CERTIFICATION OF APPROVAL

Design and Implementation of Control System for Fuel Feeding

by

Mohamad Adib Bin Ishak

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

(AP Dr Hussain Al-Kayem)

Dr. Hussain H. Ja'afer Al-Kaylem
Associate Professor
Mechanical Engineering Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750 Tronoh
Perak Darul Ridzuan, Malaysia.

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHAMAD ADIB BIN ISHAK

ABSTRACT

A biomass burner integrated with gas to gas heat exchanger has been designed, constructed and evaluated. The burner use three types of biomass energy fuel which is Empty Fruit Branches (EFB), wood chip and rice husk. The current biomass burner were designed with a manual biomass fuel feeder which will control the feeding volume of solidify biomass to the combustion area. The current design has a disadvantage which is the biomass feeder have to be operated manually thus the burner could not function without continuous monitoring. A control system has been designed and fabricated to modify the current biomass feeder to solve the problem. An important part of the design is to control the solid particle feeding into the combustion area without any disturbances. The system will operate when the temperature drop below 80°C and stop when it reach 90°C. The fabricated unit is tested experimentally and the result meets the objective of the project.

ACKNOWLEDGMENT

First of all, the author would like to express utmost gratitude and appreciation to Allah because with His blessings and help, the Final Year Project went very smoothly. Alhamdulillah, all praises to Him that the author have been able to complete this project on time.

This project would not have been possible without the assistance and guidance of certain individuals and organization whose contributions have helped in its completion. First and foremost, the author would like to express his sincere thanks and utmost appreciation to the project supervisor, AP Dr Hussain Al-Kayem for having faith and strong support in guiding the author throughout the whole period of completing the final year project. His kind assistance and guidance from the beginning to the end of this study really help me to undergo my project successfully.

The author would also like to deliver his warmth appreciation to the student who is involved with this project, namely Mr. Awang Shahrin for assisting with the technical support and guidance towards this project.

Finally many thanks to the author's family and fellow colleagues for their help and ideas throughout the completion of this study. I hope that the outcome of this report will bring beneficial output to others as well. Thank you very much everyone.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Biomass is one of the main renewable energy sources suitable for drying application. A biomass burner has been designed and fabricated with a manual fuel feeder in Universiti Teknologi PETRONAS [1]. Fuel feeder is a device or parts of a machine in this case a biomass burner, which is to store and supply the fuel into the combustion area. The fuels used are rice husk, woodchip, Empty Fruit Branches (EFB), and agricultural waste. A good design of fuel feeder is necessary to maintain a constant feeding rate of the fuels.

(a) (b) (c)

Figure 1.1 (a) current fuel feeder using ball valve (b) current hopper (c) biomass fuel stuck in valve connection (Reference no.1)

1.2 Problem statement

A biomass burner with a manual fuel feeder has been designed, fabricated and evaluated. The current design has many drawbacks and disadvantages. Because it is operated manually, the biomass burner could not operate especially during the night. The feeding process of the fuel is also disturbed because of the inner contour of the feeder, which result in inconsistent feeding rate. The inclination of the feeder's insertion or pipe is not enough to ease the flow of the feeding.

In this project, a study on the design of a control system for fuel feeder was conducted. From the knowledge gained, an automated fuel feeding system has been designed and fabricated.

1.3 Objectives and Scope of Study

The main objectives of this research are:

1. To design a control system for fuel feeder.
2. To design a new fuel feeder.
3. To fabricate the system using suitable material and method.
4. To test the completed system.

CHAPTER 2

LITERATURE REVIEW AND/OR THEOR

From the review of several books, some journals, and even website, this information below was noted for its relevancy regarding the project.

2.1 Fuel Feeding System

Khairul Anuar 2010 [1] has come with a design of a biomass burner using controllable fuel feeder. His designed was based on the design of a biomass burner from S.-A.B. Al-Omari [2]. The fuel feeder was made from galvanized iron. Below is the picture of the fuel feeder designed by him:

Figure 2.1 Fuel feeder (Reference no.1)

The fuel feeder used ball valve to control the flow of the biomass fuel. Because of uneven internal surface, the fuel clogged inside the valve.

