Design and development of a simple data acquisition system for monitoring and recording data

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Abstract

This project is about constructing a data acquisition system. These systems are very useful for technological companies because technicians can monitor every machine in the factory through a computer and see if one or several are malfunctioning.

A computer based data acquisition system is an effective and cost-effective method to have an overview of the whole production line inside a factory.

Data acquisition means the process of measuring and acquiring signals from physical or electrical phenomena such as pressure, temperature, voltage and flow with a computer and a software.

The purpose of the project is to design and develop a simple data acquisition system. Labview was used to construct the system and the system is limited to only acquire signals from flow and temperature. The measurements were made in the HPT laboratory at The Royal Institute of Technology.

By the end of the project a Graphical User Interface was developed so that the user can monitor how the flow and temperature varies with time.
Sammanfattning

I dagens industri lägger företagen stör vikt vid utveckling av metoder och verktyg som leder till att effektivisera arbetsprocesserna. Ett problem som stora fabriker kan ha är att om en av maskinerna slutar fungera korrekt kan det vara svårt att upptäcka det in tid.

Ett PC-baserat datainsamlingssystem är ett flexibelt och kostnadseffektivt sätt att se över hela processen i en fabrik och att enkelt hålla koll på alla maskiner.

Datainsamlingssystem innebär processen att mäta en elektrisk eller fysiskt fenomen såsom spänning, ström, temperatur, tryck, eller ljud med hjälp av en dator och en programvara.

Syftet med projektet är att designa och utveckla ett datainsamlingssystem. Labview användes för att konstruera systemet och den är begränsad till att endast samlar in data för flöde och temperatur. Mätningarna utfördes i HPT laboratoriet i Kungliga Tekniska högskolan.

Resultatet blev att en Graphical User Interface konstruerades så att användaren enkelt kan se hur temperaturen och flödet varierar med tiden.
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**Abbreviation/Nomenclature**

GUI – Graphical User Interface.

DAQ – Data Acquisition.

LABVIEW – Laboratory Virtual Instrumentation Engineering Workbench.

Emf- Electromotive force measured in volts.

NIST- The National Institute of Standards and Technology.

KTH- Kungliga Tekniska Högskolan.

USB- Universal Serial Bus.

PCI- Peripheral Component Interconnect.

RTD- Resistance Temperature Detectors.

IC- Integrated Circuit.

HPT laboratory- Laboratory of the Unit of Heat and Power Technology.

<table>
<thead>
<tr>
<th>Physical Quantity</th>
<th>Notation</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
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<td>T</td>
<td>°C</td>
</tr>
<tr>
<td>Volt</td>
<td>U</td>
<td>V</td>
</tr>
<tr>
<td>Flow</td>
<td>Q</td>
<td>l/s</td>
</tr>
<tr>
<td>Pressure</td>
<td>p</td>
<td>Pa</td>
</tr>
<tr>
<td>Area</td>
<td>A</td>
<td>m²</td>
</tr>
<tr>
<td>Diameter</td>
<td>d</td>
<td>m</td>
</tr>
<tr>
<td>Density</td>
<td>ρ</td>
<td>kg/m³</td>
</tr>
</tbody>
</table>
1. Introduction

In today’s industry, companies are doing everything they can to make their processes more efficient and cheap. Nowadays companies are trying to make their production process more automated because it reduces cost long term and reduces the element of human errors. However, it is difficult to keep track if all the machines are working correctly or to keep track of their maintenance schedule.

In general the most common way to see if a machine or a process is working correctly is to either look at the final product or to observe the gauges that are installed on them. So if the final product satisfies the client/customer or if the gauges are showing the right values then you know that everything is working well. But the machines will not always work perfectly and because of that, it might jeopardize the whole production line. If one machine is not working well one can easily repair it or even replace it, but imagine if you have several machines that are not working well and no one knows about it until you see the final outcome of the product. To make sure that this will not happen companies have installed DAQ modules that are both connected to the gauges and a computer. This makes it a lot easier for technicians to see if all the machines are working properly or not and with the use of internet everyone in the company can monitor the machines, even the company that has manufactured them.

The emphasis of this project is to design a similar system that can record and store data using LabVIEW. All the tests and experiments will be performed at the HPT laboratory at Royal Institute of Technology.

