

Major Project Report

by Leslie Phillip Flipping

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Major Project Report: M3X8645

*Design and Implement a method and/ or system to enable the
moisture sampling/ testing of RDF fuel during its drying
process.*

By

Les Flipping- P144245

Supervisors: Dr Gareth Jones & Dr Gary Jones

Projected submitted as part of the requirements of the BEng
(Hons) Electrical & Electronics.

April 2016

DECLARATION

I, ...Leslie Phillip Flipping..... declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

Signed :

Date : 21/4/16.....

FORM OF CONSENT

I Leslie Phillip Flipping..... hereby consent that my Project, submitted in candidature for the BEng (Hons) Electrical & Electronics Engineering degree, if successful, may be made available for inter-library loan or photocopying (subject to the law of copyright), and that the title and abstract may be made available to outside organisations.

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Date : 20/4/16.....

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Abstract

The following report documents a work based BEng major project centred on moisture content of waste derived fuel (RDF) and providing a solution to obtaining this data within the waste and recycling industry. There are no specific systems on the market that provide a solution to this issue and overcome the restrictions of the application; the project objective is to provide this solution. The project has researched the field of interest – moisture measuring and evaluated systems and methods that are available for other applications. The background research applied has identified the methods available for measuring moisture content and the various sensors types available. A system specification has been created and a PIC microcontroller based system solution designed. The system has been schematically designed using Proteus software. The system has a data logging facility with a programmed microcontroller coupled with a LCD display and means of obtained the data logged to external sources via a PC. The system ran for an 11 day cycle as per the treatment process to which the system was applied. The data collected during this test period was analysed with conclusions drawn. The project conclusion has deduced that the design is successful in achieving its main objective to design a system capable of measuring the moisture content of RDF and the system is fit for purpose within its applied environment. The system physical build encountered a number of issues including power supply issues, LCD interfacing issues and RS232 data transmission issues, despite extensive testing and modifications these issues are ongoing. The evaluation of the design has highlighted a number of improvements that can be made to the system with a view to improving the initial design and overcome issues with the build but also varying its application to other industries and environments for future developments.

Contents Page

Chapter 1: Introduction, Background, Outline & Planning

- 1. Introduction**
- 2. Background**
 - 2.1 *Personal Background*
 - 2.2 *Project Background*
- 3. Project Title/ Overview**
 - 3.1 *Project Title*
 - 3.2 *Project Overview*
- 4. Rationale**
 - 4.1 *Personal rationale*
 - 4.2 *Project Rationale*
- 5. Aims & Objectives**
 - 5.1 *Project Aims*
 - 5.2 *Project Objectives*
- 6. Planning**

Chapter 2: Research & Literature Review:

- 1. Research**
 - 1.1 *Research Philosophy*
 - 1.2 *Research Methods*
 - 1.3 *Research Strategy*
- 2. Literature and Documentation Sources:**
 - 1.1 *Company and Legislative Documentation*
 - 1.2 *University Documentation*
 - 1.3 *Research and Academic Sources*
- 3. Measurement Research:**
 - 1.1 *Frequency Domain Sensor*
 - 1.2 *TDT and TDR Sensors*
 - 1.3 *Neutron Moisture Gauge*
 - 1.4 *Resistance Sensor*
 - 1.5 *Summary*
- 4. Moisture Sampling/ measurement Areas:**
 - 1.1 *Roof Probe Access*
 - 1.2 *Exhaust Duct*
 - 1.3 *Relative Humidity*
 - 1.4 *Summary*
- 5. Current Moisture Sensors Available:**
 - 2.1 *Data Acquisition System Market Research*

Chapter 3: Development Methodology:

- 1. Project Solution PIC Based:**
 - 1.1 *Advantages*
 - 1.2 *Disadvantages*

*1.3 Summary***2. System Requirements:***1.1 Software Requirements**1.2 Hardware Requirements***Chapter 4: Design, Implementation & Testing:****1. PIC Design:***1.1 Data Resolution**1.2 Clock Speed**1.3 Summary***2. Project Design- Data Storage and Data Transfer:***1.1 USB**1.2 SD Card**1.3 RS232 Serial Output**1.4 Internal Chip Program RAM**1.5 EEPROM IC**1.6 Summary***3. System Design Features***1.1 Power Supplies**1.2 Humidity Sensor**1.3 Temperature Sensor**1.4 LCD Display**1.5 Start Button & Flashing LED***4. Circuit Protection Design:***1.1 Power Supply Protection- Decoupling Capacitor**1.2 Sensor Input Protection***5. System Design Layout:****6. System Design- Proteus Schematic:****7. System Design- Program Flow Chart:****8. System Design- Program Code Design:***1.1 Program Setup:**1.2 Internal Clock Speed:**1.3 RS232 Setup:**1.4 Start Button Function:**1.5 Flashing LED:**1.6 EEPROM Chip Setup and Data Recording:**1.7 EEPROM Command Operation:**1.8 LCD Display Interfacing***9. System Implementation- Proteus Simulation 1:***1.1 Initial Compiling**1.2 Test Run***10. System Implementation- Proteus Simulation 2:***1.1 Setting the Data Recording Time:**1.2 EEPROM Memory Store Clear***11. System Implementation- Physical Build:***1.1 PIC Programming**1.2 LCD Display Interfacing**1.3 Moisture Sensor**1.4 Initial Power Up & Testing**1.5 Initial Successes*

- 1.6 Initial Issues*
- 1.7 Power Supply Issues, Fault Finding & Testing*
- 1.8 Secondary Multi- Meter Testing for Power Supplies to System*

Chapter 5: Evaluation

- 1.1 Successful Elements and Outcomes*
- 1.2 Unsuccessful Elements and Outcomes*
- 1.3 What Would Be Done Differently*
- 1.4 Summary*

Chapter 6: Conclusion & Future Recommendations:

- 1.1 Conclusion*
- 1.2 Summary*
- 1.3 Future Recommendations*
- 1.4 Summary*

Chapter 7: Reflection

Reference List

Bibliography

Appendices :

Appendix 1: Site and Plant Pictures

Appendix 2: Humidity Sensor Research

Appendix 3: Moisture Data Acquisition Systems Market Research

Appendix 4: System Components and Parts:

Appendix 5: C- Program File

Appendix 6: H- Program File

Appendix 7: Gantt Chart

List Of Tables:

- Table 1: Sensor Comparison*
- Table 2: Moisture Data Acquisition Systems Market Research*
- Table 3: Clock Speed*
- Table 4: Ram Requirements*
- Table 5: PIC Physical Characteristics*
- Table 6: PIC Comparison*
- Table 7: System Parts List*

List Of Figures:

Figure 1: Proteus Schematic:	56
Figure 2: Code Set Up.....	67
Figure 3: Proteus Simulation.....	68
Figure 4: EEPROM Simulation	69
Figure 5: Recording Time Fine Tuning.....	70
Figure 6: Key Board Hit Feature-Read EEPROM.....	73
Figure 7: Keyboard Hit Feature- Clear.....	73
Figure 8: PIC Programming	75
Figure 9: PICKIT 3 PIC Programming	76
Figure 10: MPLABX Software	76
Figure 11: LCD Display Install	78
Figure 12: Humidity Sensor Cable Mod	80
Figure 13: Initial Power Up & Testing	81
Figure 14: Oscilloscope Testing.....	83
Figure 15: Corrupted Data Transmission	84

Chapter 1: Introduction, Background, Outline & Planning**1. Introduction:**

In order to successfully complete the BEng (Hons) Electrical and Electronic degree programme it is necessary to provide and carry out a major project.

As the assignment title suggests, the following report is a proposal for a major project. This proposal will provide a project title or area of study, personal and project background information, personal and project rationale, provide a list of relevant literature and a review, outline the aims and objectives of the project, identify the research methods to be implemented and construct a Gantt chart of timescales for the project mile stones.

The project proposal in mind is a work based project that will be particular to the fuel preparation plant and the fuel preparation process. The fuel in question is an RDF (refuse derived fuel) that is created from local authority black bag waste. The black bag waste is supplied from Neath and Port Talbot Council (the company's major shareholder) and Bridgend Council. The waste undergoes several shredding processes, FE and non- FE metal separation and bio drying. The end product of the process is a RDF bio- fuel that is used as a fossil fuel substitute mainly by the cement industry. Currently the company provides fuel to CEMEX Cement Works in Rugby and La Farge Cement works in Aberthaw. There is a contract in place with CEMEX for fuel provision of 40,000 Tonnes per annum.

2. Project Background:

2.1 Personal Background:

I am currently studying for my BEng (Hons) Electrical and Electronic Engineering degree part time. I completed my studies for the FdEng Electrical and Electronic degree last year August 2014, which I also studied part time under the previous EU funded scheme. I am employed by Neath and Port Talbot Recycling Ltd (NPT Recycling Ltd) a company for which NPT County Borough Council are the major shareholders. My employer has been supportive in my desire to pursue further and higher education and has maintained this support through the funding of my current mentioned studies. My role at NPT Recycling Ltd is currently as Shift 3 Team Leader and Electrical Technician. Previously I was the shift Electrical Technician but due to the departure of previous Team Leaders the company re-evaluated the role and constructed a new role combining supervisory and engineering responsibility. After a lengthy application process I was the successful candidate and I am now working under the frame work of this new role. My employment tenure is currently at 10 years.

2.2 Project Background:

As highlighted in the introduction, the area identified for the project is the fuel preparation and testing/ sampling its moisture content. Fuel preparation is the final process of the waste treatment, where the material entering the fuel preparation area has been subjected to both FE and Non FE metal separation and three shredding processes to reduce the material to 100mm for bio- drying. The fuel is loaded into tunnels that have a 240 Ton capacity and it then under goes a drying process, originally designed and formerly used for composting, for a period of 11 days. After 11 days the fuel is unloaded and put through its final shredding process where it is reduced to 30mm. Currently it is at this stage where the fuel moisture is tested manually

using an off the shelf hand held device. This is the part of the process that has been identified as a potential issue for the project basis.

3. Project Title/ Overview:

3.1 Project Title:

“Design and Implement a method and/ or system to enable the moisture sampling/ testing of RDF fuel during its drying process”.

3.2 Project Overview:

The solution to the above title would provide a method or system that would allow the fuel preparation team to sample the moisture content of the fuel whilst it is undergoing its drying process/ cycle. This would involve utilising moisture sampling/ testing/ monitoring equipment inside a tunnel that contains around 240 Tons of material that is loaded and unloaded by a 14 Ton wheeled JCB loading shovel. All of the mentioned criteria provide challenges that the project will have to address and overcome. The solution will have to be user friendly, environmentally compliant with the site permit, be compliant with health and safety regulations and requirements and conform to company policies. The solution, if successful, has implications for operational benefits in terms of providing previously unknown data that would assist in the operational decision making process. Currently fuel is sampled in its surface layers after it has been unloaded from the drying tunnels, if the moisture levels are undesirable then the current solution is to blend drier material with the fuel to lower the moisture level. This method involves a secondary process that is time consuming, labour intensive and can sometimes involve utilising card board or paper from the recycle building if there is no dry material/ fuel in the fuel preparation plant. The solution will provide the data during the drying process to enable operational decisions to be made such as to extend the drying period or even cut the period short if the moisture level is at a desired level. There are many influences that can affect the moisture level of the material, its effectiveness and its consistency, these include;

1. Non- uniform material i.e. a black bag may contain any number and quantity of differing items, materials, chemicals and liquids.
2. Due to equipment wear and tear not all tunnels are drying consistently.
3. Weather conditions and seasonal conditions affect the moisture levels of the material as inclement weather can have a dramatic increase in the moisture content of waste material that is delivered to the site.
4. Increased recycling has affected the composition of the material coming to the site, with more householders segregating items such as garden waste, food waste, card board, paper, metals, plastics, glass and textiles at the door step.

4. Rationale:

4.1 Personal Rationale:

The project proposal will provide a challenge not only to utilise and develop current skills but also provide the opportunity for the learning and development of new skills. The project will draw upon both electrical and electronic theories and practices in order to provide a suitable project solution. The project will provide the platform to display personal development and continuing progress through academia.

4.2 Project Rationale:

The scope of the project will provide the opportunity to apply previous and current learned academic electrical and electronic theories, principles and practices and draw upon field experience through employment to successfully apply and implement these skills in a chosen project solution. The nature of the project i.e. being work based provides the opportunity for the employer to benefit from any successes that are made and to have direct involvement in the degree program for which they sponsor. A successful outcome would provide valuable data at a stage of the process where effective decisions can be made. The data collected would potentially have the following effects and benefits on the operation of the drying process:

1. *Drying Time* could be adjusted according to the moisture content data of any measurements or samples taken. The duration of the drying cycle could be extended or shortened (based on the current 11 day drying cycle).
2. *Improved Product Quality* would result from any system improvements in effectiveness and accuracy.

3. *Efficiency* would be improved as fuel will only be submitted to the drying process for as long as is necessary.
4. *Operational Costs* could be reduced with an increase in operation efficiency and the reduction of third party waste introduction (Paper & Card board) with additional transportation costs, handling and labour costs and equipment wear and tear incurred with this method.
5. *Effective planning & Decision Making* would be achieved and increased with additional data at the earlier drying stage.

In essence this list forms the criteria for the justification of the project proposal and the chosen area- moisture measuring/ sampling method/ system. The justification isn't rooted in the exploration of literature but by the real 'live' demands and benefits of a genuine issue that has been identified in employment. The justification is the potential operational and efficiency benefits the project may yield in its successful application.

5. Aims & Objectives:

5.1 Project Aims:

The main aim of the project as the title suggests, is to design a method/ system for which the moisture sampling of RDF (refuse derived fuel) can be carried out whilst it is inside its drying tunnel with the following specifications/ requirements (Sub aims):

- 1) The solution must be accurate*
- 2) The solution must be user friendly*
- 3) The solution must be durable in terms of working conditions i.e. Temperatures up to 50C, dusty conditions, abrasive materials in the waste*
- 4) The solution must have adaptability for possible integration into existing systems or equipment*
- 5) The solution must conform to industry technical standards.*
- 6) The solution must comply with health & safety and environmental legislations including the site permit.*
- 7) The solution must comply and conform to company policies and procedures*
- 8) The solution must be retrievable to overcome loading/ unloading issues.*
- 9) To carry out the project within set time frames in accordance with submission deadlines and academic commitments.*
- 10) The solution must have the scope to satisfy the project document and assignment brief.*

5.2 Project Objectives:

In order to achieve the project proposal aims it will be necessary to set objectives that will highlight the means of achieving the aims. The following objectives have been set as a strategy or method for achieving the project aims, these include:

- 1) Research moisture measuring technology and systems.
- 2) Identify a method or system suitable for the application.
- 3) Develop the identified method into an application that satisfies the proposal specifications/ requirements, applying learned academic engineering principles and techniques.
- 4) Implement/ Install the identified method/ system with view to extracting valuable data from the process i.e. moisture sampling/ measurement.
- 5) Collect data and sample sets from the implemented method/ system and analyse.
- 6) Evaluate project success based upon data analysis, discussing effectivity of design, implementation and application in addressing the requirements of the sub aims in 5.1.
- 7) Conclude all findings and aspects of the project with possible future improvements of the system design.