Mehmet Yasar Gundogdu 2003 [3] had come out with a research to design improvements on rotary valve particle feeders. The conventional particle feeder has several drawbacks, such as; unsteady feeding, especially at low feeding rates.

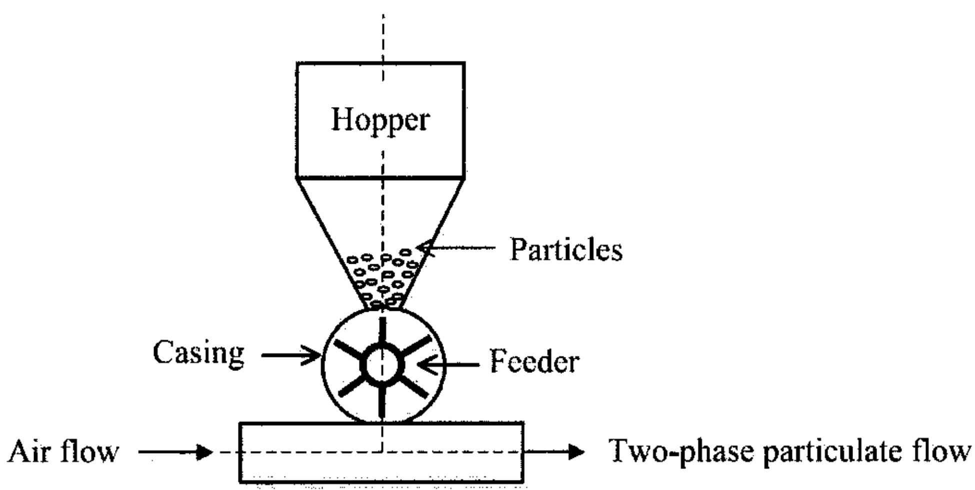

Figure 2.2 Conventional particle feeder (Reference no.3)

After the problems have been identified, modifications have been made in the design;

1. A portable top cover was added on the hoper to prevent air leakage from the system. This provided a balancing pressure to prevent the repulsion problem of low density particles by the back flow of air through the valve.
2. A novel casing for the feeder valve was designed to prevent the sticking problem of particles. Overheating because of the frictional contact between the valve and the particle was solved by increasing the amount of air circulation around the valve in the casing.
3. The unsteady feeding problem experienced with the conventional feeder at low rotational valve speeds was mitigated by increasing the number of vanes, and thereby the number of carrying pocket of the feeder valve.