1.1 Objectives

Objectives of the project are:

- Design a data acquisition system for monitoring and recording of operational parameters of a test facility installed in Heat and Power technology laboratory at KTH
- Describe the measuring principles of temperature measurements with thermocouples and flow measurements with orifice plate flow measuring devices
- Process analog signals generated by relevant measuring instruments such as thermocouples and orifice plates to be converted to digital signals and create system circuits in order to be able for computer based data acquisition system
- Design and development of a Graphical User Interface using the commercially available software LabVIEW.
- All the measurements and experiments will be done at the HPT laboratory in KTH so learning how to work collaboratively in a laboratory will also be one of the objectives.

---

\[1 \text{[3]}\]
1.2 Limitations
The limitations will be that the system will not be able to regulate the temperature or the flow, the data acquisition system cannot measure multiple flows and temperatures of two different places at the same time. The orifice plate will only be used to measure air flow, no liquids.

1.3 Angle of attack
This subchapter gives an simple overview of each step of the project and how each step will be made, see figure 1.

Figure 1 shows a simple overview of how each step of the project will be done
2 Literature Review

2.1 LabView

LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement systems, test and control by assembling intuitive graphical icons and wires in the way of a flowchart. LabVIEW integrates with thousands of hardware and offers hundreds of libraries built-in functions for analysis and visualization of data, all for creating virtual instrumentation systems. The LabVIEW platform is available on multiple targets and operating systems.

2.1.1 The Graphic Language

The programming in LabVIEW is not done with writing complex syntax code lines. The program is performed using icons, representing functions, interconnected by cables which represent the data stream (a bit in the manner of a printed circuit board with its components and integrated circuits).

The labview program consists of a front panel and a block diagram. The block diagram for a front panel is accompanying program to the front panel. Figure 1 and 2 show general views of Labview front panel and block diagram.

---

2 [13]
3 [7]
2.2 Data acquisition system/interface

Data acquisition means collecting data from different measurements and digitizing the signals for storage, analysis and presentation. Usually the signals that are collected are analog and if they are to be presented on a computer they need to be digitized. To convert these physical phenomenon one must use a transducer that converts a physical phenomenon to an electric signal. Figure 5 shows the general steps of data acquisition. There are different types of transducers that are used to convert different physical phenomenon, for instance thermistors and thermocouples are used for temperature, microphones can be used for sound and pressure transducers are used for flow. These signals are however analog and must be converted to a digital signal. To accomplish this one must use a device that can convert an analog signal to a digital signal. For this project, Keithley 2701 DAQ module will be used, see picture below.

Figure 4: The Keithley 2701

Figure 5: Showing how general data acquisition works

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[13]
2.3 Sensors overview

Sensors are hardware components that convert physical parameters usually into electrical signals. For example, a thermocouple converts temperature to an output voltage. There are various types of sensors such as temperature sensors, pressure sensors, and flow sensors.

2.3.1 Basic characteristics of sensors’:

The characteristics of a sensor may be classified as:

- Measuring range: Extreme values can be measured by the sensor.
- Sensitivity: Change of the output signal relative to changes in the input signal.
- Accuracy: The ability of the sensor to provide a measurement close to the true value.
- Speed: The sensor’s response time.
- Linearity is the sensitivity gap on the measuring range.
- Resolution: The smallest change in the measurable quantity by the sensor.

2.3.2 Temperature sensors

There are many types of temperature sensors and they are used in many areas both industrial and domestic. They have different characteristics depending on the application, and can be classified into two categories:

- Contact Temperature Sensor:
  Contact temperature sensors come in a variety of types and constructions. Thermocouples, RTD, IC and Thermistors are the most common types of contact temperature sensor.
| Table 1: Summary of advantages and disadvantages of the most common temperature sensors⁶ |
|----------------------------------|------------------|------------------|
| **Thermocouples**               | **Applications**  | **Advantages**   |
|                                 | • Plastic injection molding machinery. | • Self powered. |
|                                 | • Food processing equipment.             | • Simple.      |
|                                 | • Industrial processing.                | • Inexpensive. |
|                                 | • Medical equipment.                    | • Wide temperature range. |
|                                 | • Pipe tracing control.                 |                |
|                                 | • Industrial heat treating              |                |
|                                 | • Liquid temperature measurement.       |                |
|                                 | **Disadvantages**                       |                |
|                                 | • Non linear.                           |                |
|                                 | • Low voltage.                          |                |
|                                 | • Least sensitive output vs temperature |                |
| **RTD**                         | **Applications**  | **Advantages**   |
|                                 | • Air conditioning and refrigeration.   | • Stable.      |
|                                 | • Stoves and grills.                    | • Accurate.    |
|                                 | • Textile production.                   | • More linear than thermocouple. |
|                                 | • Plastics processing.                  |                |
|                                 | • Air gas and liquid temperature        |                |
|                                 | measurement.                           |                |
|                                 | • Micro electronics.                    |                |
|                                 | **Disadvantages**                       |                |
|                                 | • More expensive than thermocouple      |                |
|                                 | • Small change in resistance.           |                |
|                                 | • Self heating.                         |                |
|                                 | • Less rugged than thermocouple         |                |
| **Thermistors**                 | **Applications**  | **Advantages**   |
|                                 | • Textile production.                   | • Inexpensive. |
|                                 | • Plastics processing.                  | • High output. |
|                                 | • Petrochemical processing.             | • Fast response time. |
|                                 | • Air gas and liquid temperature        | • Accurate over small range. |
|                                 | measurement.                           |                |
|                                 | **Disadvantages**                       |                |
|                                 | • Non linear.                           |                |
|                                 | • Self heating.                         |                |
|                                 | • Limited temperature range.            |                |

- Non-contact Temperature Sensor: Infrared sensor is a non-contact temperature sensor and is used for detecting substances that emits energy.

### 2.3.3 Pressure sensors

Pressure sensor or pressure transducer is a device for converting differential or variation pressure into an electrical signal for control of pressure in electronic control systems. When the sensor is connected to an electrical source and exposed to a pressure source, an electrical output signal will be produced proportionally to the pressure. The pressure sensor is used especially in the medical technology and in the industrial application.

⁶ [4]
2.4 Thermocouple

Thermocouple is a device for accurate measurement of temperature. There are many different types of thermocouples, made of different types of wire and having different properties.

2.4.1 Etymology and History

From the Greek *therm* meaning heat and *couple* is two things of the same species, but with some differences. The term thermocouple is attested in English in 1890. A thermocouple is a sensor for measuring temperature and was discovered in 1821 by German physicist Seebeck.7

2.4.2 How thermocouple works?

A thermocouple is a sensor for measuring temperature. It is essentially formed of two metal conductors, joined together at one end as it is shown in figure 6. If there is a temperature difference between the two junctions a voltage potential or electromotive force (E=emf) will be generated and the current will flow through the loop circuit. The current will be proportional to the difference in temperature between the junctions. The higher the temperature difference, the higher is the electromotive force (emf) flow in the loop. This called the Seebeck effect.

![Figure 6: Showing a thermocouple circuit; A and B are two different conductors](image)

2.4.3 Characteristics of the thermocouple

A thermocouple is consisted of two conductors (metals or alloys). They are cheap and allow the measurement in a wide range of temperatures. Depending on the properties of the conductors, there are more or less effective thermocouples (a large electric flow for a small temperature difference) and all cannot be used under the same conditions. Table 2 below shows the most common types of thermocouples.

---

7 [16]
8 [6]
Table 2: Most common types of thermocouple

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Materials</th>
<th>Temp.range(°C)</th>
<th>Error +/− (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Copper-Constantan</td>
<td>0-350</td>
<td>1.0</td>
</tr>
<tr>
<td>J</td>
<td>Iron-Constantan</td>
<td>0-750</td>
<td>2.2</td>
</tr>
<tr>
<td>E</td>
<td>Chromel-Constantan</td>
<td>0-900</td>
<td>1.0</td>
</tr>
<tr>
<td>K</td>
<td>Chromel-Alumel</td>
<td>0-1250</td>
<td>2.2</td>
</tr>
<tr>
<td>R</td>
<td>Platinum-13% Rhodium/Platinum</td>
<td>0-1450</td>
<td>1.5</td>
</tr>
<tr>
<td>S</td>
<td>Platinum-10% Rhodium/Platinum</td>
<td>0-1450</td>
<td>1.5</td>
</tr>
<tr>
<td>N</td>
<td>Nickel-14.2% Chromium-1.4%</td>
<td>-270-1300</td>
<td>2.2</td>
</tr>
</tbody>
</table>

2.4.4 Type N thermocouple

In this project type N thermocouples were used. These thermocouples are designed to be used in industrial environments of temperatures up to +1200 °C.