6. Planning:

In order to effectively plan the project's tasks and requirements, it is important to construct timescales for the various stages of the project. To effectively address the issue of planning and as required by the assignment brief, I have constructed a Gantt chart below to log each main task/ objective of the project with a relevant time scale. Each task, as highlighted below, represents a milestone in the project. I have overlapped the major tasks to take into consideration that some tasks may finish and/ or begin *during* a calendar month and tasks may also be underway in tandem. I have allowed an 8 week review period at the end, where any project snagging issues can be addressed and a full document review and proof reading carried out. The Gantt chart has the following characteristics:

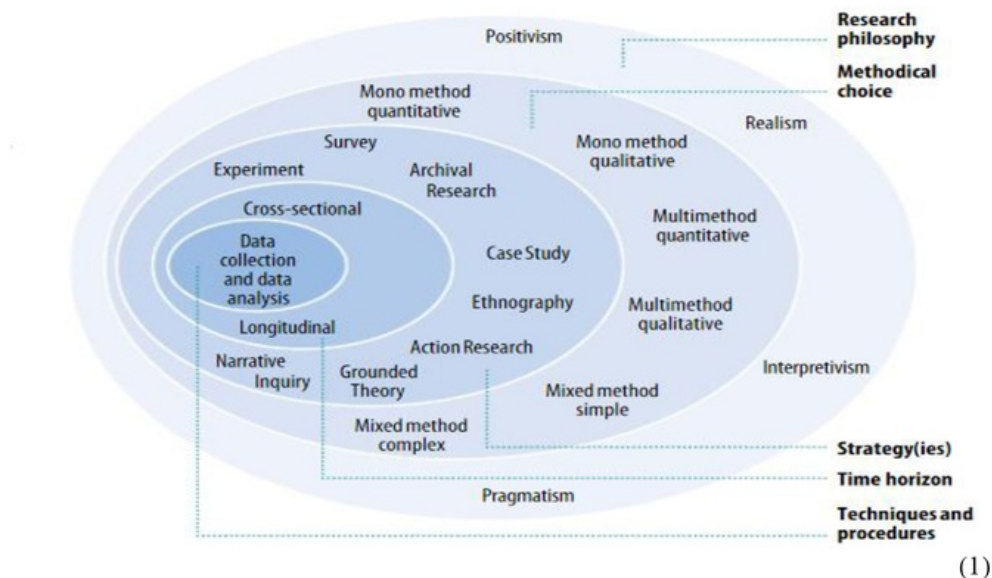
- 1) The Gantt chart is fluid and can and probably will be adjusted many times during the duration of the project.
- 2) The tasks identified are main tasks or project objectives. As the project progresses, sub tasks will be added into these main tasks to identify in more detail what each major step or milestone will entail.

The Gantt chart can be viewed in Appendix 7: Gantt chart of the Appendices document.

Chapter 2: Research & Literature Review:

6. Research:

In order to ascertain the research approach to the project proposal it is necessary to understand the subject, the field in which the subject of the proposal exists and what methods are best suited to arriving at the desired solution and applying it successfully. In order to address this issue and identify my research strategy I will be applying the notion of the 'research onion' (1). The following diagram illustrates the various components that make up the research onion;



1.1 Research Philosophy:

Due to the scientific and engineering foundation to the project, it sits in the positivist research philosophy bracket (1). Although this is not a rigid bracket under which I will categorise the whole project, it is merely positivist in its subject and approach and will reflect positivism through the scientific/ engineering aspect of the project.

1.2 Research Methods:

Initially to research the area that is pertinent to the project subject it will be necessary to carry out secondary research. This secondary research will provide the means to gather relevant background information and data to gain a better understanding of the topic and area chosen for the proposal i.e. moisture measurement and sampling and relevant methods, systems and technology to carry out such works. This secondary research will provide the necessary information as impetus and basis for the formulation for a potential project solution.

Secondary research will include;

1. Topic specific literature and Text books
2. Topic Specific Journals
3. Topic Specific Web sites

Once the project solution has been identified it will then be necessary to utilise primary research methods to implement, analyse and measure the successful outcomes of the project solution. The Primary research documentation will include;

1. Technical data sheets
2. Technical drawings
3. Schematic diagrams
4. Site planned drawings

In order to design a workable solution to the project it will be necessary to apply the highlighted primary research into the implementation of the solution. Electrical and electronic techniques will be applied in the construction of the project solution and the solution application.

1.3 Research Strategy:

In order to design a workable solution to the project proposal it will be necessary to apply the highlighted primary research into the implementation of the solution. Electrical and electronic techniques will be applied in conjunction with the primary research for the construction of the project solution and the solution application.

The research strategy will consist of three areas that will allow the proposal solution to be implemented, collect data, experimentation and evaluation.

1. Document analysis/ review, utilising secondary sources of information to gain an understanding of the project proposal subject and aide in the formulation of the proposal solution.
2. Action Research, where by the project solution will introduce a new method/ or system into the fuel preparation hall that will be utilised as part of the process and have influences on process decisions and outcomes. As the primary researcher I will be an active part of the process and it will involve implementing new practices to improve current practices, a key feature of action research (2)
3. Data collection/ logging will provide the basis for evaluation of effectiveness of the project proposal solution against the set aims and objectives.

As a whole the project in its entirety can be viewed as a longitudinal piece of the research, spanning a year. The project proposal solution will acquire a cross sectional set of data (moisture quantity measurements/ samples) that will provide a basis for data analysis to evaluate the solution effectiveness in addressing its primary aim. This final step of data sampling and analysis is regarded as the research core in terms of the research onion (1). Research and the literature, evidence, academic sources (e.g. journals) and field documentation will provide the tools for the research and the strategy. Research, in some

form will be a fundamental continuum of this projects solution identification, development, implementation and analysis.

7. Literature and Documentation Sources:

Due to the nature of a work based project, there are some literature and documentation types that are essential to this project type and to illustrate the point the list below identifies initially the various and specific literature and documentation sources relevant to the project proposal:

1.1 Company & Legislative Documentation:

- Company documentation (Policies, Work Instructions, Risk Assessments, Site Permit),
- National and European environmental documentation (ISO 14001:9001).
- Health and Safety documentation (OHSAS 18001: HASAW 1974, PUWER, LOLER, RIDDOR, Work Place Regulations 1992 etc.)
- WTT operation manuals, schematic drawings, specification, machine and plant layout drawings (Relevant to existing systems, equipment and machinery in operation in the area)

1.2 University Documentation:

- *M2X8713 Assignment 2 Brief*
- *BEng (Hons) Electrical & Electronic Engineering Project Handbook 2014*
- <http://www.uwtsd.ac.uk/> (*Moodle contains electronic copies of several course related documentation*)

1.3 Research and Academic Sources:

- Course notes and materials from academia undertaken (Referenced where applied)
- Academic and topic specific journals (Referenced when applied)
- Web sources identified (Referenced when applied)

- Subject specific text books (referenced when applied)

This list of relevant literature and documentation sources is not extensive at this preliminary proposal stage, it does however aid in source identification. This list can and will be expanded as the project progresses.

8. Measurement Research:

To commence the research, the fundamental item or piece of equipment that will be vital to any solution to the project is the means of moisture detection via a sensor of some description. Moisture sensors as their name suggests are designed to measure the water content of a given product or medium. There are many types of moisture sensors available in the commercial industrial market, manufactured by a whole myriad of industries and companies. The principles or functions of moisture sensors are where the focus of this initial research will begin and some moisture sensor technologies that have been identified are:

1.1 **Frequency Domain Sensor** can be found in two sensor types

- a) *Capacitance probe* which utilises the dielectric (insulator) properties of the material being sampled to analyse the effect the water content in the material has on the capacitance values being measured. The capacitance measurement can be directly correlated with the change in effect of moisture content and thus providing our desired moisture measurement. This type of technology is predominantly used in the agricultural industries for measuring water content (3).
- b) *Impedance Sensor* which transmits an oscillating signal through a transmission line and into probes which are buried in the medium being sampled. The difference in impedance between the transmission and probe line is what forms the basis for calculating the moisture content of the medium (3).

1.2 **Time Domain Transmission (TDT) and Time Domain Reflectometry (TDR) Sensor**

- a) TDT is a measurement of the impulse added to a transmission line and the length of time it takes to reflect back to the starting point. The moisture content of the

medium would have an effect on this reflection and thus form the basis for the moisture calculations of the medium application

- b) TDR analyses the characteristics of the reflected impulse wave properties to determine the effects the moisture in the medium has had on the impulse and thus the effect it has determines the quantity of moisture present in the medium.

1.3 Neutron Moisture Gauge

This sensor type utilises the neutron moderating properties of water to detect the quantity of moisture present in the medium being sampled (4). The major disadvantage of this method is that it contains radioactive materials in its construction to provide the neutron source and therefore this is a method that I will not be investigating any further, however at this stage it has a valid inclusion.

1.4 Resistance Sensor.

As the name suggests, resistance sensor use the resistance readings between two probes as an indication of moisture content in the medium they are being applied. The basic principle of water conductivity is the fundamental here, as the more moisture that is present, the less resistance between the probes (due to moistures high conductivity properties) and vice versa the less moisture the higher the resistance of the device..

1.5 Summary:

Although the moisture sensor types identified has validity in their function there are some comparisons that can be drawn here at this early stage. From the initial research carried out it is feasible to deduce that although the frequency domain sensor is relatively cheap to construct and has a fast response time, due to the complexity of the electric field technology it uses it requires frequent calibration and is particularly prone to inaccuracy. The TDR and

TDT methods of moisture sensing technology are the more costly option and it for this reason that in bio mass moisture probe design by Mercer University in Florida they used resistance moisture sensors as the basis for their work (5). This sensor choice i.e. resistance sensor is particularly interesting at this early stage and without an in-depth analysis there are some factors that are of interest:

- 1) Resistance probes are cost effective option for moisture measurement.
 - 2) Resistance probes have been used in a waste application before by Mercer University of Florida (albeit their work centred on the actual sensor development) and are a valid option as the product solution method.
 - 3) A resistance method may allow for incorporation into the current temperature monitoring method used in the fuel prep tunnel systems whereby a multi-functional sensor probe maybe a solution option i.e. monitoring moisture as well as temperature.
- This is definitely an area to be explored in further detail in the major project section as there are a lot of advantages to benefit from and disadvantages to be overcome if system incorporation can be achieved.

1. Moisture Sampling/ measurement Areas:

Due to the confines of the drying chambers or tunnels themselves, in that they are encased by foot thick reinforced concrete walls and loaded/ unloaded by 14 ton JCB loading shovels, the plant and process limits the access somewhat. Therefore the project has identified only 2 possible methods of moisture sampling and measuring:

1.1 Roof Probe Access:

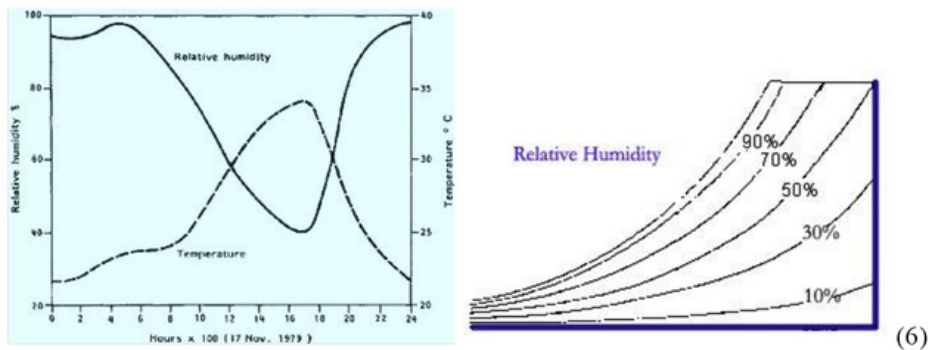
Currently the process drying system, designed by a company based in Holland called Horstmann, has three temperature probes inserted into the waste through access holes in the roof of the tunnels. These temperature probes are vital to the system operation as damper control and fan speeds rely on the feedback from the temperature probes. Therefore at this stage we are not able to interfere with the Horstmann system as this would affect the process and also there is some modification works planned in the near future by Horstmann themselves.

1.2 Exhaust Duct:

An alternative option and the one in which the project will focus on will be the exhaust duct. Here it is possible to measure the moisture content of the air inside the tunnel in relation to the moisture of the material that is inside the tunnel under going the drying process. Due to the heating up feature of the tunnel drying program/ process and the range of temperature it operates at and fluctuates this will need to be taken into consideration. Therefore the measurement will focus on relative humidity:

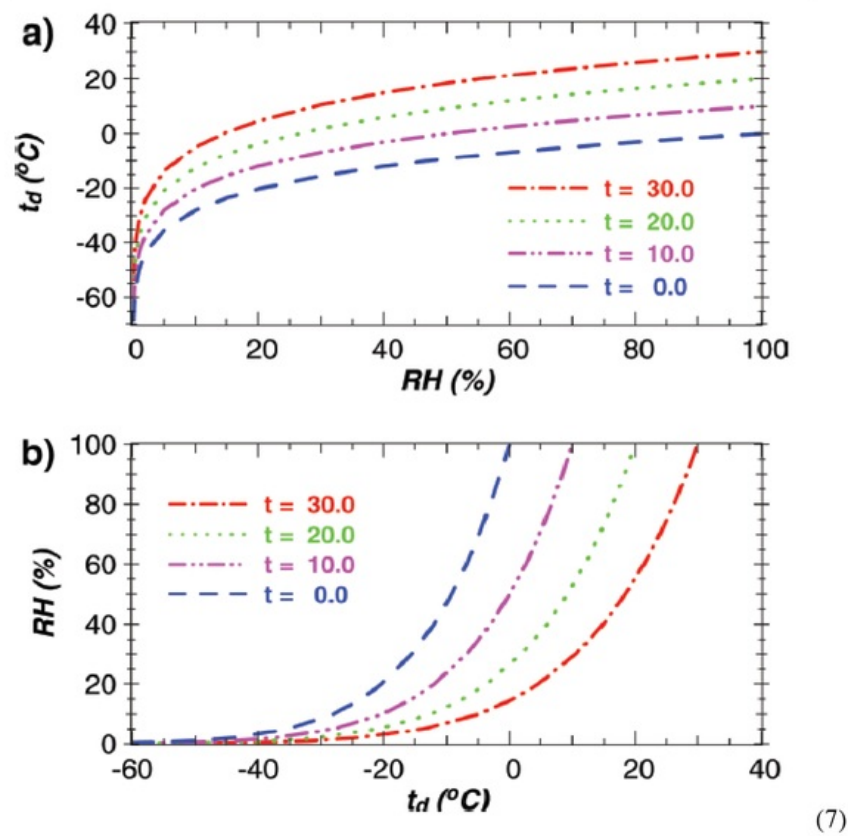
1.3 Relative Humidity:

“Relative Humidity is the amount of water vapour (moisture) in the air compared to the maximum amount that the air could hold at a given temperature.” (6). We have to consider the temperature range of the drying process as this will have an effect on the moisture content of the exhaust gas being measured as the temperature of the material and gas increases and decreases. The following graphs show the relationship between temperature change of air in relation to the moisture content:



As we can see, as temperature of a gas increases its humidity or moisture content decreases. Relative humidity then is a percentage quantity of moisture in a gas that takes into account the moisture carrying capacity of gas in relation to the temperature of the environment. The mathematical representation of this relationship is expressed below:

$$\text{Relative Humidity (\%)} = \frac{\text{Moisture Content}}{\text{Potential content for temperature}} \times 100$$



1.4 Summary:

Due to access issues and being limited to only sampling moisture from the exhaust duct of the tunnels, the system requires a sensor of resistive/ capacitive technology that can sample duct gases. The system therefore will require a probe that can be inserted into the exhaust duct.

The following table summarises research carried out on humidity duct probes/ sensors that are suitable for the system, with further information contained in Appendix 2: Humidity

Sensor Research of the project: Sensor research:

Table 1: Sensor Comparison:

Features	Vaisala DMT152	RHT-3-D	SKU: 314010012	HM1500LF
Voltage	5VDC	0-5VDC	3-5VDC	3-10VDC
Range	0-80%	0-95%	0-100%	0-100%
Consumption	10mA	12mA	12mA	5mA
A/D	Analogue	Analogue	Analogue	Analogue

The sensor of choice for the project system is the MN1500LF as it is easily purchasable from RS =that the company has an account with and it is relatively cheap at £31. The sensor is compact and can be operated at a voltage between 3-10VDC. It is anticipated the system will be operating at 5VDC and can measured between 0-100% humidity. The sensor has an analogue output that can be scaled in respect of the voltage change between 0-5VDC to represent its 0-100% humidity range.