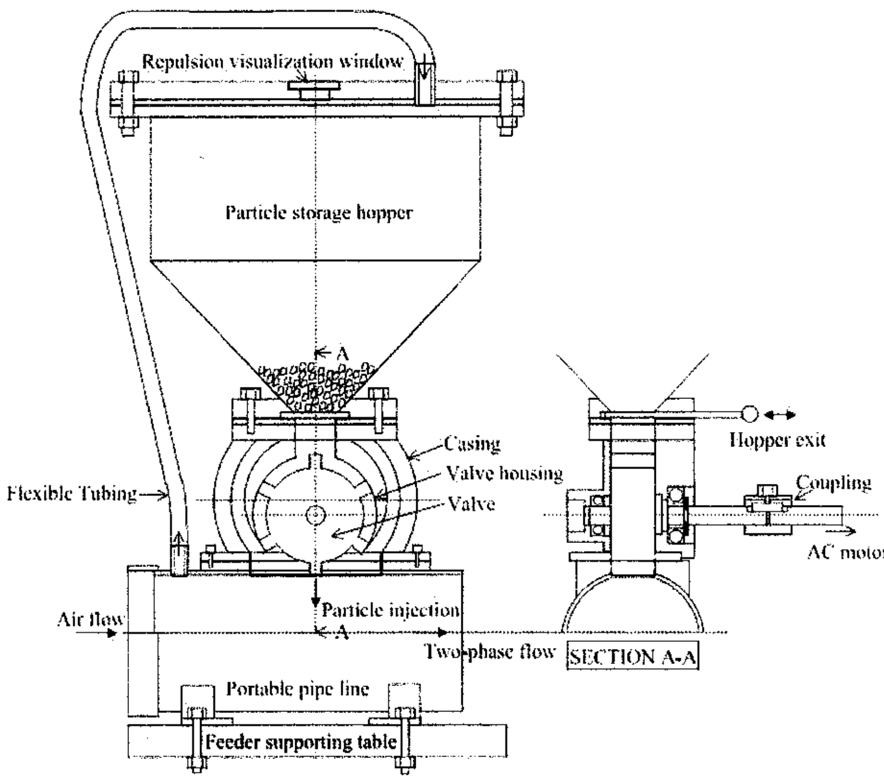

Figure 2.3 Modified particle feeder (Reference no.3)

2.2 Stepper Motor

A stepper motor is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely without any feedback mechanism as long as the motor is carefully sized to the application [4]. A Stepping Motor System consists of three basic elements, often combined with some type of user interface (Host Computer, PLC or Dumb Terminal):

Figure 2.4 Stepper Motor available in market (Reference no.6)

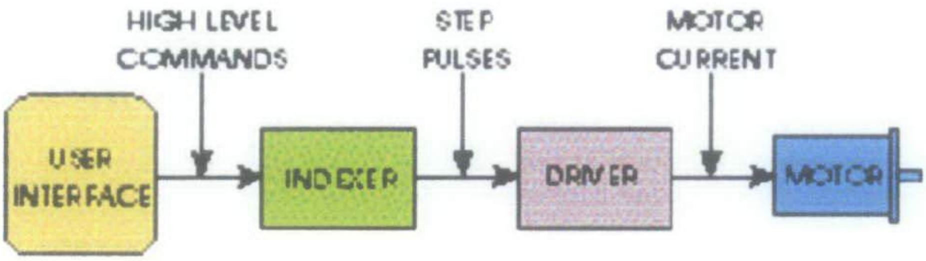

Figure 2.5 Stepper Motor System (Reference no.5)

2.2.1 Step Modes

Full Step

Standard (hybrid) stepping motors have 200 rotor teeth, or 200 full steps per revolution of the motor shaft. Dividing the 200 steps into the 360°'s rotation equals a 1.8° full step angle. Normally, full step mode is achieved by energizing both windings while reversing the current alternately. Essentially one digital input from the driver is equivalent to one step.

Half Step

Half step simply means that the motor is rotating at 400 steps per revolution. In this mode, one winding is energized and then two windings are energized alternately, causing the rotor to rotate at half the distance, or 0.9°'s. (The same effect can be achieved by operating in full step mode with a 400 step per revolution motor). Half stepping is a more practical solution however, in industrial applications. Although it provides slightly less torque, half step mode reduces the amount "jumpiness" inherent in running in a full step mode.

Micro Step

Microstepping technology controls the current in the motor winding to a degree that further subdivides the number of positions between poles. Microstep drives are capable of rotating at 1/256 of a step (per step) which corresponds to 51200 steps per revolution (for a 1.8° step angle motor).

2.2.2 Indexer

The indexer, or controller, provides step and direction outputs to the driver. Most applications require that the indexer manage other control functions as well, including acceleration, deceleration, steps per second and distance. The indexer can also interface to and control many other external signals [5].

Microprocessor based indexers offer a great deal of flexibility in that they can operate in either stand-alone mode or interfaced to a host computer. Communication to the indexer is either Bus-based or through an USB serial port. In either case, the indexer is capable of receiving high level commands from a host computer and generating the necessary step and direction pulses to the driver.

The indexer includes an auxiliary I/O for monitoring inputs from external sources such as a Limit switch. It can also initiate other machine functions through the I/O output pins [5].

2.2.3 Drivers

The stepper motor driver receives low-level signals from the indexer or control system and converts them into electrical (step) pulses to run the motor. One step pulse is required for every step of the motor shaft. In full step mode, with a standard 200 step motor, 200 step pulses are required to complete one revolution. Likewise, in microstepping mode the driver may be required to generate 50,000 or more step pulses per revolution [5].

