50 - Testing Table

After carrying out all the required testing the system passed all the required objectives set.

Good use of test table



Setup shows all the components are present.

Figure 51 - Final testing complete project

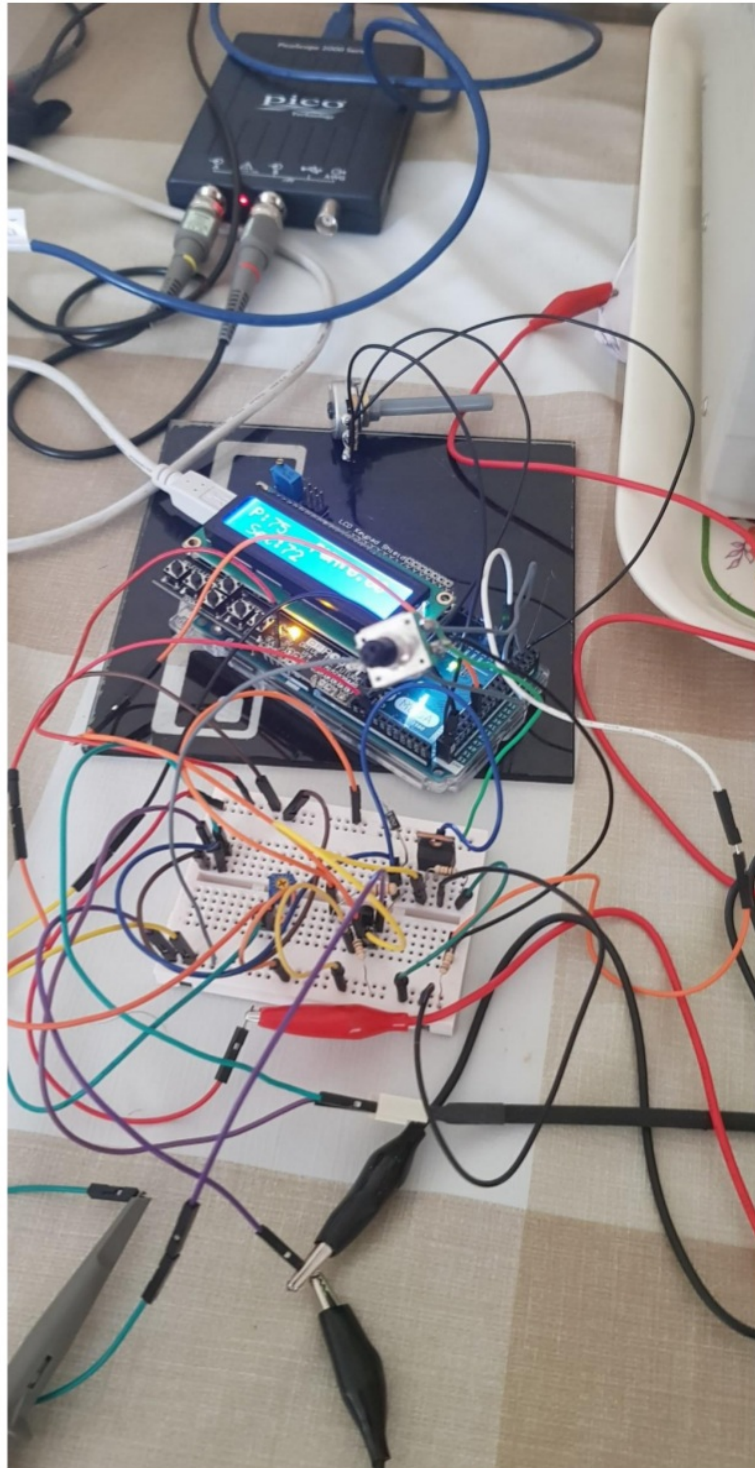


Figure 52 - Final complete circuit

The graphs in the figures below show the Pico scope results of PWM output tests:

Set point lower that process variable:

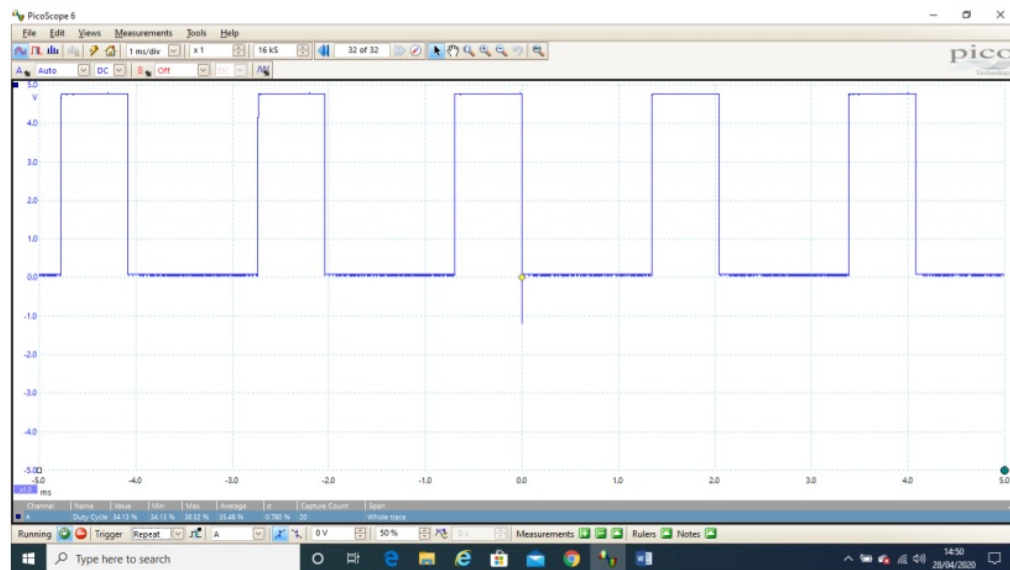


Figure 53 - Graph 1

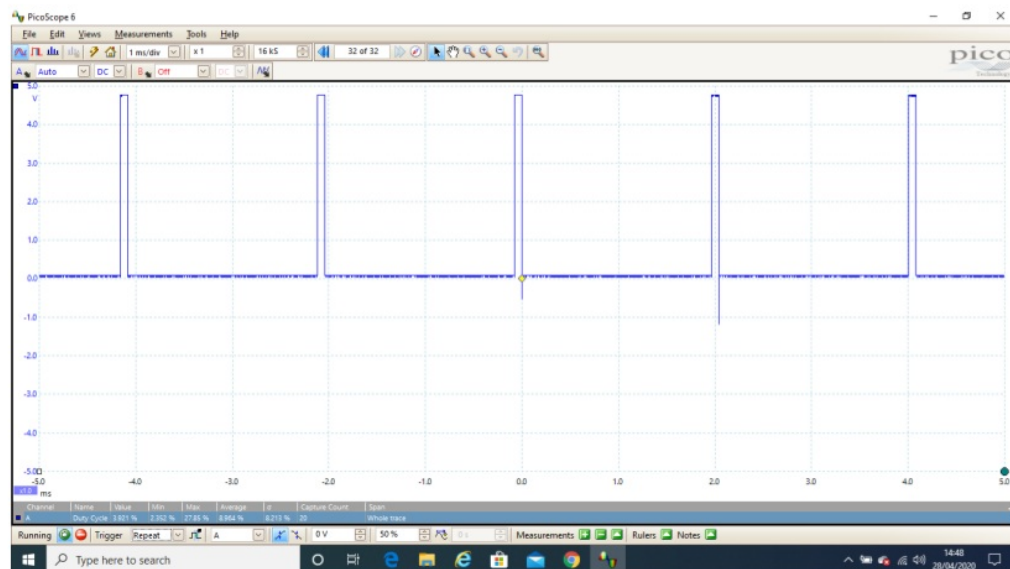


Figure 54 - Graph 2

Good test to show the system holding position and no shift in the PWM.

Set point higher than process variable:

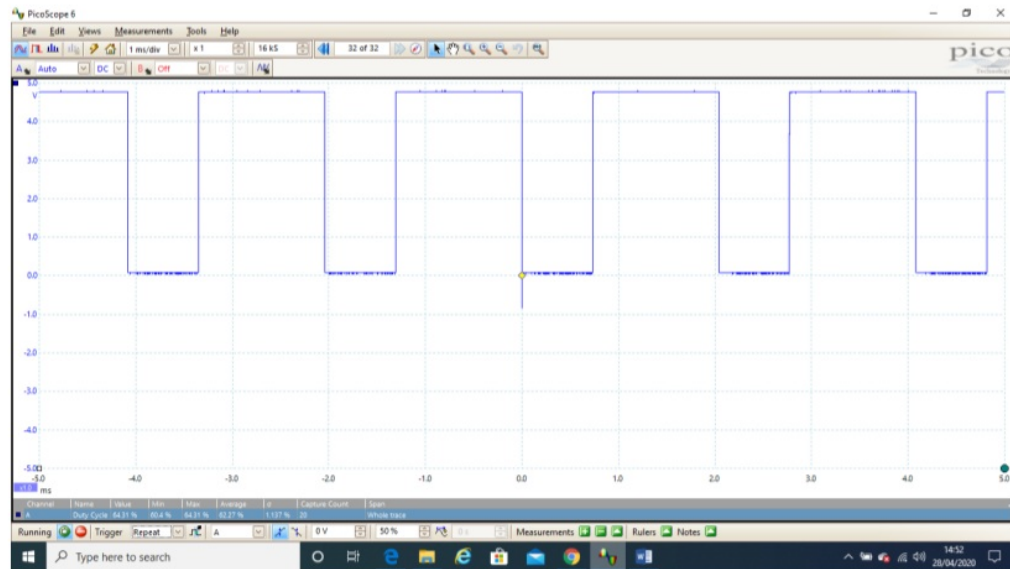


Figure 55 - Graph 3

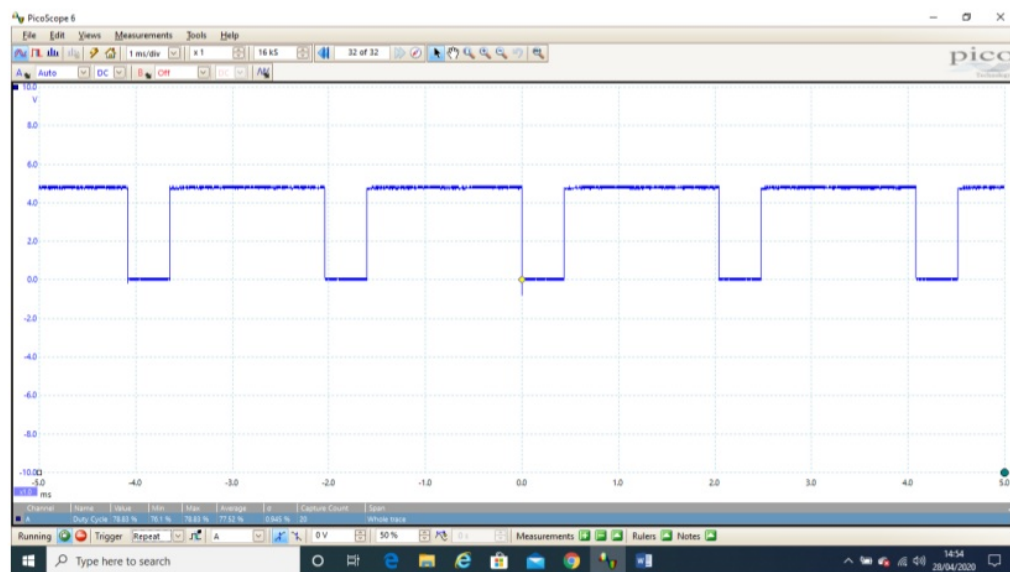


Figure 56 - Graph 4

Shift in PWM
is clear.

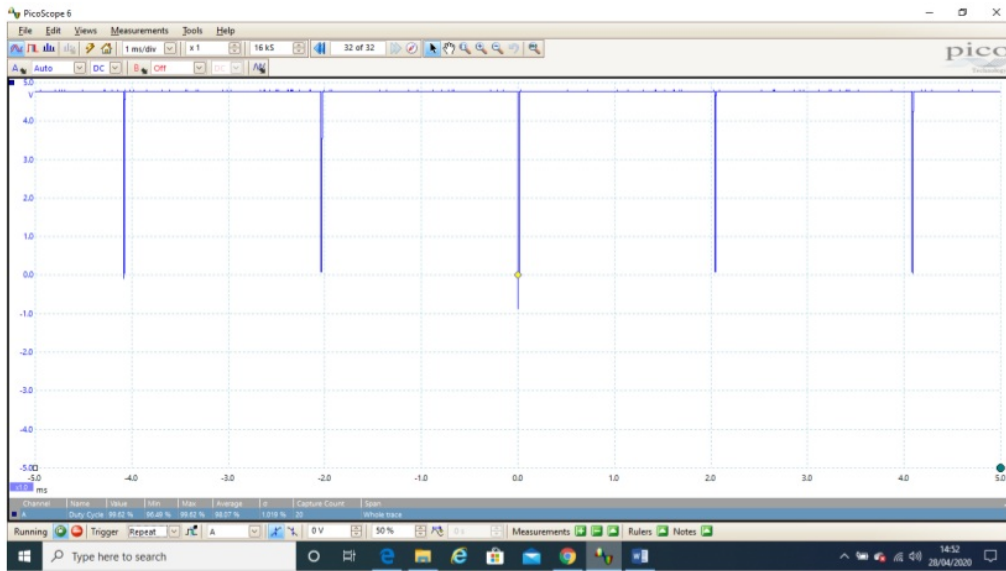


Figure 57 - Graph 5

Set point equal to process variable:

The output remains stable to hold the process variable at the setpoint value. The disturbance is adjusted to hold these 2 variables in the equal state.