9. Moisture Data Acquisition Systems Research:

In order to assess and choose a method that may be suitable for the project application, it is necessary to analyse the open market and discover what systems are currently available and what has already been developed. Current moisture data acquisition system analysis will provide an overview of where the current technology is in terms of development and the features that have been developed. Although it is not feasible to assume that the project outcome will surpass the current technology, it will certainly have a place in terms of engineering application.

2.1 Data Acquisition System Market Research:

In order to gauge the technology already in the market place for moisture data acquisition systems it is necessary to carry out some wider market research. The research will provide the project with some technological background research that will aid in the design of the project solution. Potential system features can be gleaned from market research of systems already established and developed. All development based projects consider competition and although the project isn't to design a new concept or create a market rival, researching the market will be a useful tool for the project and its design.

The table below outlines the key features of the researched moisture data acquisition systems that are available on the wider market. This will provide some scope for the features that can and maybe incorporated into the project design. Although there isn't a dedicated system for the application i.e. waste or recycling industry, the systems measure moisture and store/ log/ display this data.

Table 2: Moisture Data Acquisition Systems Market Research Comparison:

Moisture Data Acquisition Systems					
Key Features	Lignomat Moisture Log System	HygroTrac Moisture Transmitter	Soil Moisture Data Logger	Model 7120	Vaisala DMT340 Series
Analogue Inputs	4	10 A/D	2	4 A/D	3
Digital Inputs	4	10 A/D	None	4 A/D	None
Removable Memory	None	SD Card	None	USB Interface	None
Serial Ports	None	Yes	Yes	Yes	Yes- LAN/WLAN
Communication	Wireless transmission 1000FT	Internet LAN Gateway	Computer interface via USB	Chandler Software Via USB	Wireless
Power Supply	Rechargeable Battery	3.3V Power Supply	10YR Battery	Mains	Battery
Data Storage	50,000 Readings	2000-3000 Data Sets	1,000,000 Readings	50MB of data storage	Datalogging capabilities
Connectivity	Wireless	Wireless	USB Interface	Wireless	Serial Connection
In Built Sensors	Multiple Transmitters	Multiple Probes	2x probes	4x sensors	3x sensors
Expandable	Yes	Yes	Yes	Yes	Yes
Cost	£1,499.00	£599.95	£200.00	£999.99	£350
Display	HMI	LCD	None	LCD	LCD
Alarm Outputs	Yes	Yes	Yes	Yes	Yes
Others	Remote inputs PLC compatible	Detachable Antenna	Password Protected	Ethernet connectivity	Auto- Calibration
Source	http://www.lignomatusa.com/	http://www.ge-mcs.com/	http://www.omega.co.uk/	http://www.chandlereng.com/	http://fluidic-ltd.co.uk/product/

*Table created using Microsoft Excel.

Further Information relating to the market research can be found in Appendix 3: Moisture Data Acquisition Systems Research.

Summary:

What is obvious from the results of the market research is that every system employs a micro controller of some description, programmed to operate the system and collect data for the end user. Features of note are that the systems have serial connectivity, SD card or USB memory storage, LCD displays, large internal storage capacity, low power consumption and Ethernet connectivity. All of these features would benefit the design and solution to our application, however it would be unachievable to attempt to include all of these features in the project design. That is not to say that some features such as an LCD display, Serial connectivity and internal memory storage would be ideal in the project design.

Chapter 3: Development Methodology

1. Project Solution- PIC Based:

Current moisture data acquisition systems encompass a means of sampling or testing via a sensor with the data being recorded or logged on a data acquisition device comprising of a micro controller. The project solution will be incorporating this same method, whilst the wheel is not being reinvented here, a bespoke system will be custom designed and built to the exact requirements of the project and its application. A micro controller based solution provides the flexibility that lends itself to a custom design. It will be necessary to specify hardware, software and incorporate both simulation and programming software. There are some advantages to a PIC based solution and the include some of the following:

1.1 Advantages:

- 1) **Flexibility:** A PIC based solution provides flexibility for a custom design solution. The system will have a specified measuring device (sensor), with a data acquisition that has been programmed to suit the application.
- 2) **Accuracy:** A PIC based system can be fine-tuned and programmed to ensure accurate measurements are taken that are both valid and usable.
- 3) **Compact:** A PIC based solution will be compact and therefore transportable for sampling at various locations as well as presenting the system for project based VIVAs and presentations.
- 4) **Adaptable:** A PIC based system is easily modifiable and running adjustments and modifications to software and hardware can be made relatively easily and quickly.
- 5) **Reliable:** There is a whole market of PIC based moisture sampling and data acquisition systems available and a whole myriad of companies have developed this

tried and tested method of data acquisition making for a reliable and proven project solution option.

- 6) **User Friendly:** The design will incorporate a LCD screen that will allow plant operatives and technicians to have an accurate method of viewing current and actual moisture measurements that will allow production decisions to be made.
- 7) **Data storage:** Data can be easily stored in a PIC solution with on board EPROM, RAM and expandable memory via EEPROM chips, SD cards and USB sticks.
- 8) **Retrievable data:** Data can be retrieved from the system using RS232 serial connections for PC use, USB downloading via a USB connector and SD card storage. USB and SD options also make the data transportable and allow multiple copies.
- 9) **WIFI:** Although due to time constraints and complexity it is not envisaged that the design will have wifi capabilities, this is still a feature that is available for PIC based systems. Data can be streamed live to a host device or delivered by a network.
- 10) **Portable:** The system has the option of being supplied by batteries which makes the system portable, with the ability of being installed in remote locations or places where there is no immediate power source making the system usable virtually anywhere.
- 11) **Complexity:** A PIC based system has a degree of complexity that provides the scope and opportunity of not only satisfying the project requirements but exceeding these requirements.

1.2 Disadvantages:

- 1) **Complexity:** A PIC based system has a high degree of complexity and the ability and knowledge of programming is essential in building and designing the system.
- 2) **Specialist:** Modifications to the system require rewriting the program and then reprogramming micro controller with the new modified version of the program, this requires specialism and adds further complexity. Specialist programming software is

required such as a CCS compiler and also specialist hardware such as the PICKIT device to programme the chip.

- 3) Specification:** There are virtually endless lists of various microprocessors on the market and careful consideration will be required when specifying the PIC of choice. Features such as connectivity (SD, USB, RS232 etc), memory capacity, RAM, processor speed, ATD conversion options and speeds all add to the specification requirement and will require precise evaluation before the PIC is chosen for the project and its application.

1.3 Summary:

As the prior highlighted analysis show, the PIC based system as a project solution has many advantages to lead to a successful solution to be developed. Although the main disadvantage highlighted is complexity, this indeed is one of the main advantages as it satisfies the project brief and covers the scope of a BEng major project. The level of complexity incorporated into the system will be governed largely by time constraint but it is anticipated that there will be more than enough features included to satisfy the technical requirements. A PIC based system will not only be fit for purpose but ideal for the application intended as it offers the features required for its intended use.

2. System Requirements:

1.1 Software Requirements:

In order to design a PIC based system it is necessary to utilise software for circuit design, simulation and programming. The following software packages will be utilised for this:

- 1) Proteus Design Suite:** Proteus design suite will be utilised for circuit design and simulation of the system operating for testing purposes before the build.
- 2) CCS Compiler:** CCS compiler will be utilised as a help tool and to construct the PIC programme in conjunction with Proteus. Although the actual programme will be constructed and simulated in Proteus, CCS will be utilised in its design.
- 3) Easy PC:** Although at this early stage it is envisaged that the project will not include a printed PCB, it is anticipated that the design and 3D simulation files will be constructed using Easy PC. Although this task can be completed in Proteus, Easy PC has better PCB simulation for this task.
- 4) MPLAB X IDE v2.00:** Software required for installing the PIC software created in Proteus (C-File & H-File) onto the PIC via the Microchip Pick-it 3 device. Without the software and Pick-it device there is no means of downloading the system software onto the chosen PIC microcontroller.

1.2 Hardware Requirements:

Although the hardware specifications will be addressed in the proceeding design section of the report it is anticipated at this early stage that some key hardware will be required, these will include:

- 1) PIC Microcontroller:** The system will require a microchip to enable the system to have a means of running its programme, capturing data, storing data and then to

retrieve the data. The microcontroller will convert the sensor input into the data required and be the 'brain' of the system, processing data.

- 2) **A Moisture Sensor:** A means of measuring moisture and capturing this data for the system. The data is crucial to the system a sensor capable of measuring the variable of moisture is required for the application.
- 3) **Power Supply:** The system will require a power supply whether it be battery operated, mains supply and or an attenuation of the mentioned, the system will need a power source.
- 4) **Memory Storage/ capacity:** The system will need to store data that is retrievable this can be done with chip memory, EEPROM, SD card or USB. A method suitable for the system will need to be chosen.
- 5) **Display:** The system will need to display the data being measured for operational purposes as it is not feasible to download information each time it is required. A visual check can be carried out during shift checks or as and when required via a display such as an HMI, LCD display or LED display.

Chapter 4:- Design, Implementation & Testing

Project Design:

1. PIC Design

In order to specify the PIC microcontroller to be included in the system it is necessary to calculate the resolution of the inputs (sensors), the sensor signal types (digital/ analogue), the number of conversions required, program memory, RAM, Pin numbers, interfacing (SD/ USB) and processor speed. The following section outlines these specifications:

1.1 Data Resolution

Temperature:

Temperature will be measured from a range of -5°C to 55°C. This will give a range of 60 steps which will be measured per 0.5°, therefore the resolution required will be:

$$\frac{60^{\circ}}{0.5^{\circ}} = 240 \text{ Steps}$$

Therefore 8 bits of resolution will be required = 256 steps.

Moisture:

Moisture will be measured from a range of 0% to 100% which will be measured at 0.5% increments giving a resolution of:

$$\frac{100\%}{0.5\%} = 200 \text{ steps}$$

Therefore 8 bits of resolution will be required = 256 steps.

1.2 Clock Speed

Now that the resolution of the data for the inputs (sensors) has been derived, we must consider the clock speed requirements of the processor or PIC to be chosen. Again we must look at the inputs of the system in order to calculate the reading time per input (sensor).

Table 3: Clock Speed

Input/ Sensor	Time/hr
Temperature	60
Humidity	60
Total	120

Readings per second:

$$\frac{120}{60 \times 60} = 0.03/s$$

If we consider that there will be approximately 30 instructions per second then:

$$30 \times 0.03 = 1$$

If we consider there are 4 clock pulses per second then the readings are:

$$1 \times 4 = 4$$

Therefore there are 4 readings per second for our system, 500 KHz would suffice for our system design and however 8MHz will be specified as a minimum requirement in order to

overcompensate for any unforeseen increases in specification or modifications that may be made.

Table 4: RAM Requirements

Inputs	Resolution (Bits)	Resolution (Bytes)
Temperature	8	1
Humidity	8	1
USB	-	2
Total		4

In order to ensure the design is fit for purpose, the calculated RAM is multiplied by 15 to ensure the system has adequate RAM once the sensors have been chosen.

$$4 \times 15 = 60 \text{ or } 64 \text{ Bytes}$$

Table 5: PIC Physical Characteristics

Input	Channel Type (A or D)	Resolution (Bits)	Reading Time (Per Second)	Pins
Temperature	A	8	1/hr- 1/3600s	1
Humidity	A	8	1/hr- 1/3600s	1
USB	-	-	-	3
Power	-	-	-	2
Start Button	-	-	-	1
Stop Button	-	-	-	1
Pin Total				9
Program Memory				16K
RAM				64 Bytes

Table 6: PIC 2.Comparison:

PIC18F2458	PIC18F2553	PIC18F4458	PIC18F4553
USB 2.0	USB 2.0	USB 2.0	USB 2.0
1x SPI	1x SPI	1x SPI	1x SPI
1x UART	1x UART	1x UART	1x UART
48MHz	48MHz	48MHz	48MHz
10 CH, 12-bit ADC	223	214	13 CH, 12-bit ADC
2,048 RAM	2,048 RAM	2,048 RAM	2,048 RAM
28 Pins	40 Pins	28 Pins	40 Pins
10 A/D Channels	13 A/D Channels	10 A/D Channels	13 A/D Channels
1x 8Bit Digital	1x 8Bit Digital	1x 8Bit Digital	1x 8Bit Digital
Timer	Timer	Timer	Timer
3x 16Bit Digital	3x 16Bit Digital	3x 16Bit Digital	3x 16Bit Digital
Timers	Timers	Timers	Timers
£3.99	£4.39	£4.14	£4.61

Data from <http://www.microchip.com/wwwproducts/Devices.aspx?product=PIC18F2458>

viewed 14/12/15 (8)

1.3 Summary:

The PIC chosen for the project design is the PIC18F2458 as it has all the characteristics required by the system. The PIC above more than satisfies the criteria that we have laid out for the project PIC design. The chip has overcompensated in its RAM capacity, ATD conversion (12bit), number of inputs, processor speed. It has SPI (SD) capabilities, USB connectivity and RS232 serial outputs which are a key requirement of the project design. To view the PIC18F2458 please refer to Appendix 4: System Components And Parts.

2. Project Design- Data Storage and Data Transfer:

One of the main objectives of the project is to capture data, store it and then transfer it into a useable format. There are many methods of completing such tasks but we must consider all of the options available and determine the best method of data storage and transfer for the project design considering not only the methods effectiveness at achieving the desired outcome but also what is most feasible within the time constraints of the project itself.

1.1 USB:

The project could incorporate a USB port either a panel mounted socket or a through hole PCB style socket that could be mounted directly to the circuit medium e.g. PCB, Veriboard or bread board. The system microcontroller will need to have USB capabilities to incorporate this facility. The USB facility would provide the ability for not only connecting to a PC or laptop to stream data from the system but could also transfer stored data from the system. The USB option would also allow a USB stick to be attached with up to 64GB of storage space where the system could be writing to the USB stick creating a portable data bank that can be transferred to any number of devices. The system would have to incorporate the relevant code into the system program to allow USB integration and operation and it would contain the following:

The only drawback is that the USB stick can be corrupted, fail, have the data wiped and also be physically lost or removed during key operation periods by unwitting operators leaving room for human error.

1.2 SD Card:

A PIC with SD/ SPI capabilities could provide the project with a writable portable data storage or memory capacity in the form of an SD card. The system would need to incorporate

a SD card holder PCB mountable or SD socket in the enclosure. Similarly to the USB, the SD card could provide the system with 64GB of removable memory storage that can be easily transferred to a PC or laptop with an SD card slot. The relevant code to facilitate the SD card would need to be included in the program design.

1.3 RS232 Serial Output:

An option for the project would be to export data from the system via the RS232 serial output. This could include live streaming of the data via the RS232 or exporting stored data from the system. The RS232 connectivity would need to include the relevant code but also a means of connection either via a RS232 header on the host computer or via a USB adapter that would plug into the PC/ laptop socket.

1.4 Internal Chip Program Memory RAM:

Although unconventional, it is possible to utilise the internal RAM capacity of the chip to store data. The program size would need to be taken into account to ensure the unused capacity is capable of storing the required amount of data created by the system. The program would need to include the relevant code to perform this operation to ensure the system operates correctly and writes the correct data to the correct memory location without interfering with the program memory itself.

1.5 EEPROM Chip:

An EEPROM chip would provide the system with storage capacity for data created by the system. The EEPROM chip size can be chosen to match the requirements of the system but it is good practise to over spec the capacity to ensure any modifications or miss calculations can be catered for. In order to operate the EEPROM chip it is necessary to install 2x 10KOHM pull up resistors on SDA and SCK to power the chip. This will ensure the chip operates when

the system is powered up. The EEPROM chip utilises I2C which is a serial computer bus making it compatible for use with a microcontroller. The Chip or IC is very compact and usually the size of a finger nail, low in cost and has very low power consumption for our system. These characteristics are the reasoning for using this as the chosen method for data storage as it is compatible, compact, and cheap and has low power consumption.