Speed and torque performance of the step motor is based on the flow of current from the driver to the motor winding. The factor that inhibits the flow, or limits the time it takes for the current to energize the winding, is known as inductance. The lower the inductance, the faster the current gets to the winding and the better the performance of the motor. To reduce the effects of inductance, most types of driver circuits are designed to supply a voltage greater than the motor's rated voltage.

2.3 Control System

A control system is a device or set of devices to manage, command, direct or regulate the behavior of other devices or systems. Control system also defined as the components that are added to other components, to increase functionality or to meet a set of design. There are two common classes of control systems, with many variations and combinations: logic or sequential controls, and feedback controls.

2.3.1 Sequential Control/Open Loop System

An open-loop controller, also called a non-feedback controller, is a type of controller which computes its input into a system using only the current state and its model of the system. A characteristic of the open-loop controller is that it does not use feedback to determine if its output has achieved the desired goal of the input. This means that the system does not observe the output of the processes that it is controlling. Consequently, a true open-loop system can not engage in machine learning and also cannot correct any errors that it could make. It also may not compensate for disturbances in the system. Open-loop control is useful for well-defined systems where the relationship between input and the resultant state can be modeled by a mathematical formula.

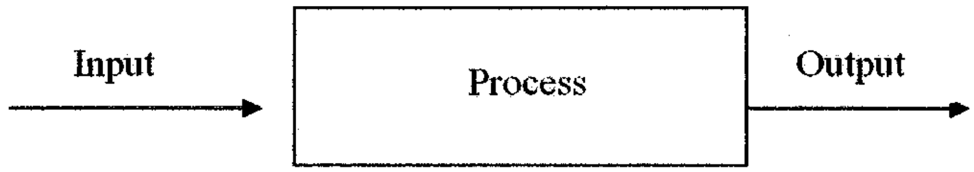

Figure 2.6: Sequential control/Open loop system

2.3.2 Feedback Control/Closed Loop System

Systems that utilize feedback are called closed-loop control systems. The feedback is used to make decisions about changes to the control signal that drives the plant. A basic closed-loop control system is shown in Figure 2.7 below.

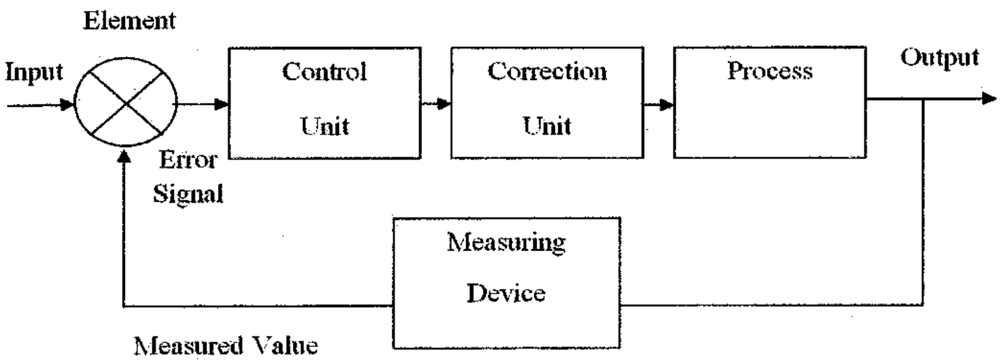

Figure 2.7: Feedback control/Closed loop system

Closed-loop components:

a) *Element/Comparison Element*

   It compares the required or reference value of the variable condition being controlled with the measured value of what is being achieved and produces an error signal.

b) *Control Unit*

   It decides what action to take when it receives an error signal.

c) *Correction Unit*

   It produces a change in the process to correct or change the controlled condition. The term actuator is used for the element of a correction unit that provides the power to carry out the control action.

d) *Process Element*

   Process element is what is being controlled.

e) *Measuring Devices*

   It produces a signal related to the variable condition of the process that is being controlled.