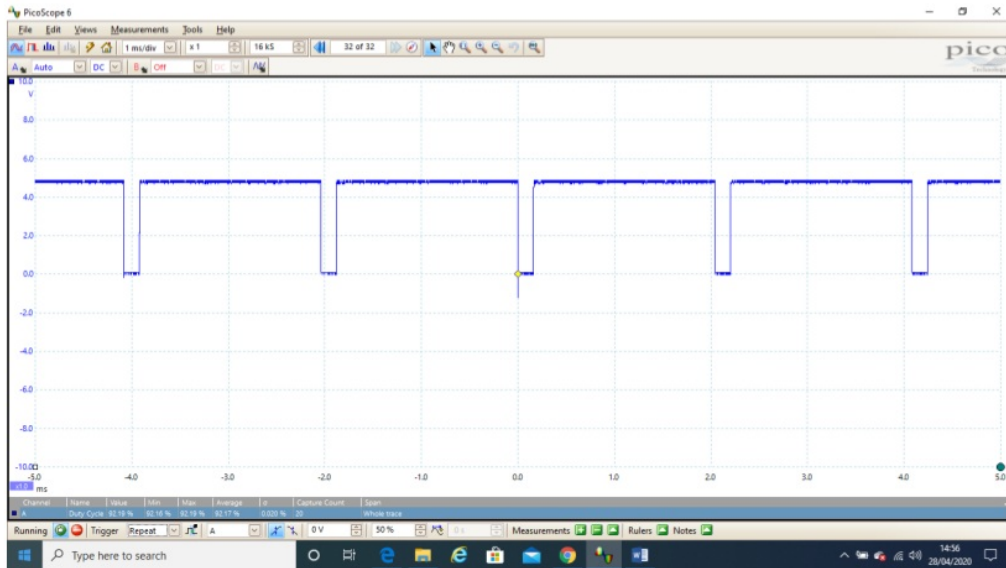


Figure 58 - Graph 6

PWM
no shift
and
holding
values

The disturbance is altered to make the set point slightly higher than the process variable and then made equal after a few seconds and the result is the output power slightly goes lower and then holds once the variables are equal again.

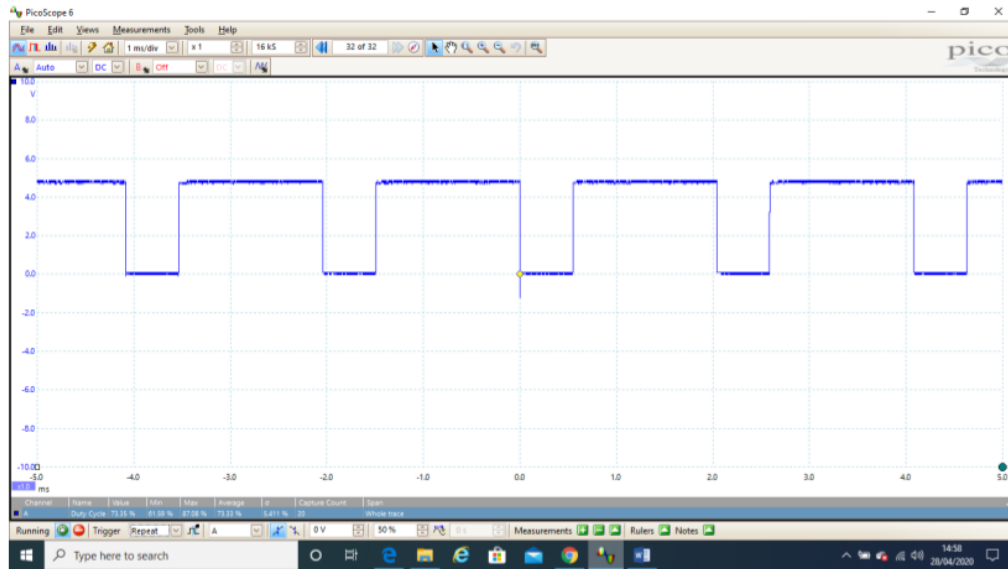


Figure 59 - Graph 7

The disturbance tests the PID control and it is clear that the PWM output has changed due to the disturbance.