1.6 Summary:

The method of data storage chosen for the project design is an EEPROM IC that data will be written to by the PIC from the sensor outputs at an hourly rate. The system program will initiate reading from the chip via connection to the RS232 serial port of the PIC with use of a TTL lead to a host PC or laptop. Software such as Tera Term will be utilised to read the data being sent to the PC into a readable and useable format where transfer to software such as Excel to create spreadsheets and graphs can be made. The EEPROM chip chosen is a 24LC256 IC that has 256Kbit storage capacity which is more than sufficient for the system demands. The IC operates at 2.5-5.5V which will not require any attenuation or amplification for its supply. Its compatible with the PIC18F2458 microchip chosen for the system and at 64p per chip is very reasonably priced. It is also readily available from RS which is being utilised by the company to purchase the project parts and components. For further information on the EEPROM chip please refer to Appendix 4: System Components and Parts.

3. System design features:

There are a number of key features that require identifying to ensure that the system design is not only fit for purpose but also satisfies the requirements of the application. This section will highlight the design requirements and the chosen method to meet the requirement:

1.1 Power Supplies:

System Supply:

The system will require a power supply and the supply options at the location are as follows:-

- 1) Mains supplied 415V
- 2) Mains supplied 230/240V
- 3) Mains supplied 110V
- 4) Battery power using 12V batteries.

For a purely work based installation the supply choice would have been mains 110V.

However due to the requirements of the BEng project module and the need to present and demonstrate the project, the system power supply will be supplied by mains 230/240V. This will allow the system to be demonstrated for VIVA presentations and also allow the system to be simulated and fine-tuned in the university lab and site workshop. The system will also be running for anything up to two weeks so a limited power supply capacity in the form of batteries will not be suitable for the system design and application.

PIC Supply:

The PIC requires a low voltage DC power supply to run the PIC microcontroller in the range of 2V-5V. In order to reduce our mains supply 230/240V supply, a transformer will be used stepping down from 240V to 5V. Although there will be some losses in the form of heat (it is

inevitable) it will be the most efficient form of voltage reduction in terms of power losses. However to adjust the supply voltage from AC to DC a voltage rectifier will be utilised to provide this. This method chosen will allow the system to be supplied by the required mains 230/240V AC supply but also provide the PIC with an efficient low cost method of power supply. To ensure there is no increase in voltage from rectification a voltage 5V regulator will be used in line with the 5VDC from the bridge rectifier. This regulator will ensure that no stepping of the voltage output from the rectifier will be transferred to the system and damage any components. Please refer to Appendix 4: System Components and Parts.

1.2 Humidity/ Moisture Sensor:

HM1500LF – Relative Humidity Module:

As identified in the research section, the system will measure moisture via the humidity of the exhaust duct gas. This will be carried out via a humidity probe that will be installed in the exhaust duct of the fuel preparation tunnel/ chamber. The humidity probe will be analogue 5vDC and therefore not require any attenuation or amplification for PIC connection. By eliminating signal conditioning it not only simplifies the circuit/ system but also eliminates the number of connections and components reducing cost and likelihood of circuit related problems during build. The 0-5v analogue signal will be coded to provide 0-100% readout by the PIC and provide a useable readout for the operator/ end user. Please refer to Appendix4: System Components and Parts.

1.3 Temperature Sensor:

LM35DZ/NOPB 3-Pin Temperature Sensor 5V:

The humidity probe takes care of the temperature in terms of measuring the humidity of the exhaust gas and waste. The temperature sensor chosen will be installed on the breadboard itself and serve the purpose of monitoring the temperature of the environment where the system is situated. The environment here has been known to reach high levels and cause issues with the tunnel fan inverters and despite forced air fans being installed recently, the temperature sensor will have a purpose in the design. Operators will be able to monitor the temperature of the area where the system is installed and for the first time have an accurate reading of the temperature. This will be particularly useful during the summer months. Please refer to Appendix 4: System Components and Parts.

1.4 LCD Display:***16x2 Transflective STN Blue/ White, 84x44:***

As highlighted in the research the system will require a visual output of the measured variables (Moisture/ humidity and temperature) and this will be done via an LCD display. The display is compact and will integrate perfectly with the system. The display requires a 3.6V supply and to provide this a voltage regulator will be utilised that will regulate the 5VDC supply to the system regulated to 3.6. The display chosen has 16 characters on 2 lines allowing for both variables to display at all times providing the user with instant feedback of the variables being measured. The LCD display has low power consumption and will add a well-lit clear display to the system. The LCD display will be easily mounted to the chosen enclosure via fixing screws/ bolts. Please refer to Appendix 4: System Components and Parts

1.5 Start Button & Flashing LED:

It may be possible that the PIC may stall or suffer running issues during its operation. To provide an indication that the PIC is running and operating correctly an LED will be utilised to provide this visual indication. A flashing LED loop will be written into the program to facilitate this function. The clear enclosure cover will provide the operator and/or technician with a means of viewing the LED and confirming that the PIC is operating correctly.

4. Circuit Protection Design:

1.1 Power Supply Protection- Decoupling Capacitor:

In order to protect the PIC microcontroller from spurious voltage spikes or high loads during connection and disconnection of the power source a decoupling capacitor will be utilised for the PIC supply. The decoupling capacitor will also eliminate any noise caused by the power supply switching and its chosen value will be 100nF as specified by the manufacturers datasheet.

1.2 Sensor Input Protection:

In order to ensure the components and equipment are not subjected to overloading it is necessary to incorporate a form of circuit protection. The design to ensure that this feature is included will utilise 2 components in the form of a Zener diode and capacitor. The diode and capacitor will be connected prior to all connections/ inputs to the PIC microcontroller. The Zener diode will clamp the voltage to the PIC at 5.1V and will be rated to achieve this. This will ensure that should the system be subjected to any voltage spikes then these will not be transferred to the PIC and cause damage to the microcontroller. The capacitor will serve the purpose of filtering any voltage variations as the PIC is designed to receive DC voltages only. Any variations or AC being supplied to the PIC through inputs and sensors will be filtered as the capacitor will block these variations and only allow DC to pass through. By incorporating the two components it provides reassurance for circuit protection by combining 2 different forms of component acting like a failsafe for our PIC. The table below shows the parts list and cost of the system parts and components for the project:

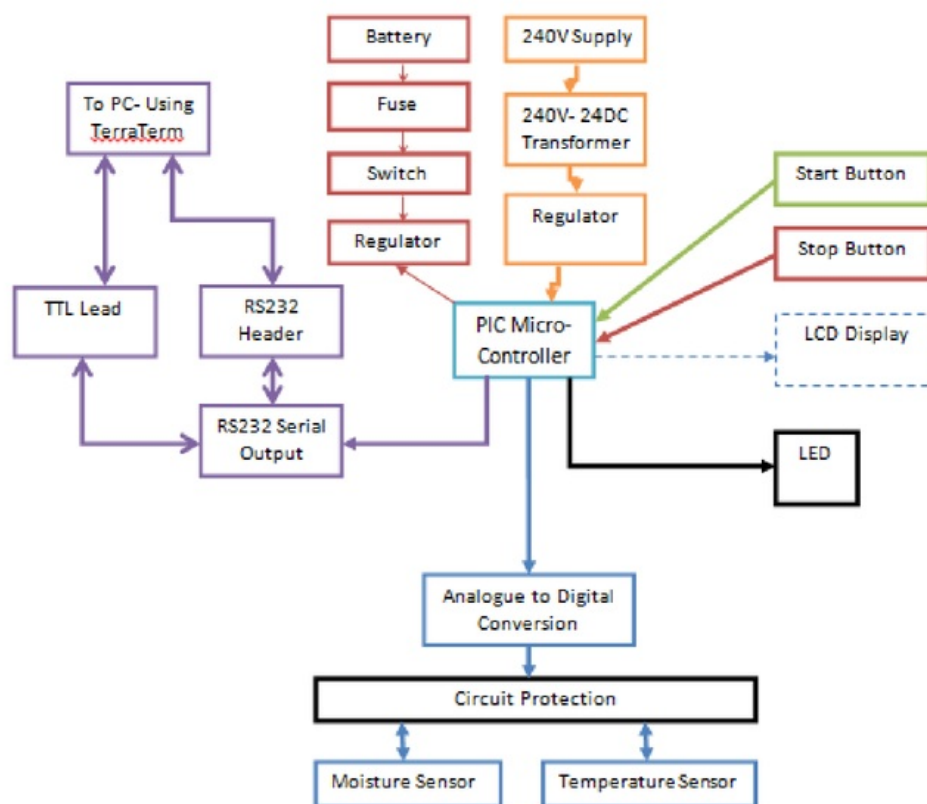
Table 7: Parts List

Item	Cost	Quantity	Total Cost	Source	Part No
PIC18F2458	£3.99	2	£7.98	RS	666-8936
LCD Display	£5.67	2	£11.34	RS	532-6385
Zener Diode 5.1V/ 5W	£0.184	50	£1.84	RS	625-6451
Zener Diode 5.1V/ 0.5W	£0.075	40	£3	RS	544-3597
Temperature Sensor	£1.01	3	£3.03	RS	533-5907
Humidity Probe	£31.69	1	£31.69	RS	893-7247
5V Green LED	£0.208	10	£2.08	RS	228-5584
Push Buttons Green IP65	£4.02	2	£8.04	RS	706-4060
Fuse holder 5x20mm	£0.333	10	£3.33	RS	176-9047
1nF/ 5V Capacitor	£0.56	5	£2.79	RS	214-5931
100uF/ 5V Capacitor	£0.03	100	£2.50	RS	711-1407
100nF/5V Capacitor	£0.01	100	£1.40	RS	711-1396
230V- 5V Transformer	£3.57	1	£3.57	RS	504-694
Transformer Shrouds	£1.28	1	£1.28	RS	503-912
IP65 Enclosure	£11.99	1	£11.99	RS	104-199
EEPROM Memory Chip	£0.648	5	£3.24	RS	454-371
Total			£102.99		

5. System Design- System Layout:

In order to design the system and its components, initially it is necessary to identify all the parts of the system and construct a block diagram illustrating the position, purpose and relationship of all the different parts of the system. The block diagram can then be used to construct the schematic design of the system and all the relevant components added to build the system.

System Block Diagram:



6. *System Design- Proteus Schematic:*

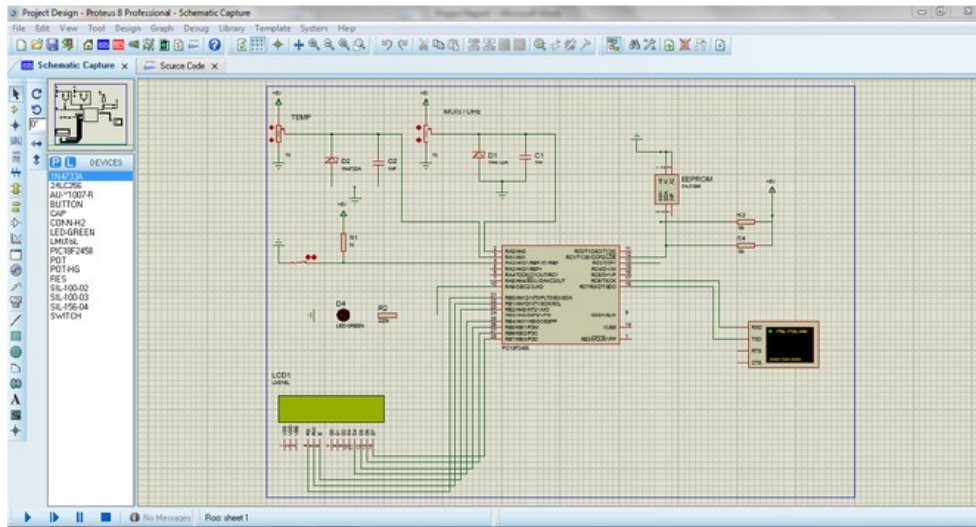
To ensure that the system is functional, fit for purpose and for fine tuning, Proteus will be utilised to design the system its circuitry and simulate the program and its operation.

Components can be utilised, modified and experimented with in the safety of the Proteus simulation software providing a safe and cost free method of design, testing and simulation.

The final Proteus design will provide the project with the system schematic for the physical build. All the components identified in the design will be added to the schematic with the exception of the sensors. These will be replaced by variable resistors purely for simulation purposes where the resistors can be adjusted to simulate the system sensor inputs and simulate the system operation. This method will provide the output to simulate the LCD screen and the also the EEPROM memory chip data recording. Once the design has been constructed and simulated successfully with its desired operational outcome, the physical build can then be carried on the premise that there is a functional simulation to work from.

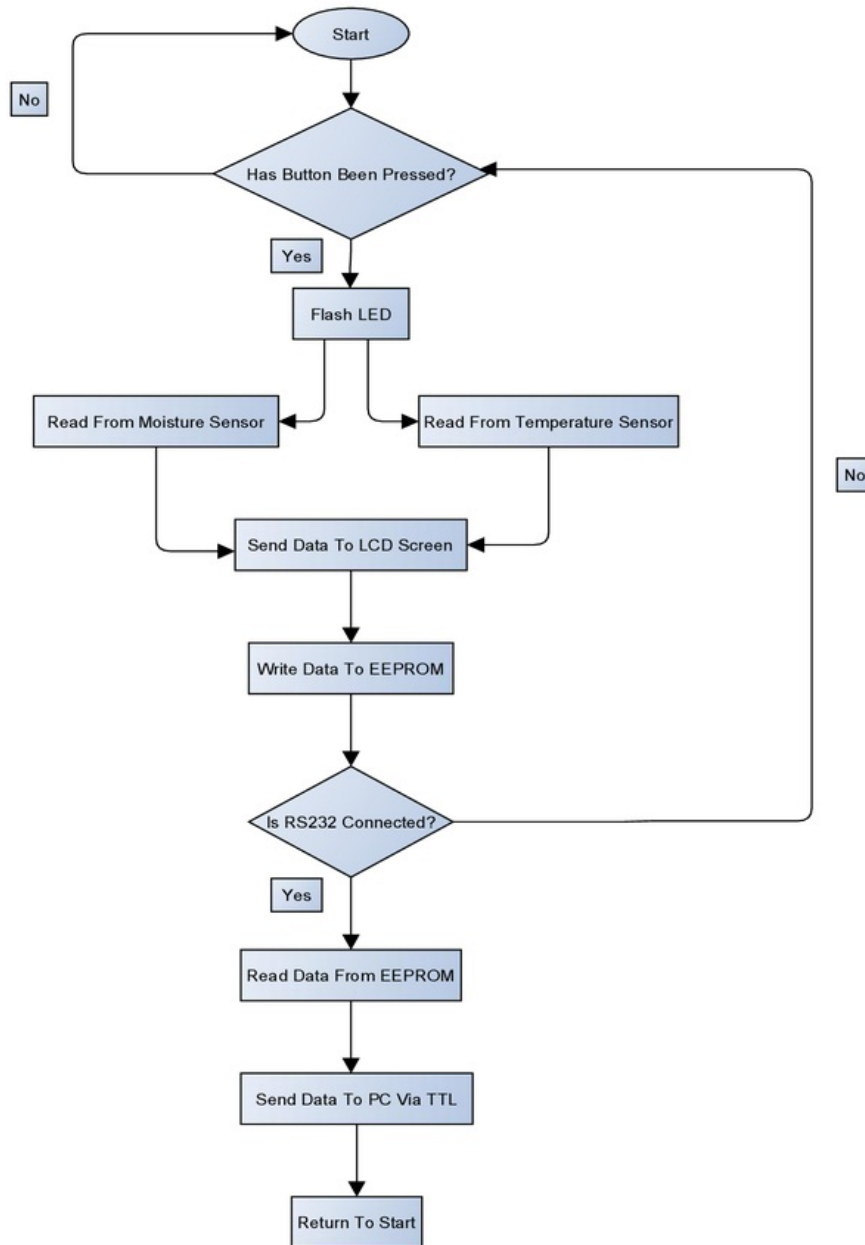
The snip shot below shows the circuit design containing all the components identified for the design, Note the virtual terminal connected to RX and TX is simulating the RS232 connection and ensuring data is outputting here from the system:

Figure 1: Proteus Schematic:



7. System Design- Program Flow Chart:

The flow chart below outlines the instructions required by the program. The chart will layout the structure set for the program outlining the program steps required.