The Type N thermocouple is composed of a nickel-14.2% chromium-1.4% silicon (+) wire versus a nickel-4.4% silicon-0.1% magnesium (-) wire.

2.4.5 Voltage to temperature conversion

Unfortunately, the temperature-voltage relationship of thermocouple is not linear and to convert the voltage reading by the thermocouple to temperature a power series polynomial need to be calculated. Figure 8 shows the relationship between the temperature and the Seebeck’s coefficient which has been empirically developed.

Table 3: Coefficients for some thermocouples

<table>
<thead>
<tr>
<th>TYPE E</th>
<th>TYPE J</th>
<th>TYPE K</th>
<th>TYPE R</th>
<th>TYPE S</th>
<th>TYPE T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel-10% Chromium(+) versus Constantan(-)</td>
<td>Iron(+) versus Constantan(-)</td>
<td>Nickel-10% Chromium(+) versus Nickel-5%(−) (Aluminum Silicon)</td>
<td>Platinum-13% Rhodium(+) versus Platinum(-)</td>
<td>Platinum-10% Rhodium(+) versus Platinum(-)</td>
<td>Copper(+) versus Constantan(-)</td>
</tr>
<tr>
<td>-100°C to 1000°C ± 0.5°C 9th order</td>
<td>0°C to 760°C ± 0.1°C 5th order</td>
<td>0°C to 1370°C ± 0.7°C 8th order</td>
<td>0°C to 1000°C ± 0.5°C 8th order</td>
<td>0°C to 1750°C ± 1°C 8th order</td>
<td>-160°C to 400°C ±0.5°C 7th order</td>
</tr>
<tr>
<td>a₀</td>
<td>0.104967248</td>
<td>-0.048868252</td>
<td>0.226584602</td>
<td>0.263632917</td>
<td>0.927763167</td>
</tr>
<tr>
<td>a₁</td>
<td>1.1789.45282</td>
<td>19873.14503</td>
<td>24152.10900</td>
<td>179075.491</td>
<td>169526.5150</td>
</tr>
<tr>
<td>a₂</td>
<td>-282639.085</td>
<td>-218614.5353</td>
<td>67233.4248</td>
<td>-48840341.37</td>
<td>-31568363.94</td>
</tr>
<tr>
<td>a₃</td>
<td>12695339.5</td>
<td>11569199.78</td>
<td>2210340.682</td>
<td>1.90002E + 10</td>
<td>8990730663</td>
</tr>
<tr>
<td>a₄</td>
<td>-448703094.6</td>
<td>-264917531.4</td>
<td>-860963914.9</td>
<td>-4.82704E + 12</td>
<td>-1.63565E + 12</td>
</tr>
<tr>
<td>a₅</td>
<td>1.10886E + 10</td>
<td>208441314</td>
<td>4.83506E + 10</td>
<td>7.62091E + 14</td>
<td>1.88027E + 14</td>
</tr>
<tr>
<td>a₆</td>
<td>-1.76807E + 11</td>
<td>-1.18452E + 12</td>
<td>-7.20026E + 16</td>
<td>-1.37241E + 16</td>
<td>-2.66192E + 13</td>
</tr>
</tbody>
</table>

9 [16]  
10 [13]
Temperature conversion equation: \( T = a_0 + a_1 x + a_2 x^2 + \cdots a_n x^n \) \hspace{1cm} (1)

Where \( a \) the empirically developed coefficients and \( x \) is the voltage.

Different thermocouples have different temperature ranges. When converting from voltage to temperature one must use the polynomial equation that has been developed empirically. This equation is an approximate of what the temperature would be for a given voltage. Table 3 above shows the coefficients required to calculate the temperature with a given voltage. Figure 7 above shows residual errors after calibrating the thermocouple with a function of polynomials.

Figure 7: The residual error for type N thermocouple\(^{11}\)

Figure 8: The non-linear relationship between the temperature and the Seebeck coefficient\(^{12}\)

\(^{11}\) [11]
\(^{12}\) [5]
2.4.6 Type N calibration equation

The calibration equation is another alternative to convert voltage to temperature and defined as:

\[
(T - T_0) = \frac{P - P_0(v - v_0) + P_1(v - v_0)^2 + P_2(v - v_0)^3 + P_3(v - v_0)^4}{1 + q_1(v - v_0) + q_2(v - v_0)^2 + q_3(v - v_0)^3}
\]

or

\[
T = T_0 + \frac{(v - v_0)(P_0 + (v - v_0)(P_1 + (v - v_0)(P_2 + (v - v_0)q_3))))}{1 + (v - v_0)(q_1 + (v - v_0)(q_2 + q_3(v - v_0)))}
\]

Where \( T \) is the temperature in °C, \( V \) is the voltage measured in millivolts and the rest of the terms are coefficients given in the table below. The coefficients given in table 4 were calculated by performing a least square fit to NIST\(^{13}\) data for type N thermocouples\(^{14}\).