The figures below show the LCD display on the system at different stages with the setpoint and current pressure, the PWM is also displayed showing 0- 255 dependent on how much demand is requires to reach set point.

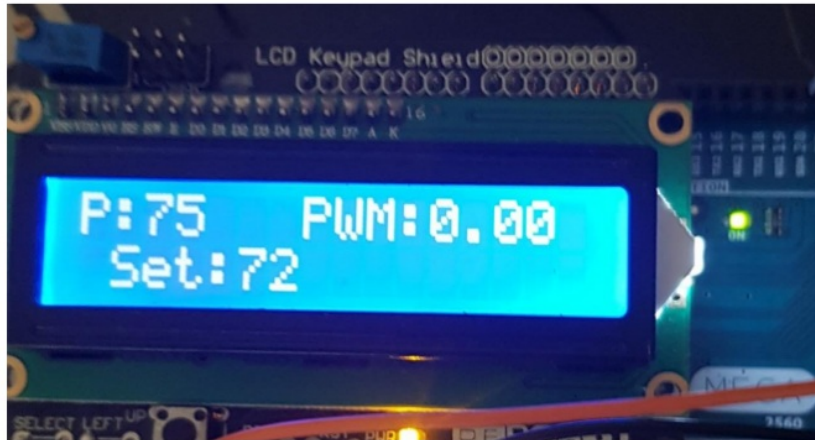


Figure 60 - Pressure above set point



Figure 61 - Pressure close to set point PWM slowing down



Figure 62 - Pressure below set point PWM demand increased



Figure 63 - Pressure well above setpoint PWM at 0 until pressure drops below



Figure 64 - Pressure exceptionally low below set point PWM asking for full 255 demand

Good test showing
the PWM output
reacting to the set
point values and
process variable.

The figures below show the testing from the point of view of the LabVIEW front end Testing Pressure System PID:

Setpoint at 50bar, input reading from sensor at 51bar and output holding system stable at 214 which is 83% PWM Duty Cycle power.

Calc: $(100 / 255) * 214 = 83\%$

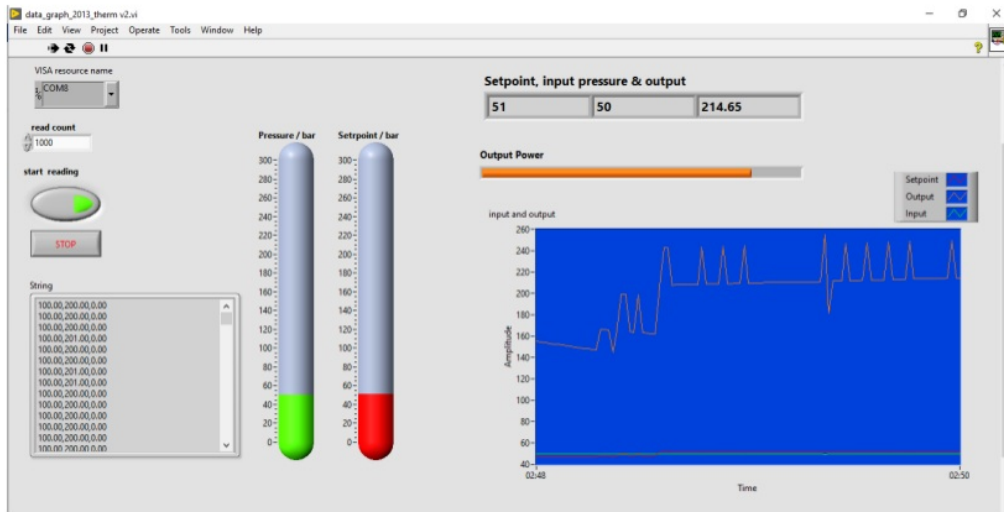


Figure 65 - LabVIEW test 1

Set point higher than actual pressure.