8. System Design- Program Code Design:

In order for the system to operate, it is necessary to design and implement a program to run the system and carry out the tasks or instructions that are required by the system. To design the system operating program CCSC compiler will be utilised as this will provide the necessary features required to design, build and simulate the program. The program can then be added to the Proteus design and compiled if the build is successful. The program can then be simulated and the system operation simulated. Modifications can be made to the program and fine tuning carried until the system is performing all the desired tasks effectively and then the program can be downloaded onto the PIC micro controller.

1.1 Program Setup:

Initially there are a number of protocols that have to be set and initialised in the primary set up of the program.

1.2 Internal Clock Speed:

As discussed previously the chosen clock speed will be set at 8MHZ and this will be more than ample for the system as the readings taken will be hourly and from two sensor inputs. The code to set the internal clock speed is contained in the H-File and is as follows:

```
#use delay(internal=8MHz)
```

1.3 RS232 Set Up:

In order for the system to send data to the RS232 serial port, the RS232 output has to be set. The pins to transmit and receive data also have to be set to accommodate this. As per the Proteus schematic design we can see that the pins of concern are transmit pin= C6 and

Receive pin= C7. This will allow data to be transferred via the TTL lead when connected to the system. The program code to set this feature up is as follows:

```
#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8,stream=PORT1)
```

1.4 Start Button Function:

As highlighted in the design a start button is incorporated in the design to initiate the PIC and to run its program. To incorporate this function a small IF routine is included which will start the PIC running and the internal clock incrementing. A delay will be included in this function to stop the PIC stalling and give it a small window to energise and configure whilst also protecting it from an initial spike, the delay will be 50ms and prove ample for this purpose. The code to carry out this function is as follows:

```
if (!input(Startpin))  
  
    {  
  
        delay_ms(50);        //If start value is 0 move on////Switch  
settling time//  
  
        Count++;            //If start value remains 0 move  
on////Increment Count by 1//  
  
    }
```

1.5 Flashing LED:

As outlined in the system design a flashing LED will be included to give the user a visual indication that the system is running and the PIC has not stalled. The code to perform this task includes a IF routine that is initiated by the internal clock COUNT which is initiated by the start button. The code to perform this function is included below:

```
if (Count)           //Start Button pressed

    {

        //Flashing LED to show PIC running//

        output_high(LED);

        delay_ms(DELAY);

        output_low(LED);

        delay_ms(DELAY);

    }
```

1.6 EEPROM Chip Set Up and Data Recording:

As highlighted in the research section, the system will incorporate a24LC256 EEPROM chip that will provide the system with a data storage facility. As identified in the schematic design, the chip will require two connections to the PIC to allow data to be written to the chip. The SCK or clock pin of the EEPROM chip will be connected to pin RC2 and the SDA data pin of the chip connected to RC1 of the PIC. The program code to assign the pins and initiate the I2C of the EEPROM chip in the program H-File is as follows:

```
#use i2c(Master,Slow,sda=PIN_C2,scl=PIN_C1)
```

This program function also has to be included in the program C-File and to ensure its inclusion the following code performs this function:

```
#include <24256.C>

init_ext_eeprom();
```

The EEPROM chip has 25Kbit of data storage capacity and to ensure the program steps through the memory storage banks the code must increment its data storing and ensure once a piece of data has recorded that the program steps to the next storage byte. The 16bit storage is split into a 2 positions stores, the Low level store of 8 bits and high level store 8 bits totalling the 16bit storage capacity. The moisture sensor will write to the Low level 8 bits and the temperature sensor to High level 8 bits. An IF command will set a flag for the program to perform this task and the steps or instructions for the command will be contained inside its instruction set via the brackets. The program must also direct the location for the data to be recorded from and as outlined in the design this is the two sensor inputs to the system. The program will need to include the pins A0 and A1 for the moisture and temperature inputs to the system. The program will include a +1 feature to increment the data storage. The program code to perform this quite intricate function is as follows:

```
if(timer_flag)

{

    // read the next data position (16bits)

    data_posL = read_ext_eeprom(0);

    data_posH= read_ext_eeprom(1);

    data_pos= (data_posL+(data_posH*256));

    // write moisture to data pos

    write_ext_eeprom(data_pos, Moisture);

    write_ext_eeprom((data_pos+1), Temp);
```

```
// add 2 to data pos and restore  
  
data_pos+=2;  
  
data_posH=data_pos/256;  
  
data_posL=data_pos-(data_posH*256);  
  
write_ext_eeprom(0, data_posL);  
  
write_ext_eeprom(1, data_posH);  
  
timer_flag=0;  
  
}
```

1.7 EEPROM Command Operation:

In order for us to access the EEPROM data obtained from our system then it is necessary to design a feature to do this. You simply cannot just plug in the TTL lead and expect the system to know that it is required to send stored data to the host PC. To provide our system with a means of telling it to extract its stored data the system will incorporate a key board hit function. This function, written into the program code, will allow the user, once connected to the RS232 via TTL to command the system with an assigned keyboard key (in this case S) to extract data. An IF command will contain the whole keyboard hit routine but will include predefined unsigned long and short integers and a CHAR. Once 'S' key has been hit then the

routine will incorporate lines to read the low level data storage from our moisture sensor and read the high level data storage from our temperature sensor. A PRINTF command will be included to send the data to the RS232 serial port from the EEPROM data storage where it can be viewed on the host PC via Tera Term. The following code shows the defined integers and IF routine for this function:

```
unsigned long int Q;

char fetchedbyte;

int command;

int a;

if(kbhit())

{

    command=getc();

    if (command=='S')

    {

        data_posL = read_ext_eeprom(0);

        data_posH= read_ext_eeprom(1);

        data_pos= (data_posL+(data_posH*256));

        a=0;

        printf("data_pos=%Lu\n\r", data_pos);
```

```
for (Q=0;Q<data_pos;Q++)  
  
    {  
  
        fetchedbyte=read_ext_eeprom(Q);  
  
        printf("%u,",fetchedbyte);  
  
        a++;  
  
        printf("\n\r");  
  
    }  
  
    delay_ms(5);  
  
    }    // end for loop  
  
    printf("\n\r");  
  
    }    // end if command
```

1.8 LCD Display Interfacing:

As outlined in the system design, an LCD screen is included in the design to provide the user with a visual output of the data being sent by the sensors. In order to send data from the sensors to the LCD via the PIC the program will need to contain the necessary instructions to perform this task. A GOTO command will highlight the LCD and a PRINTF command send data from the PIC to the LCD screen. The relevant pins will be included to read from with a READ command and delays in between of 10us to give the PIC time to execute each part of the routine. The code to carry out this function is as follows:

```
lcd_gotoxy(1,1);

// lcd_putc(" Moisture and Temp To LCD Display ");

printf(lcd_putc,"Moisture = %u ",Moisture);

lcd_gotoxy(1,2);

printf(lcd_putc,"Temp = %u ",Temp);


set_adc_channel(0);                // select and read channel 0

delay_us(10);

Moisture = (read_adc(ADC_START_AND_READ)/2.55);


set_adc_channel(1);                // select and read channel 1

delay_us(10);

Temp = (read_adc(ADC_START_AND_READ)/2.55);


printf(" Temp = %2u and that value = %u\n\r",Temp,Moisture);
```

9. *System Implementation- Proteus Simulation 1:*

Proteus software not only allows the schematic design to be built but also a simulation of the components and software during operation. The program can be run to operate the schematic design and provide a simulation of the system and components providing the ability to fine tune the system. The screen shot below shows the simulation of the system running; it simulates the sensor outputs on the LCD screen and also the RS232 serial output on the virtual terminal. The simulation will provide vital in ensuring that the software is working and the components chosen also perform well. The Schematic will also be utilised as a wiring diagram for the physical build of the project.

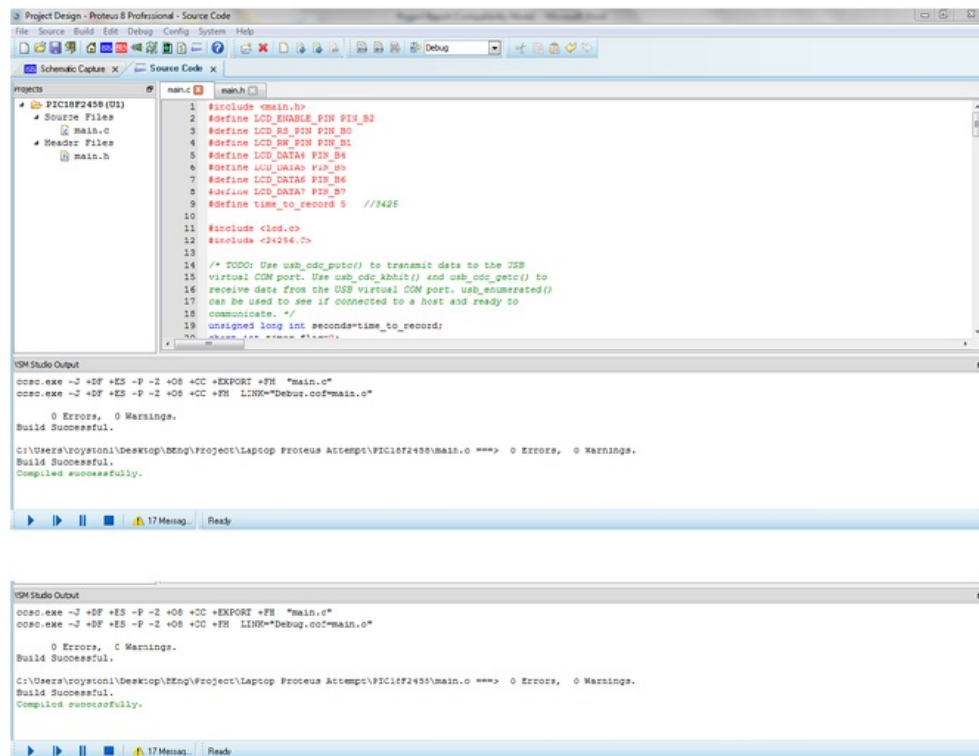
1. Initial Compiling:

Now that the schematic has been constructed and the program been written to operate the system, it is necessary to compile and build the system. This will identify any faults with the program and indicate any coding errors. After working through initial coding errors, including:

- 1) Tabbing issues and misaligned function brackets.
- 2) Semi colon errors either missing or in the wrong place.
- 3) Incorrect use of functions e.g. the KEYBIT function was used incorrectly.
- 4) INT issues, where definitions were incorrectly assigned.

After working through 91 initial compiling errors the build was finally successfully compiled and the snip shot below shows the successful build results for the program code:

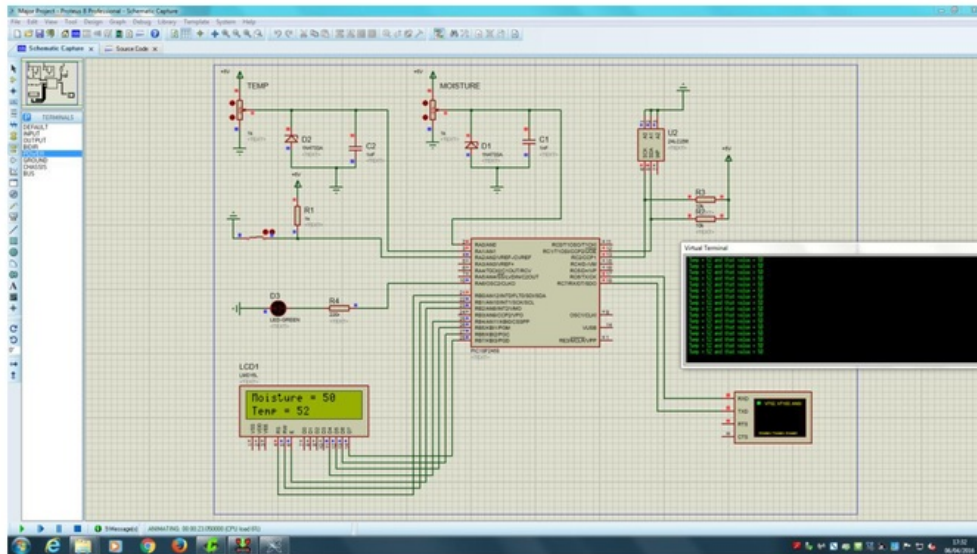
Figure 2: Code Set Up



1.2 Test Run:

In order to prove the build was successful the simulation function of Proteus was used. The Sensor inputs, set as variable resistors for the simulation, provide the input for the LCD screen, the RS232 output to the virtual terminal and the data store for the EEPROM storage. The snip shot below shows the initial simulation:

Figure 3: Proteus Simulation



The system is operating exactly as designed. The start button initialises the PIC, the LED flashes to illustrate the PIC is running simultaneously. The sensor outputs are displayed on the LCD screen and the RS232 serial output with the outputs carrying as the resistors are adjusted accordingly. The snip shots below show the LCD screen and Virtual terminal outputs more closely:



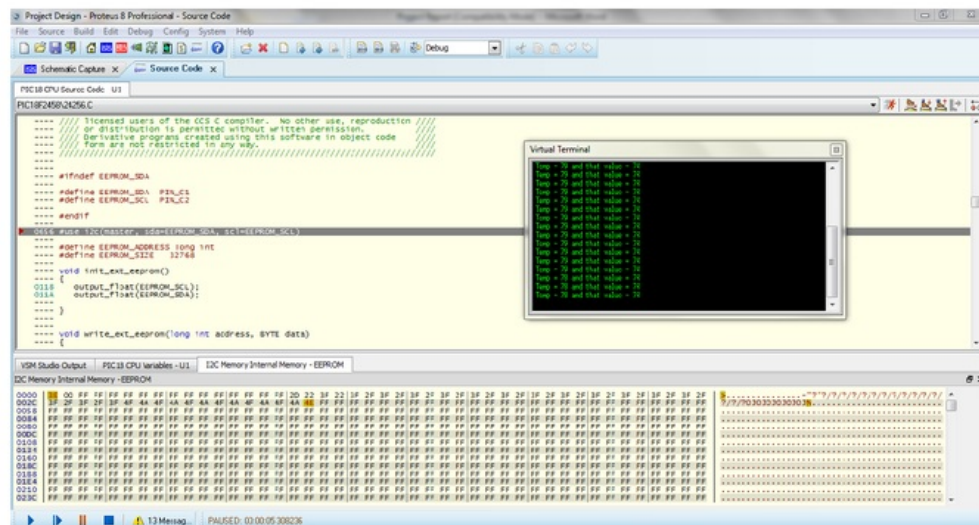
As we can see the system is indeed operating the RS232 function correctly and what is being sent to the system from the sensors as seen on the LCD display is also being accurately sent to the serial port and this will allow the system to successfully extract data to the PC. If we

now pause the simulation it is possible to view the data being sent and stored on the EEPROM chip. For the purpose of the simulation the data recording time in the program H-File has been set at 5s:

```
#define time_to_record 5
```

The following snip shot shows the paused simulation and the EEPROM memory store:

Figure 4: EEPROM Simulation



As we can see the system is writing data to the EEPROM memory store ready for exporting via RS232 via the TTL lead on the physical build.