### Table 4: The coefficients used for equation\(^{15}\) (2)

<table>
<thead>
<tr>
<th>Range</th>
<th>Voltage:</th>
<th>Temperature:</th>
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<tr>
<td></td>
<td>-4.313 to 0 mV</td>
<td>-250 to 0°C</td>
</tr>
<tr>
<td></td>
<td>0 to 20.613 mV</td>
<td>0 to 600°C</td>
</tr>
<tr>
<td></td>
<td>20.613 to 47.513 mV</td>
<td>600 to 1300°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>( T_0 )</th>
<th>( V_0 )</th>
<th>( p_1 )</th>
<th>( p_2 )</th>
<th>( p_3 )</th>
<th>( p_4 )</th>
<th>( q_1 )</th>
<th>( q_2 )</th>
<th>( q_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-5.9610511E+01</td>
<td>3.1534505E+02</td>
<td>1.0340172E+03</td>
<td>1.6385664E-01</td>
<td>6.2600036E-02</td>
<td>-2.5351881E-02</td>
<td>1.7088177E-06</td>
<td>11 ([12])</td>
<td>14 ([11])</td>
</tr>
</tbody>
</table>
2.5 Orifice plate

Before one starts to do flow measurements it is vital to empirically calibrate the equipment so that a standard can be used when measuring other quantities (1).

There are different ways flows can be measured; mechanical flow meters, pressure flow meters and optical flow meters are the most common ones. For this project, differential pressure based flow meters will be used namely the orifice plate which is a part of a subgroup that consist of the venturi flow meter and the flow nozzle. The principle of an orifice plate is based on the venturi tube that was invented by Italian physicist Giovanni Battista Venturi. The orifice plate is used to measure the static pressure difference between the upstream and downstream sides. The pressure difference occurs from the contraction, see figure 9.

![Flow](image)

Figure 9: An overview of a pipe that has a contraction in the middle which results in a pressure difference

The contraction increases the speed of the flow according to the laws of fluid mechanics which decreases the static pressure, so the static pressure is lower after the plate than it is before the plate. This pressure difference can either be measured empirically with a “u shaped pipe” in which a fluid with higher density is used where you can see that the fluid is not “equally distributed” in the pipe because of the pressure difference. You can also connect the pipes to a pressure sensor.

The ideal flow can be given by the equation:

\[
Q = A_2^* \sqrt{\frac{2\Delta p}{\rho}}. \tag{3}
\]

However, the vena contracta which can be seen in figure 9, has not the same diameter as the hole in the orifice plate. The vena contracta has the smallest diameter of the stream and the fastest velocity. To compensate this, a coefficient has to be added to the equation which is the discharge coefficient \( C_d \). This coefficient is a relation between the ideal flow and the real flow\(^\text{17} \). \( A_2 \) denotes the area of the hole from the orifice plate.

---

\(^{16}\) [15]  
\(^{17}\) [10]
Since the fluid is compressible, when it passes through the orifice it will change its shape and an expansibility factor $\varepsilon$ has to be added to the equation. If the fluid is liquid the expansibility factor is $\varepsilon = 1$ otherwise it is $\leq 1$.

The actual flow rate is given by the equation:

$$Q = A_2 \cdot C_d \cdot \frac{\sqrt{2\Delta p}}{\rho \cdot \left(\frac{d_2}{d_1}\right)^4}$$  \hspace{1cm} (4)$$

The venturi flow meter has the same characteristics as the orifice plate since the orifice plate was developed from the venturi flow meter. The biggest difference is that the pressure drop is not that big if the angle at the diverging part $\theta_2$ is small enough see figure below. Venturi tubes can be found in gas, oil and petrochemical industries.

![Figure 10: Showing a venturi flow meter with shorter converging part and the longer diverging part](image)

The flow nozzle is a sort of a mixture of the venturi tube and the orifice plate. It consists of a tube in the pipe that has about the same diameter as the vena contracta see figure below. Flow nozzles are often used in high velocity applications.