Setpoint: 146

Actual: 140

Power increasing:

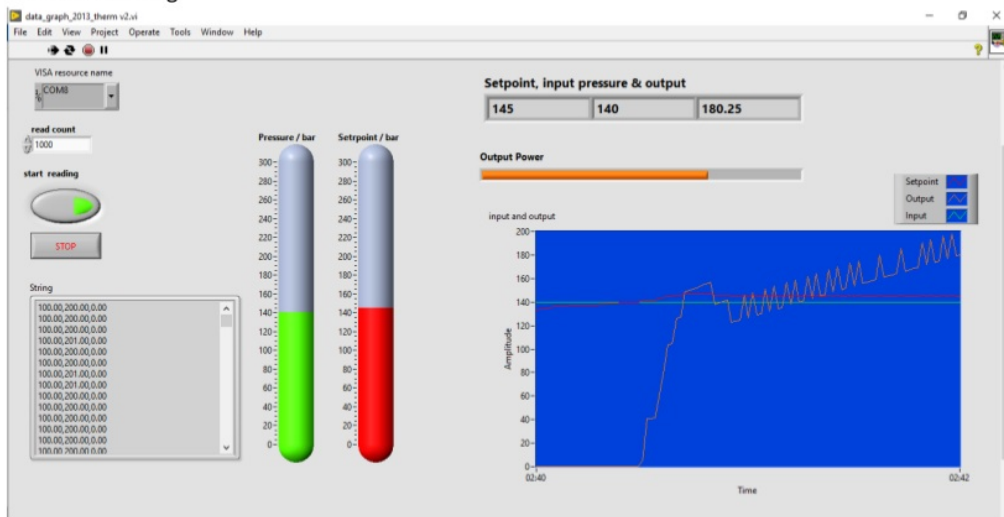


Figure 66 - LabVIEW test 2

Set point lower than actual pressure.

Setpoint: 195

Actual: 200

Power decreasing:

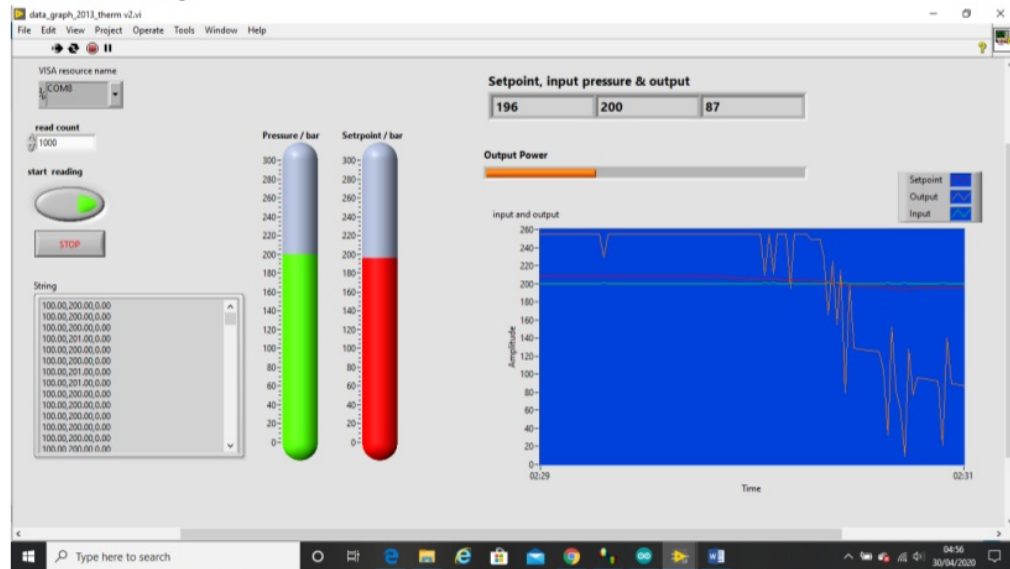


Figure 67 - LabVIEW Test 3

Set point much lower than actual pressure.