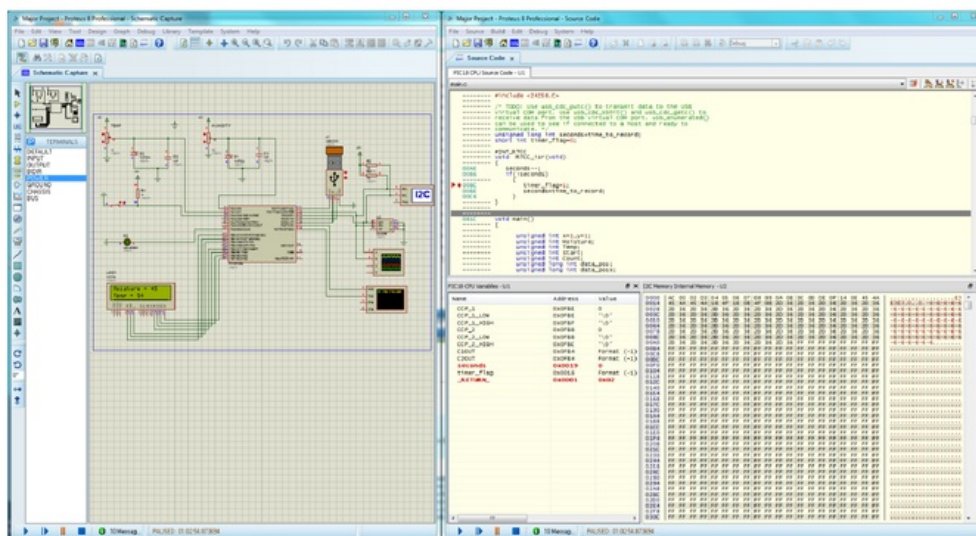
10. System Implementation- Proteus Simulation 2:

1.1 Setting the Data Recording Time:

As outlined in the objectives of the project, the data recording of our system is once per hour. However due to the nature of the PIC operation, there is lag between the set recording time and the actual real time that the recording takes place. This is unavoidable as it is a characteristic of PIC operation. There is a solution though and Proteus provides this through the simulation. A breakpoint can be set at exactly the time a recording in the program takes place which we can then analyse how long the program has run to reach this point and compare it with our objective of 1 hour/ 60 minutes/ 3600 seconds. The following snip shot shows the recorded time once the program has stopped after toggling a program break point at the data record function:

#define time_to_record 3600 (H-File code for a 1 hour data recording)

Figure 5: Recording Time Fine Tuning





We can see that although the data recording time was set for 1 hour or 3600 seconds, the program actually performed this function at 1.0254 hours or almost 3775 seconds. If we now reduce the set data recording time by the amount that it has over ran i.e. 175 seconds, then our fine-tuned recording time is 3425. The following snip shot shows the simulation stopping at the set breakpoint of data record with the new recording time added to the program code:

```
#define time_to_record 3425
```



As the results show the recording time difference has been reduced to just over 8 seconds at 3592 seconds which is far closer to our desired recording time of 3600 seconds. This 8 seconds difference between set recording time and actual recording is quite acceptable for our system design and Proteus has given us this tool for fine tuning our data recording time.

1.2 EEPROM Memory Store Clear:

Although the system is successfully writing data from our sensor inputs to the data store of the EEPROM chip, what has not been considered is how to clear the chips memory to start a new stream of data recording. Currently the system will write data to the EEPROM memory storage and we, in theory are able to access it via RS232 serial connection and TTL.

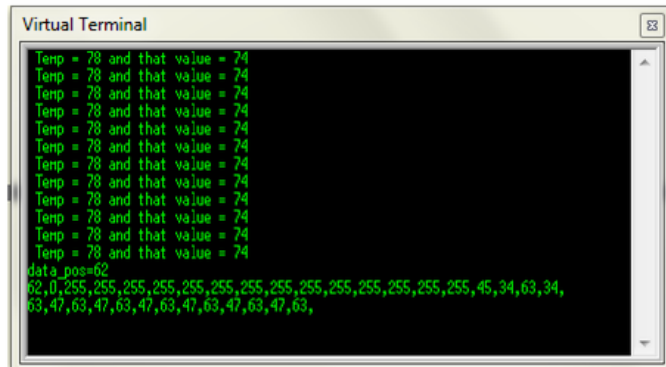
However, it would be helpful that after the data has been obtained, viewed and stored on a host PC that we could then clear the EEPROM memory before returning the system back into service. To enable us to incorporate such a feature we must go back to the program code and add this function. There are a number of ways that the memory can be cleared, such as using a timer loop whereby once a count has reached clear the memory, but a far more user friendly

method is to give the operator that control via a key board hit. Similarly to our command set for data receive by hitting the keyboard 'S' button, we can assign a key and program code to suit to clear the memory store. The key assigned to perform this function is the '#' key and the program code to include this is as follows:

```
if(command=='#')  
  
    {  
  
        write_ext_eeprom(0, 0x10);  
  
        write_ext_eeprom(1, 0x00);  
  
    }  
  
    } // end kbhit if
```

By utilising the virtual terminal on Proteus we can simulate the system responding to the keyboard hit functions and the following snip shot shows this:

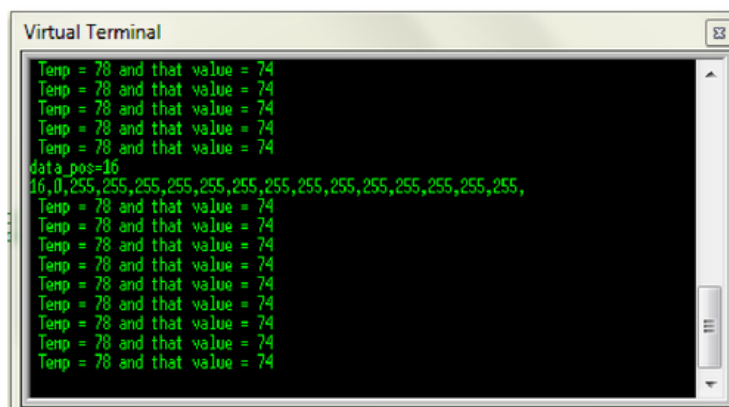
Figure 6: Key Board Hit Feature-Read EEPROM



```
Virtual Terminal
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
data_pos=62
62,0,255,255,255,255,255,255,255,255,255,255,255,255,45,34,63,34,
63,47,63,47,63,47,63,47,63,47,63,47,63,47,63,
```

The snip shot above shows the data being read from the EEPROM store when the 'S' key is hit. If we run the simulation and now hit the '#' key we should see the EEPROM memory being cleared:

Figure 7: Keyboard Hit Feature- Clear



```
Virtual Terminal
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
data_pos=16
16,0,255,255,255,255,255,255,255,255,255,255,255,
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
Temp = 78 and that value = 74
```

As we can see the snip shot shows the memory has been cleared as the data stream is far less after hitting the 'S' key once the '#' key has cleared the EEPROM memory. This additional feature will provide another useful function for the user and ensure the system meets the needs of the user.

Now that the system is operating and simulating as we want it to we can now move onto the physical build of the implementation stage:

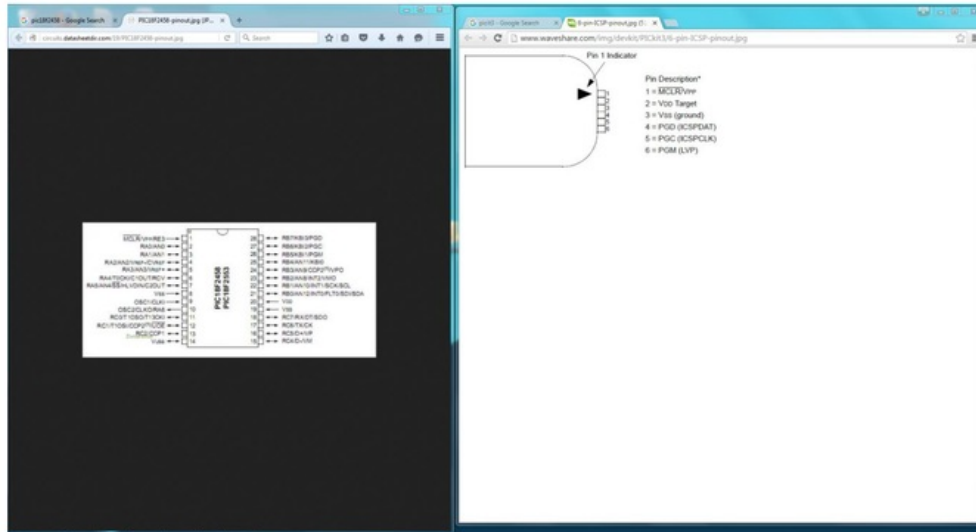
11. **System Implementation- Physical Build:**

Now that Proteus simulation has proved that the program code and system design simulates and performs as desired by the design specifications, we can now proceed with the physical build of the project utilising the components as compiled in the design. Initially the project will be build using a breadboard as the circuit platform as it will be easier for testing and modification purposes.

1.1 PIC Programming:

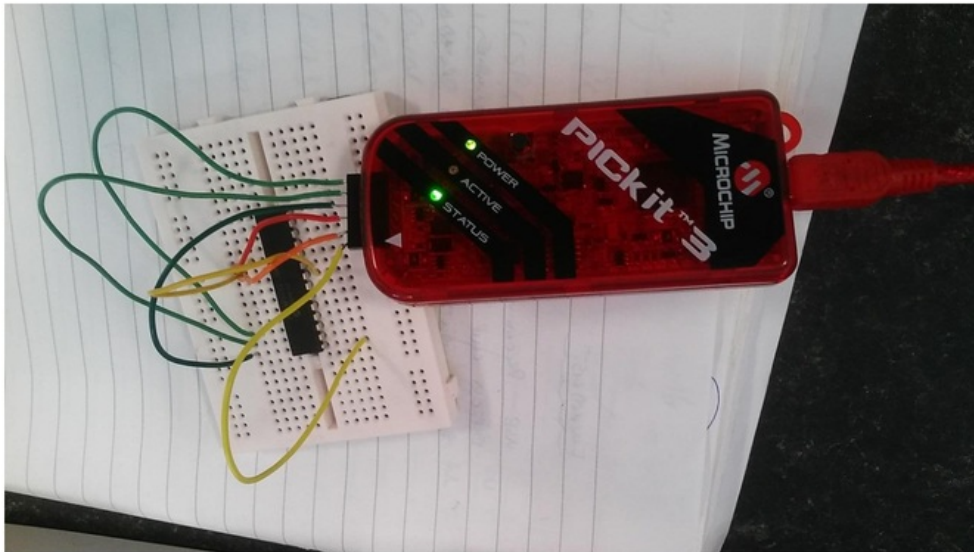
The system operation is carried out by the PIC and it is necessary to download out program design onto our PIC18F2458 microchip. To perform this task the PICKIT 3 device will be utilised along with MPLABXDE software. The software will need to have the relevant PIC18F2458 drivers and software selected to perform the programming operation along with a HEX file of our program code using the release function on Proteus to create this file. It is vital to ensure that the PICKIT 3 device and the relevant PIC pins are connected correctly prior to programming to avoid any damage to the chip. To ensure this is done correctly it is necessary to use PIC18F2458 datasheet for the pinout diagram and also the PICKIT 3 pinout diagram. Both these documents will provide the connections to enable successful connection:

Figure 8: PIC Programming



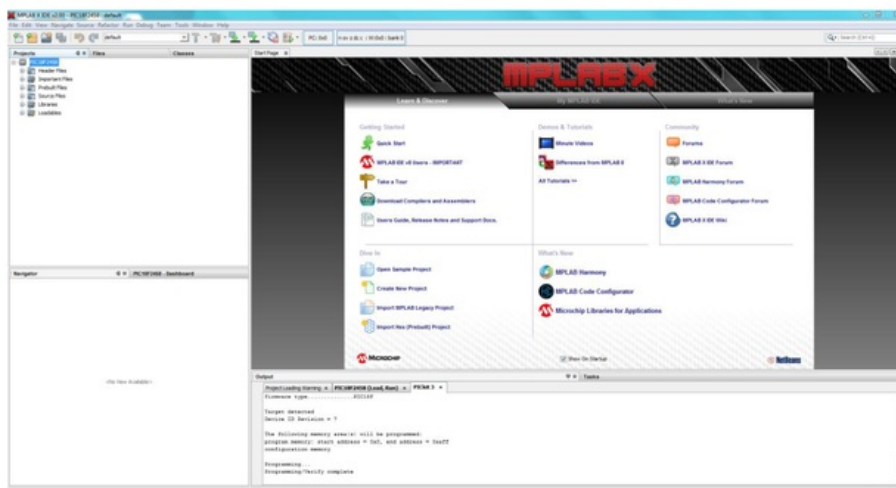
Now that the device has been connected correctly as per the component and device datasheets the program from the HEX file created by Proteus can now be downloaded onto the PIC chip:

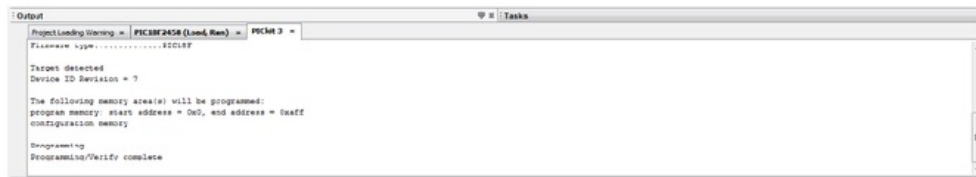
Figure 9: PICKIT 3 PIC Programming



The MPLABXDE software can now be used to download our program onto the PIC:

Figure 10: MPLABX Software





As the snip shows, the programme download to the PIC has been successful and now the circuit can be built.