![Figure 11: Showing a tube with the flow nozzle in the middle](image)

\[18\] [9] 
\[19\] [20] 
\[20\] [1] 
\[21\] [18]
3. Methodology

The initial phase of the project consisted of familiarizing oneself with Labview and studying the transducers that were to be used in the project. Two different transducers were used, a thermocouple for temperature and an orifice plate with a pressure transducer for the flow. The transducers generate an analog signal, which needs to be converted into a digital signal in order for the computer to be able to read it. An analog to digital converter was used to solve this problem.

Figure 12 shows a detailed overview of how the whole project was done and how the whole system was designed from creating an electrical circuit with the transducers to how the interface was developed.

To design the system, one must learn how to use Labview. There are many tutorials on the net on how to design different systems and how to run different simulations on the program. Once these simulations are mastered, one can start doing real measurements of the temperatures on the thermocouples using Labview.

The thermocouples were placed inside a combustion chamber that was off and the other end was connected to the DAQ module. The DAQ module has two cards in which the wires of the thermocouples can be connected. Figure 13 and 14 shows how the thermocouples were connected.
Each wire is connected to a specific channel that Labview recognizes and the user can modify the program to read the values that is the most interesting. The voltage that is generated by the thermocouples has to be converted to temperature and Labview does this automatically using either equation (1) or (2).
The orifice plate was placed on a test rig that had been previously used. To measure the flow and pressure one must first calibrate all the equipment so that they give the correct value, the DAQ module is designed to tolerate maximum 5Volts. If this limit is exceeded, the module will malfunction. This was not necessary for measuring the temperature because room-temperature generates millivolts.

To get the flow rate in the pipe generated by the fan two pressure sensors are placed on the orifice plate and because of the contraction in the plate, there will be a pressure difference and the flow is proportional to the square root of this pressure difference see equation (4). An instrument that can convert pressure to voltage will be connected to the pressure transducers and this voltage can be read by Labview. The ratio between the voltage and the pressure is linear in certain intervals. However, the ratio between the flow rate and the voltage is approximately proportional only for a certain interval depending on what type of pressure sensor is used and how high the value for Δp is. A table can be made for some specific values for the voltage, pressure and the flow rate. With this table, a conversion factor will be used to convert the voltage that is given to Labview to flow. This coefficient is not accurate and it is linearized for a certain interval.

The actual flow rate can be either calculated with equation (4) or it can be measured with a flow meter.

The system was designed by using examples on Labview and modifying them so that they can satisfy the objectives.

![Figure 15: Showing a block diagram for collecting both the temperature data and the flow data](image)

Both the wires from the thermocouples and the pressure transducer are connected to the same module so that the user can see the variations in temperature and flow in the same interface.
3.1 Connection with DAQ module

There are many ways you can connect the DAQ module to the computer. USB, PCI, or TCP/IP are the most common ways\textsuperscript{22}. The module used in this project was connected with TCP/IP through Ethernet connectivity. There are many advantages to connect the module via Ethernet, some of them are:

- No long cables are needed to connect the module to the computer
- The user can control the system anywhere around the globe if the local network is connected to the internet.

\textsuperscript{22} [3]
4. Results and Discussion

4.1 Result

The pressure transducer that was used had the operational range from 0 to 25bar and gave the output voltage from 0 to 10Volts. This means that 1bar gives 0,4Volts. The corresponding pressure is inserted in equation (4) to get the flow. The table below shows the relationship between the voltage, pressure and flow.

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Pressure (bar)</th>
<th>Flow (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,4</td>
<td>1</td>
<td>0,235</td>
</tr>
<tr>
<td>0,8</td>
<td>2</td>
<td>1,33157</td>
</tr>
<tr>
<td>1,2</td>
<td>3</td>
<td>3,6693</td>
</tr>
</tbody>
</table>

The coefficient was calculated by taking the flow and dividing it with the voltage. Table 5 shows how the coefficient changes with increasing voltage and pressure.