Setpoint: 100

Actual: 200

Power at minimum: 0%

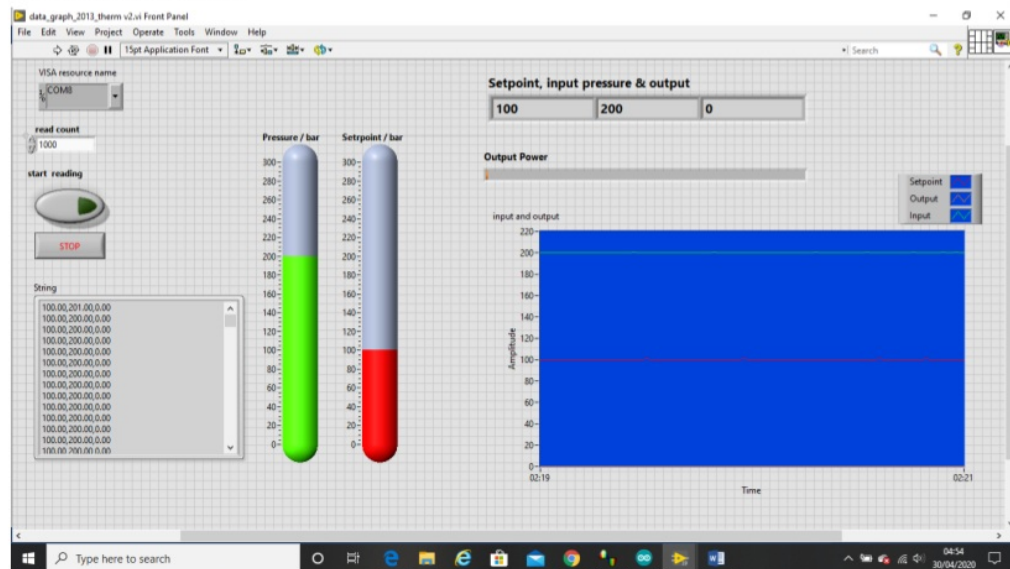


Figure 68 - LabVIEW test 4

Set point much higher than actual pressure.

Setpoint: 220

Actual: 150

Power at maximum: 100%

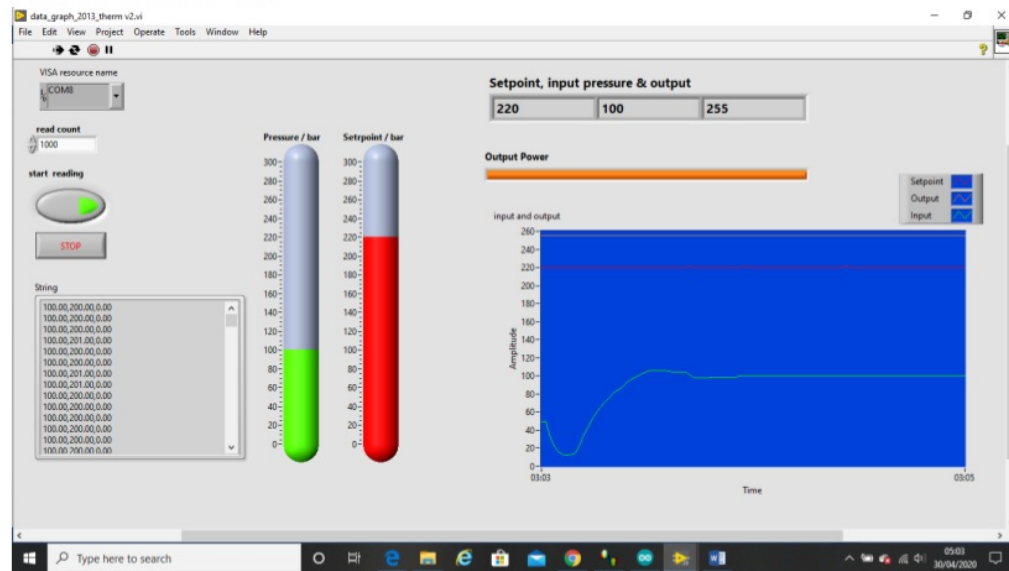
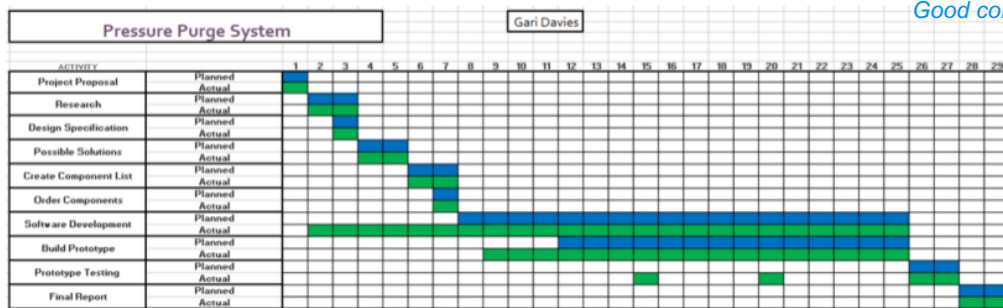


Figure 69 - Lab View test 5

The test images show the output reacting to the setpoint value condition.