1.2 LCD Display Interfacing:

In order to mount the LCD screen it is necessary to solder the cables according to the PIC design and datasheet. The data sheet will identify the pins and the C-File of the program code will identify the terminations required for the PIC. The following snip shot shows the excerpt from the datasheet that details the relevant pin connections for the LCD screen:

Displaytech Ltd

LCD MODULE 162B SERIES Version : 1.2 P.9 of 17

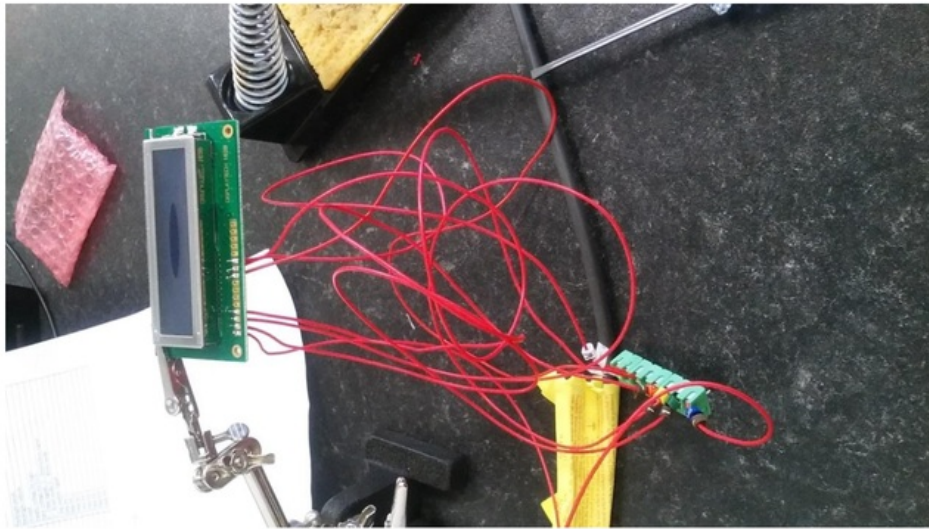
■ INTERFACE PIN CONNECTIONS

Pin NO.	Symbol	Level	Description
1	A	---	Backlight anode
2	K	---	Backlight cathode
3	VSS	0V	Ground
4	VDD	5.0V	Supply voltage for logic
5	VO	---	Input voltage for LCD
6	RS	H/L	H : Data signal, L : Instruction signal
7	R/W	H/L	H : Read mode, L : Write mode
8	E	H, H → L	Chip enable signal
9	DB0	H/L	Data bit 0
10	DB1	H/L	Data bit 1
11	DB2	H/L	Data bit 2
12	DB3	H/L	Data bit 3
13	DB4	H/L	Data bit 4
14	DB5	H/L	Data bit 5
15	DB6	H/L	Data bit 6
16	DB7	H/L	Data bit 7

(9)

The following snip shot shows the soldering process of the cables as per the datasheet:

Figure 11: LCD Display Install



1.3 Moisture Sensor:

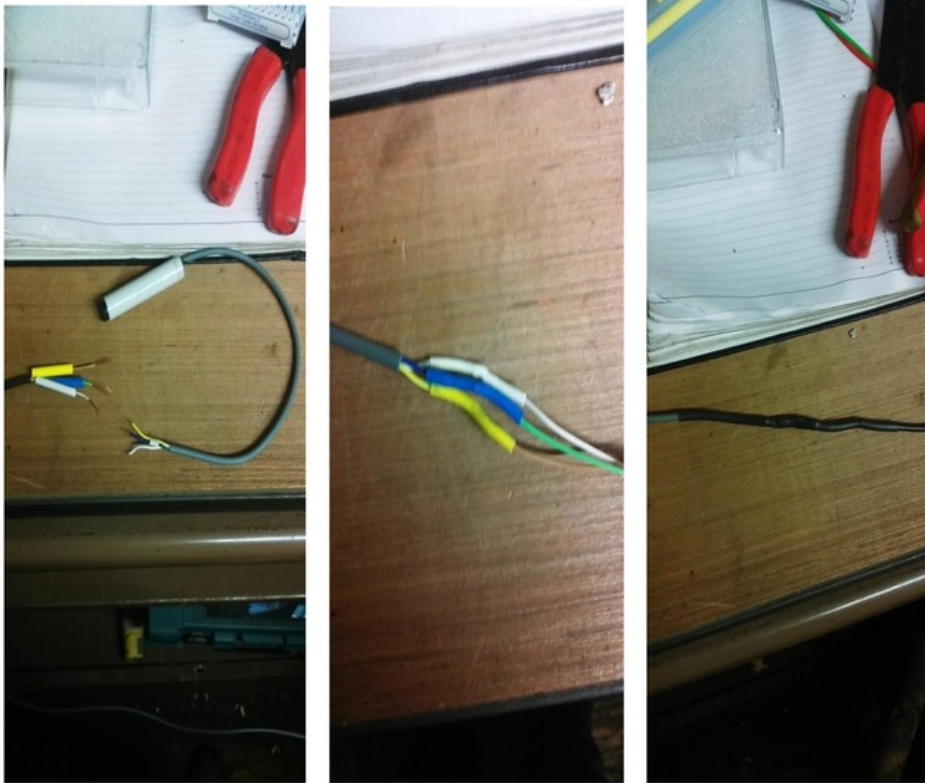
The HM1500LF – Relative Humidity Module is supplied only with a short lead of approximately 10 inches. This is far too short and not fit for purpose for the system as the sensor requires at least 3M of cable to reach the exhaust duct of the tunnels. To modify this it is necessary to lengthen cable and the methods available are quite limited as the cable supplied with the sensor is sealed and moulded to the sensor body itself. The limited options available are:

- 1) Use a Junction box to connect a longer length of cable to the sensor.
- 2) Use a terminal block to extend the cable length with an additional length of cable.
- 3) Solder and heat shrink a length of cable to the existing sensor cable.

A junction box, although a good option for a fixed installation, doesn't provide the system with the ability to be easily transportable, which is a requirement for testing purposes and VIVA presentations. A terminal block alone isn't good practise and would certainly breach

the H&S company policy and Electricity at work act. Therefore the chosen method is to utilise a length of cable of desired length at 5M to ensure there is enough length for use and to implement a solder joint with heat shrink tube to maintain integrity and insulation of the joint. The photos below show the modification being carried out:

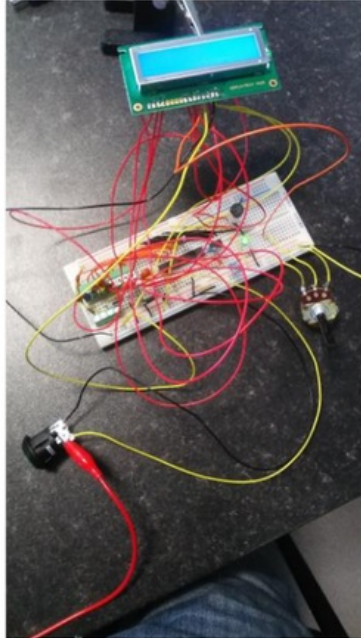
Figure 12: Humidity Sensor Cable Mod



1.4 Initial Power Up & Testing:

Powering up any device, particularly a custom self-build for the first time is always a daunting experience as there is an element of the unknown no matter how often components, terminations and solder joints are checked. The initial power up consisted of utilising a regulated 5V DC supply in a lab environment with a pot connected to the LCD screen to initially ensure that the screen back light voltage could be adjusted accordingly. The initial power up proved to have successes and failures, but nothing excreted smoke initially which was promising.

Figure 13: Initial Power Up & Testing



1.5 Initial Successes:

- 1) The start button for the PIC operated correctly and started the PIC operation, verified by the flashing LED. The start button pressed a second time stopped the PIC, verified by the flashing LED.
- 2) The flashing LED operated when the start button was pressed and then stopped at the second start button press.
- 3) The PIC program successfully downloaded as it allow the start button operation and flashing LED routines to work accordingly showing that it was running as designed at least.

- 4) The LCD display backlight illuminated.

1.6 Initial Issues:

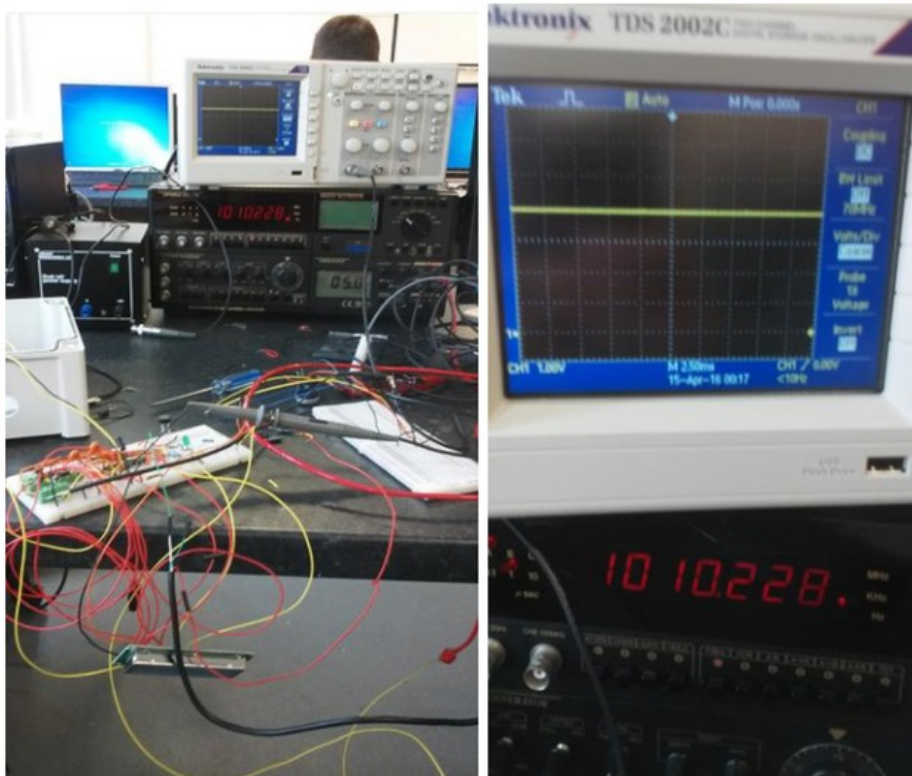
1) The LCD display did not display any data:

In order to begin looking at the issue with the LCD display another check of the code was made and another program build and compile carried out. This proved that the code was indeed correct and without fault. To ensure the system was receiving the data, the moisture sensor was connected. Again the LCD display illuminated but did not output or display any data. To ensure the sensors were indeed giving the PIC the correct output an oscilloscope was utilised for this test:

Oscilloscope Testing (Prove Sensor System Inputs):

In order to test the sensor outputs and prove that the correct inputs are being sent to the PIC and that the sensors are actually operating correctly an oscilloscope has been used. The oscilloscope will provide a display for the sensor outputs which can be verify that they are operating correctly. This is particularly useful as the moisture sensor cable was extended and this test will also test the solder joints carried out on the cable to extend its length. The picture below shows oscilloscope connection to the moisture sensor and the output on the display:

Figure 14: Oscilloscope Testing



To prove the sensor was operating correctly, air was blown onto the sensor module and the voltage line rose to reflect the increase in moisture being detected. Once the air supply was stopped the line gradually returned to its start position as the moisture evaporated from the module. This although encouraging for the sensor operation in proving the sensor was working correctly and the PIC was indeed receiving the correct signal, it didn't offer any explanation as to why the LCD would not display the data.

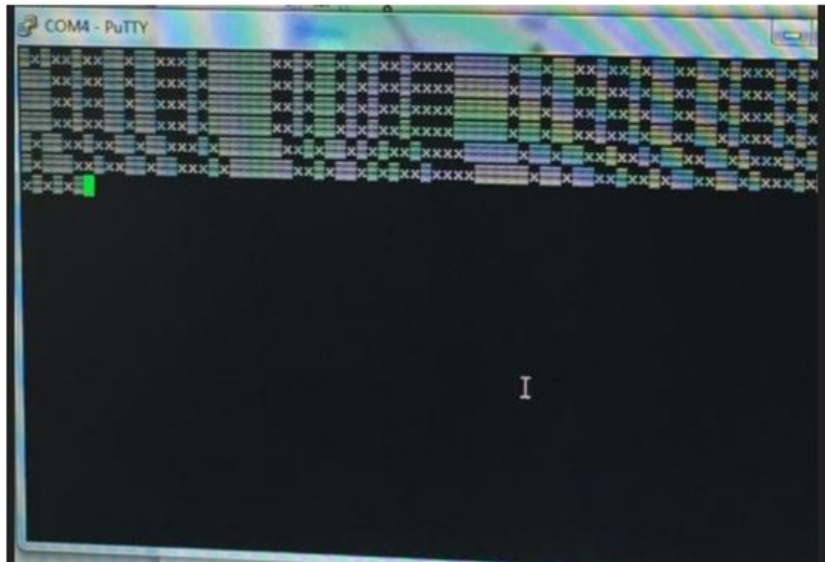
Although the datasheet for the LCD display states an operating voltage of 5VDC, there is a 3.6VDC for the backlight and although it has been powered by 5VDC it is still operational. To prove this was not the issue a 3.6VDC supply was connected to the LCD display but this had the same result. To prevent any long term damage to the LCD display back light a

100OHM resistor was placed in series with the back light supply. At this stage fault finding is still ongoing prior to the VIVA presentation.

2) Serial Connection via TTL & Tera Term Issues, fault finding & Testing:

As set out in the objectives and system design, the system was required to export data to the serial port via TTL lead which would then transmit stored EEPROM data to a host PC. Tera Term software is to be utilised to carry out this transfer and handle the transmitted data with view to be converted into spreadsheet or tabulated format for the user. Tera Term software was downloaded to a host pc and the TTL lead connected as per the schematic design. The picture below shows the results:

Figure 15: Corrupted Data Transmission



As we can see the system has transmitted data from the EEPROM chip via the TTL lead successfully although the data is not reading correctly. Although the program simulated correctly and the code compiled and built without error an attempt to reassign 2 different pins was made in an effort to transmit readable data. The modified code is as follows:

~~#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8,stream=PORT1)~~-Original
Code

~~#use rs232(baud=3300,parity=N,xmit=PIN_C4,rcv=PIN_C5,bits=8,stream=PORT1)~~-
Modified code.

Despite altering the baud rate and transmit and receive pins, although transmission of data was successful it was still unreadable and printing random characters to the PC. A new TTL lead was utilised to ensure the TTL lead used was not at fault but again this made no difference to the data transmission results. At this stage investigations are still ongoing as to the cause of the data corruption with both hardware and software being looked at.

1.7 Power Supply Issues, fault finding & testing:

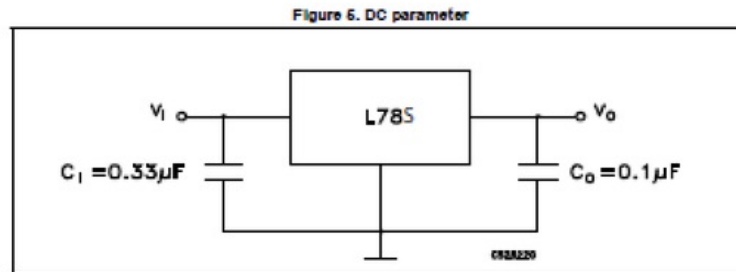
For testing and initial implementation purposes, a regulated 5VDC external supply was used to power the system in the university laboratory. This external supply powered the system sufficiently and allowed the initial power up and system testing to be carried out. However, despite there being issues with serial data transfer and the LCD display, the designed system power supply was connected via the 240-5VAC transformer providing a rectified 5VDC system supply. Initially there appeared to be no supply to the system as the flashing LED would not work or the LCD display back light illuminate. Testing with a multi meter was carried was carried and the results are below:

Initial Multi-Meter testing for power supplies to the system & components:

- 1) The 240V/AC supply to the transformer was present and correct.
- 2) The 5VAC supply from the transformer was present and correct to the bread board.
- 3) The voltage at the AC-DC rectifier was not present indicating component failure.

Initially the rectifier was found to have failed and a replacement component installed with a check of the data sheet to ensure that the connections were correct. What was missed in the design was that the RMS of the rectifier was in fact stepping up the rectified output voltage close to 9VDC. This was cause for concern as the components of the system are rated at 5.5VDC maximum. To ensure the integrity of the system components the 5VDC regulated external supply was reconnected and thankfully the system operated as before with the start button operating the PIC, the flashing LED illuminating indicating the PIC operation and the LCD backlight illuminated. This inadvertently tested the protection circuit and its design as a success if unintentionally and with a not recommended unconventional method! To overcome this issue of voltage step up, a 5V regulator and capacitors from the university lab stores was

installed in the circuit prior to the rectified 5VDC supply to the system. This was connected as per the datasheet instructions below:



Once this had been completed, a second power up from the transformer supply was made and again there was no flashing LED or LCD display backlight. As the multi meter method identified a component failure, this was utilised for a second time to test for power supply failure, the results as follows:

1.8 Secondary Multi-Meter testing for power supplies to the system & components:

- 1) The 240V/AC supply to the transformer was present and correct.
- 2) The 5VAC supply from the transformer was present and correct to the bread board.
- 3) The voltage at the AC-DC rectifier supply voltage was correct but the output was 3.2VDC indicating a voltage loss in the circuit.

To prove the rectifier the rectified supply to the circuit was disconnected and the rectified 5VDC supply tested with the regulator removed as it was anticipated that this was dragging down the voltage. This proved to be around 6VDC and although above the maximum rated value of the components was deemed satisfactory at this stage as the protection circuit had already been proven. The rectifier was reconnected without its regulator but although 6VDC

was supplying the system it still would not power up. At this stage further investigations are ongoing as despite this issue the system can be powered up using a regulated 5VDC external power supply.

1.9 Issues Still Under Investigation:

At the time of submitting the report the following issues are still ongoing with vigorous testing and modifications taking place with a view to rectifying the issues in time for the VIVA presentation and these include the following:

- 1) The LCD display not displaying data from the sensor inputs.
- 2) The serial output of the RS232 although transmitting data, the data is unreadable and potentially corrupted or with a transmission issue.
- 3) The designed power supply to the system via the 240VAC transformer isn't working and still undergoing testing.