<table>
<thead>
<tr>
<th>Flow/Voltage</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,235/0,4</td>
<td>0,5875</td>
</tr>
<tr>
<td>1,33157/0,8</td>
<td>1,6644625</td>
</tr>
<tr>
<td>3,6693/1,2</td>
<td>3,05775</td>
</tr>
</tbody>
</table>

The thermocouples were connected to the heat chamber and the Keithley module, the Keithley module was in turn connected to the laboratory computer through Ethernet. The thermocouple generates an analog signal because of the temperature in the chamber and this signal is converted to a digital signal with the Keithley module which the computer recognizes. Figure 17 shows how the temperature is acquired from the heat chamber as an analog signal and is converted to a digital signal which can be read by the computer. The red color represents that the signal is analog and the green color represents that the signal is digital.

Figure 16: Shows how the electrical signal is transferred to the computer

Figure 18 shows how the flow is acquired by generating a pressure difference with the orifice plate and this pressure difference is converted to voltage with the pressure transducer. This voltage is an analog signal and it needs to be digitized for the computer to be able to read it. Same process as for the temperature is applied to convert the analog signal to a digital signal. The wine-red color represents that the orifice plate generates a pressure difference.

Figure 17: Describes how the flow is converted to an electrical signal which and transferred to the computer
The interface has been designed to be as readable as possible. There were six thermocouples connected to the channels in the Keithley module. Their values can both be seen in the XY Graph and in the temperature data. The temperature chart can be used to see how the temperature varies with time. These data can be stored and saved as an excel file by right clicking on the chart. The user can choose from the channel list which thermocouples should be seen on the graph. With the GUI the user can also choose what type of thermocouple should be measured. All of this can be seen on figure 19 which shows the GUI.

Only one orifice plate was used to generate pressure which in turn is used in equation (4) to get the flow and consequently only one channel is required to get the data flow. If the user wishes to get more data from different signals the user can simply add the channels that signals are connected to in the card. The flow chart shows the user how the flow changes with time and to store this data with the same method as with the thermocouples.
4.2 Discussion

The project was made with some limitations, the transducers that were used to measure the temperature are not linear when converting from voltage to temperature and empirically developed equations were used to convert the voltage. There are other transducers that can measure the temperature and that are linear as well, these are called RTD’s. If RTD’s were used the conversion from voltage to temperature would be 100% accurate. The module that was used to convert the analog signal to digital signal was Keithley 2701. The module uses a card in which you can connect the thermocouples through a wire and there is a possibility that there can be interference in the wire or in the card compared to if a thermocouple with a USB port was used instead. The card type is 7706 and its accuracy decreases with time23.

The flow rate is not linear to the pressure difference and this makes it difficult to find a coefficient to convert the voltage to flow see table 5. The coefficient used was roughly approximated in a certain interval because the value got greater for a higher pressure difference. There are orifice plates that can both measure the pressure difference and the flow, these are however expensive and it would destroy the purpose of the project which is to learn, develop and use different methods to acquire and measure different signals.

When the calculations were made the corresponding coefficient were checked for each bar. To find some linearity between the pressure and flow perhaps the intervals should be smaller than 1bar.

4.3 Conclusion

With the Graphical User Interface the user can record and store data for flow and temperature. An electrical circuit was made to transfer the analog signals generated from the thermocouples and the pressure transducer to the Keithley module which converted the analog signals to digital so that they could be read by the computer. Six channels were used to acquire the temperature from six thermocouples and one channel was used to acquire the signal from one pressure transducer. All these seven signals were assembled in one DAQ module, the Keithley 2701 with card type 7706. Because all the signals were in one module, the user can monitor both the temperature and the flow.

Labview was used to design the system with block diagrams and wire connection which resulted in the development of the user interface.

4.4 Future studies

For further studies on the area development of a GUI could be to design the system for controlling and regulating different quantities from different transducers instead of just recording and storing data24. The module that was used could only read signals from one system at a time. In figure 16 the right part acquires the temperature and the left part acquires the flow, the module could only process first the temperature signals and then the flow signals. With a more sophisticated and complex module processing two or more systems at the same time should be possible.

The card which the module uses has a certain frequency of how fast it can process the systems. It is fast enough detect for instance temperature differences inside an engine when air and fuel is

23 [8]
24 [2]
compressed, however it is not quick enough to detect changes in temperature, pressure etc. at a molecular level.

The relationship between the pressure difference and the flow should be looked into deeper to develop a model or an equation that has a higher accuracy that you can calculate by hand just like with thermocouples.
5. References


Appendix A: Pictures of instruments/equipment used during the project
Appendix B: block diagram and control panel from the LabVIEW