7 - Discussion, Conclusions and Recommendations

To conclude this project was successful in meeting its objective. The specification was met to the requirements stated and all testing concluded shows this was met. Although the project was successful in its outcomes there are some improvement that can be made, the first is a practical and visual which is to construct a box to hold all the components in security and safety in a IP67 enclosure, and the second would be to produce a printed circuit board to remove the need for the breadboard. These recommendations would need to be implemented before the prototype can be used in a commercial setting. The cost of the project was kept below the £250 budget, the total spend was £126.81 this did not include the software cost as this was already available at college and my workplace. From the finished Gantt chart in the figure below it can be seen that the schedule was pretty accurate with the project completed on time, the largest discrepancy was the software development which was a large learning curve which can be seen started immediately after project start. The two different software C++ and LabVIEW were the biggest stumbling blocks of this project and the Gantt chart reflects this, by breaking down the build into stages greatly assisted in the development by knowing each stage worked correctly before moving on.



The reliability of this system can only be monitored over time when this system is implemented fully, but buy the testing results I do not expect this to be a issue as component numbers are small, and if there is a requirement to change this will be low cost. For future development, this system can be adapted for other uses by using different sensors for example temperature to monitor and bring on heating.

Do not use first person terms

Good Gantt chart showing actual and planned time lines for comparison.

References

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Good relevant sources used.

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*Good list of figures but should be
after the contents page.*

1809811

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

PAGE 1

PAGE 2

Text Comment. Contents list is good and informative

PAGE 3

Text Comment. Do not use first person terms

Text Comment. Good explanation with a good block diagram.

PAGE 4

Text Comment. Good explanation and breakdown of functions.

PAGE 5

PAGE 6

PAGE 7

Text Comment. Good clear specification with environmental and safety issues identified.

PAGE 8

Text Comment. Good argument for sustainability

PAGE 9

Text Comment. Good use of Gantt chart

Text Comment. The use of a table for test analysis is a good method

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

Text Comment. This is a good method and the software and components identified

PAGE 15

PAGE 16

PAGE 17

Text Comment. A good possible solution

PAGE 18

PAGE 19

Text Comment. This is a good option which ties in with IIOT 4.0 and most probably is the future of automation.

Text Comment. Costs is probably the main driver here

PAGE 20

Text Comment. Good diagram showing the system connections

PAGE 21

Text Comment. The test looks successful

Text Comment. Set point values look correct

PAGE 22

Text Comment. The test looks successful with the values changing

Text Comment. Circuit looks correct

Text Comment. This test looks good. This obviously shows the PWM function is working.

Text Comment. Good test setup

Text Comment. Duty cycle of PWM control looks correct.

Text Comment. This labVIEW program looks correct but it must be connected to the Arduino to test.

Text Comment. The front end visual has all the necessary components.

Text Comment. The program could have been put in an appendix and referenced from the main report.

Text Comment. Good use of test table

Text Comment. Setup shows all the components are present.

Text Comment. Good test to show the system holding position and no shift in the PWM.

Text Comment. Shift in PWM is clear.

PAGE 34

Text Comment. PWM no shift and holding values

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Text Comment. The disturbance tests the PID control and it is clear that the PWM output has changed due to the disturbance.

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Text Comment. Good test showing the PWM output reacting to the set point values and process variable.

PAGE 38

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Text Comment. The test images show the output reacting to the setpoint value condition.

PAGE 41

Text Comment. Good conclusion

Text Comment. Do not use first person terms

Text Comment. Good Gantt chart showing actual and planned time linesfor comparison.

PAGE 42

Text Comment. Good relevant sources used.

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PAGE 44

Text Comment. Good list of figures but should be after the contents page.

GARI DAVIES

0

RESEARCH-INFORMED LITERATURE



The research carried out is of a good quality and appropriate number of relevant sources used. 7/10
Good relevant sources used 7/10

14/20

KNOWLEDGE AND UNDERSTANDING



Specification is clear with budget breakdown and good use of diagram. 6/10 The solutions considered are the final solution which is good and in depth. You have also carried out good relevant research on the alternative solutions. 7/10

13/20

ANALYSIS



Testing and results are good and clearly explained. There is sufficient detail in this section. 7/10
Conclusion and recommendations make a relevant point. 6/10

13/20

PRACTICAL APPLICATION AND DEP.



Planning with the use of a Gantt chart and a comparison chart is clear and the project seems to have run to the plan. 3.5/5 Final solution considered and the relevant alternative solutions are good. 7/10 Implementation is explained very well with supporting images as evidence. 7.5/10

18/25

SKILLS FOR PROFESSIONAL PRAC.



The quality of the report is good with some minor grammatical errors.

10/15