Chapter 5: Evaluation

In order to evaluate the outcomes of the project we must first consider the aims and objectives outlined in the initial stages of the project research and outline. The main aim of the project as laid out in the initial research and discussions is :

The main aim of the project as the title suggests, is to design a method/ system for which the moisture sampling of RDF (refuse derived fuel) can be carried out whilst it is inside its drying tunnel. (Taken from Chapter 1).

As far as the design is concerned the project is a success in meeting its main aim as outlined above and this was achieved by the following:

1.1 Successful Elements and outcomes:

- 1) The research identified a project addressing a moisture data acquisition in the waste industry (Mercer University), despite being a landfill site that provided some background into the type of project being undertaken here. Although the project was based on developing sensors capable of measuring the medium of interest in a particular environment, the design and testing processes were of particular interest into directing what had to be considered for this project.
- 2) The background research into relative humidity, as the medium for which the project was measuring proved helpful in understanding exactly what was being measured. The research here identified how the humidity related to moisture content and the formula for deducing moisture from humidity.
- 3) The research identified the technologies available for sensor types and highlighted resistive/ capacitive sensor technology as the most suitable method for meeting the project requirements and cost.

- 4) The research identified the humidity probes that were available on the market place and one that was suitable for the project design and application and within the budget.
- 5) The research identified the current moisture data acquisition systems that are available in the market place, providing an insight into the features and technology used in current moisture data acquisition systems.
- 6) The research identified a PIC based system as a method to meet the project requirements and demands.
- 7) The research identified the different forms of memory storage that could be utilised by the project and directed the choice made i.e. EEPROM IC. This choice proved to be successful, even if only proved by simulation at this stage.
- 8) The project being design and development based, met its main aim as the simulation section of the implementation proved that the design of the system was successful and actually worked.
- 9) A code was designed to run the PIC based solution and its design was proved to be successful from the simulation results outlined in the implementation chapter.
- 10) The sensors chosen were also proved to be successful as the simulation and oscilloscope testing proved that they were performing as intended and actually measuring the elements intended.
- 11) The memory storage choice of an EEPROM IC also proved successful in both choice and implementation as the simulation proved it to be a method that met the needs of the system and its design
- 12) The protection circuit design, although inadvertently proven, was well designed in both structure and component design and ratings at it withstood a high voltage input of around 9V with all components protected.

- 13) The system was designed to withstand the environment that it was to be used in via IP65 rated moisture sensor and enclosure and also with the power supplies available to power it over a near 2 week period.
- 14) The data extraction design serial RS232 via a TTL lead and Tera Term software, proved successful in that stored data was actually transmitted despite data corruption issues

1.2 Unsuccessful Elements and outcomes:

Ultimately there were a number of issues with the physical build, physical implementation and testing. These include:

- 1) The power supply design did not work correctly and although attempts have been made to incorporate voltage regulators and modify the design at this stage investigation are still ongoing.
- 2) The LCD screen, although illuminated, it isn't displaying the system sensor output data and despite attempts to solve the problem through rewriting code etc., it still isn't working correctly although the design simulation is sound.
- 3) Although data is being transmitted through the serial RS232 via a TTL lead, the data is corrupted in some way and unreadable. This means that we cannot prove physically that the EEPROM IC is storing data correctly although the simulation proves it does.
- 4) Due to implementation issues with physical build and testing as mentioned in the previous points, the system was not ready to extract data from the process in the time frame of submitting the project report, which for me is personally disappointing.

1.3 What would be done differently?

There have been a number of areas for improvement that would ultimately address the unsuccessful elements and outcomes of the project if it were to be undertaken under these circumstances and time frame again:

- 1) Time management: Although during the research and parts of the design stages of the project, the project was on track in terms of its time frames, there were issues that held areas up. Notably the CCSC programme design was a particularly lengthy process that proved of difficulty. Not having carried out PIC programming prior to the project made this part of the design particularly difficult and troublesome with 91 programme errors at one stage! Although too much time was spent on the programme design a lot was learned and this would make future programme design projects more well managed in terms of time allocation and experience in tackling programming issues and faults.
- 2) Physical Build: Due to the excessive time spent on the programme design that meant the issues encountered in the physical build had insufficient time to address prior to the report submittal. In hind sight, the physical build could have been carried out at an earlier stage with basic tests such as power supplies etc, being eliminated earlier with more time available for the operational issues once the PIC was programmed and installed. Although the physical build has its issues and ultimately it isn't working as intended, the issues encountered facilitated further learning in that further testing and analysis was carried out, modifications using components not in the original design were utilised aiding further learning.

1.4 Summary:

Overall the project design was proved to be successful from a design perspective and this was proved with successful simulation results and partial physical build results. The build had its issues and ultimately a fully working system that could extract data from the process it was to be applied was not carried out within the time frame of the project and submittal of this report. However the system was designed for the environment intended, was capable of measuring the medium of moisture and additional temperature, record and store data, transmit data (even if corrupted) and run for any number of days as long as it was powered. Although there were a number of issues that led to the physical build not being fully operational, these issues led to further learning. There was more learning and knowledge to be gained from the subject and technical knowhow through addressing issues and carrying out further testing, analysis and modifications to both software and hardware.

Chapter 6: Conclusion & Future Recommendations:

1.1 Conclusion:

The project from a research and design perspective was successful in addressing its main aim of *to design a method/ system for which the moisture sampling of RDF (refuse derived fuel) can be carried out whilst it is inside its drying tunnel*. The project failed in carrying the design through to the fully operational physical build that could be applied to the process. The design simulated perfectly with both software and components performing as designed and intended. This success however could not be replicated in the physical build and a number of issues were present. Despite some extensive testing, modifications of circuit design, components and software the issues still remain ongoing with the hope of achieving a fully working system for the VIVA demonstration/ presentation. The issues that remain under investigation are:

- 1) Issues with the 240VAC-5VDC supply to the system.
- 2) Issues with interfacing system data to the LCD display.
- 3) Issues with interfacing transmitted data via RS232/ TTL with unreadable corrupted data.

Despite these issues and there not being a fully operational physical build there were some successes in meeting the initial aims and objectives set in the preliminary introductory stages of this report and these include:

Project Sub- Aims:

- 1) *The solution must be accurate- The system designed simulated reading accurately 0-100% humidity levels and 0-100° temperature readings. Although the system interfaces i.e. the LCD display and RS232 didn't display this data,*

the oscilloscope testing showed that the sensors were outputting a range of 0-5V indicating that the data would have been accurate had it been displayable.

- 2) *The solution must be user friendly-* The system had user friendly features and design such as an LCD display, A USB TTL lead, a visible flashing LED indication of PIC operation via a clear fronted enclosure and a start button to operate the system. Although there were issues with the interfaces, the features none the less met the user friendly objective that was set.
- 3) *The solution must be durable in terms of working conditions i.e. Temperatures up to 50C, dusty conditions, abrasive materials in the waste-* The project research identified a method of moisture measurement via exhaust gas humidity that avoided direct contact with the abrasive medium being sampled and the design highlighted a duct probe suitable for the application.
- 4) *The solution must have adaptability for possible integration into existing systems or equipment-* Although this objective was a potential avenue for the project to take and I still believe it can be, modifications to the existing system by the manufacturer during the tenure of this project meant that any integration of the existing system was impossible.
- 5) *The solution must conform to industry technical standards-* The solution adhered to the H&S at work act 1974, the Electricity at work act and the design ensured that sensors and components were IP65 rated or enclosed in an enclosure of IP65 rating to ensure integrity is maintained in its environment.
- 6) *The solution must comply with health & safety and environmental legislations including the site permit-* The company H&S policies and environmental

operating permit conditions were adhered to and all work carried out had these criteria in mind.

7) *The solution must comply and conform to company policies and procedures-*

No breaches of company policies or procedures were made during the span of the project and all work was carried out in accordance with company requirements.

8) *The solution must be retrievable to overcome loading/ unloading issues- As*

highlighted in sub aim 3, the project research and design identified a method of moisture measurement via the humidity of the exhaust gas from the drying process which meant there was no contact with the medium and the system did not interfere with the operation in anyway and the design therefore met this objective.

9) *To carry out the project within set time frames in accordance with submission*

deadlines and academic commitments- Although there are issues with the physical build during submission of this report, the project report and submission deadlines have so far all been met as required by the project brief and timetable.

10) *The solution must have the scope to satisfy the project document and*

assignment brief- The project research identified a system incorporating a PIC microcontroller as best suited to the project solution and its application has met the requirements of the project brief.

Project Objectives:

In order to achieve the project proposal aims it will be necessary to set objectives that will highlight the means of achieving the aims. The following objectives have been set as a strategy or method for achieving the project aims, these include:

- 1) Research moisture measuring technology and systems- The preliminary project research identified current moisture data acquisition systems, moisture measurement technology and available sensors suitable for the system design and application. The results of the research aided the design of the system and the features to be included.
- 2) Identify a method or system suitable for the application- As previously mentioned, the research identified a suitable method of moisture measurement via exhaust duct humidity and a PIC based system to collect data and operate the system.
- 3) Develop the identified method into an application that satisfies the proposal specifications/ requirements, applying learned academic engineering principles and techniques- The project solution utilising a microcontroller based system provided an opportunity to apply system design, software programming and program code construction, utilising software packages to design and simulate the system and apply fault finding through issues encountered in the build.
- 4) Implement/ Install the identified method/ system with view to extracting valuable data from the process i.e. moisture sampling/ measurement- The project failed to meet this objective due to the issues with the physical build as it was not ready for installation in the process.
- 5) Collect data and sample sets from the implemented method/ system and analyse- Despite the design being proven through software simulation, issues with LCD interfacing and RS232 data transmission meant that the system was unable to display data from the process.

- 6) Evaluate project success based upon data analysis, discussing effectivity of design, implementation and application in addressing the requirements of the sub aims in 5.1.-
The evaluation section successfully evaluated the project performance in terms of meeting its aims and objectives or not in the case of the physical build. Simulated data was analysed, design discussed and project implementation.
- 7) Conclude all findings and aspects of the project with possible future improvements of the system design- Currently under progress during this chapter but anticipated to be addressed successfully.

1.2 Summary:

Although there are issues still ongoing with the physical build and hardware of the system, the project has had many successes with much learned and applied along the way. Ultimately the software programme construction was under estimated due to having never carried out this task before. This eat into the time available for the physical build although there was enough time to carry out the build there was not enough time to address faults encountered. The design was proved through simulation software and parts of the physical build e.g. start button system initiation, flashing LED, data storage and transmission were successful even if transmitted data was corrupted. Despite this there are future recommendations to be made in regards to the project and its application.

1.3 Future Recommendations:

Although the design satisfies the aims and objectives of the project solution requirements and the system has all the features required by the user, there are still a whole myriad of other features that would not only add to the design but improve the systems usability and performance. The following list, while not exhaustive identifies a number of improvements that could be made to the project and system design:

1. *Integration into existing systems*; although this was identified in the preliminary objectives, it was not possible to incorporate this feature into the project design due to ongoing works to the system by the manufacturers. This feature however would undoubtedly add to the on- site usability as it could be incorporated into the existing system. The temperature probes of the current system could be replaced with a temperature and moisture probe, with the temperature measurement providing existing system input and the moisture measurement providing the project system with its measurement. This would give the project system another form of moisture measurement that would be incorporated and compared with the duct humidity to provide a more accurate moisture measurement of the medium in the tunnels.
2. *Ethernet Connectivity*; an Ethernet connection would provide a PC interface for downloading of data that can then be used for other logging purposes potentially to a laptop in remote locations, this may have overcome the RS232 data corruption issues with the system.
3. *WIFI Capabilities*; WIFI would provide wireless control and connectivity to external PC/ Laptop allowing information to be downloaded without having to open up enclosures exposing equipment to the environment it was installed in, this method may also have overcome the RS232 data corruption issues with the system.

4. *DC Battery Supply*: The system being powered by a DC source may have overcome the power supply issues encountered by the system, however due to the length of recording time, batteries would have to be specified accordingly.
5. *Alarms*, in built alarms could alert the user to excessive temperatures, memory storage full, moisture levels at a level required or any other parameters built into the system.
6. *Serial RS232 Header*: Although a TTL lead was used for PC interfacing, an RS232 header connection may have overcome the data corruption issues with the system.
7. *Remote Control*; replacing the start/ stop buttons with a remote control or activation fob would be a contactless added feature that would add user friendliness and modernisation to the system whilst reducing physical connections that would degrade over time.
8. *Multiple Sensors*: Taking more measurements, particularly from multiple areas and different methods (Direct Contact) can only lead to more accurate readings and a wider measurement of the medium's moisture content and level.
9. *Fuse Holder*, Although the design listed a fuse holder for the system, this was never installed as the physical build never passed the testing stage and was not ready for installation into the process. If it had been then the fuse holder and fuse would have been installed as an additional protection device for the regular power surges that are experienced on the site.
10. *Use of Mosfets*; would provide the system with a means of switching off supplies to components or sensors that are not in use. This would add energy efficiency to the system.
11. *Moisture Transmitter*: As the preliminary research findings showed, many current moisture data acquisition systems utilise wireless sensor transmitters. This would have meant that the system could purely have been a software design with the sensors

transmitting directly to a host PC or interfacing via a receiver module. This may have overcome the power supply issues, LCD interface issues as it would be replaced by the PC monitor and data transmission as it would be direct to the PC.

12. *USB Connectivity*: May have overcome the serial RS232 data transmission issues experienced by the system and also provided another means of data storage with a removable USB stick. Although the necessary simulation software license was not available for Proteus for this device it would still have added to the system design and may have overcome some of the issues experienced.
13. *SD/ SPI Connectivity*: This feature again would have provided another form of removable memory storage and may potentially have overcome data transmission issues experienced by the system design.
14. *PCB Printing*: A PCB board could be printed of the circuit design which eliminate the number of physical connections in the circuit and may eradicate faults with the design and be a more compact board for the enclosure.

1.4 Summary:

This list of potential recommendations and system design improvements, whilst not exhaustive, open up a whole myriad of options for improving the system and potentially overcoming some of the issues that remain with the system. The recommendations of interest at this point are the removable memory storage options as these methods undoubtedly would have overcome the data transmission issues experienced by the system design as the main aim of the project was to extract moisture data from the process for use by the end user. Time constraints, the availability of some resources (e.g. USB software simulation license) and personal shortage in experience at handling a design project of this nature all contributed in the inability to incorporate or further investigate the inclusion of some of these recommendations.

Chapter 7: Reflection

The BEng Electrical and Electronic engineering degree has provided a stern challenge particularly in a part time capacity juggling shift work, weekend work as well as family life. The major project being a large part of the degree encompasses not only the academia being taught for the BEng but has made a provision to show case skills already attained as well as gaining new skills and experience. For me personally, coming from a predominantly electrical background, the project entirely focusing on the electronic aspect has been a challenge and virtually every aspect of the design and implementation has been learned for the purpose of the project. Particularly the software programming side of the project has proved a challenging task that ultimately narrowed the time of the build with little time available to address the issues encountered with the build. The issues themselves though, provided an opportunity to apply fault finding techniques and carry out further investigations which again aided further learning that would not have been possible had the system worked first time. Being able to apply my academia to a work based project allowed me to directly transfer what I had learned into the work place which demonstrated to my employer (who sponsored my studies) what I had gained from the BEng and my ability to undertake an engineering project.

The project module has definitely created an appreciation of time management and prompted me to personally improve my time management and organisation of all aspects of my working life. I feel personally better equipped to take on an engineering project from scratch and believe the skills and confidence that I have gained will improve me as an engineer in the work place. I feel that the support along the way from lecturers, mentors, peers and employers have been more than I could have asked for and this is my opportunity to thank them for the opportunities that I have been given. Despite studying has taken a large portion

of my personal time over the last two years I have enjoyed not only the learned academia but also the challenge that it has proposed.

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