CHAPTER 3

METHODOLOGY

Research and the concept of a control system for fuel feeder are to be done. After that, the fuel feeder will be designed using AutoDesk Inventor. The CAD drawing will be analyzed for final design to be made before fabrication. After finalization of the design, fabrication process can be started. Testing process will take place after the fabrication completed. Then, proper documentation of the whole process is completed.

3.1 Flow Chart

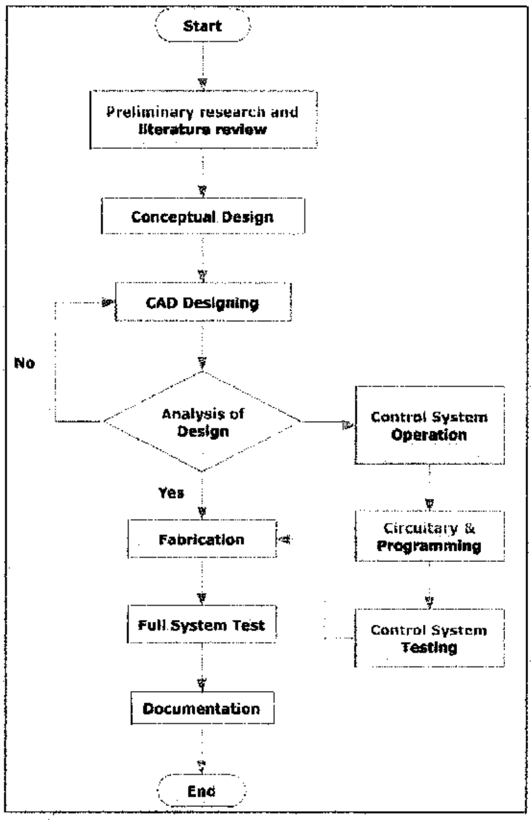

Figure 3.1 Flow diagrams of activities such as designing, fabrication and testing

3.2 Tools and Equipment Required

During the progress of the project, some equipment and tools are needed in the design and fabrication of the fuel feeder. The tools and equipment uses are:

1. Softwares:
   - AutoCAD
   - Autodesk Inventor
   - Microsoft Office
2. Tools & Equipments
   - Drilling machine
   - Lathe and milling machine
   - Welding machine
   - Fabrication tools

3.3 Design Process

The designing methodology has been used in designing the fuel feeder. The design considerations that have been taken into account are:

a) The feeding of the fuel must be constant to achieve accurate results during the experiments.

b) The system must operate when the temperature is below 80°C and stop when it reached 90°C.

c) The degree of inclination of the feeder with respect to the burner must be small to ease the flow of the fuel.

d) Light material should be considered because of the position of the feeder.

3.3.1 Morphological Chart

Morphological chart have been used in generating the design of the fuel feeder. Morphological chart is a visual way to capture the necessary product functionality and explore alternative means and combinations of achieving that functionality. For each element of product function, there may be a number of possible solutions. The chart enables these solutions to be expressed and provides a structure for considering alternative combinations. This can enable the early consideration of the product architecture through the generation and consideration of different combinations of sub-solutions that have not previously been identified.

3.4 Experiment

An experiment was done after the fabrication which is the feeding rate test. The test involves using two types of fuels which are wood chip and rice husk. The purpose of doing the feeding tests is to test the effectiveness of the new feeding system of the fuel feeder. In this experiment, the effectiveness of the feeder is tested to observe the accuracy of the temperature sensor to give the correct signal for the microprocessor.

Experiment procedures:

1. Rice husk is weighed to 20 grams.
2. Set the motor speed to PWM 50.
3. The motor is started.
4. The rice husk is feed into the hopper.
5. The time until the entire rice husk transferred towards the exit is taken.
6. Redo the experiment using motor speed of PWM 100,150, 200, and 255.
7. The feeding rate (g/s) is calculated.
8. Graph of Feeding Rate versus Motor Speed is plotted.
9. Redo step 1 to 8 for wood chip.

CHAPTER 4

DESIGN AND FABRICATION

4.1 Fuel Feeder

4.1.1 Conceptual Design

An initial design of the fuel feeder has been hand sketched and discussed with supervisor. The design is based on the morphological chart used to generate the idea for design.

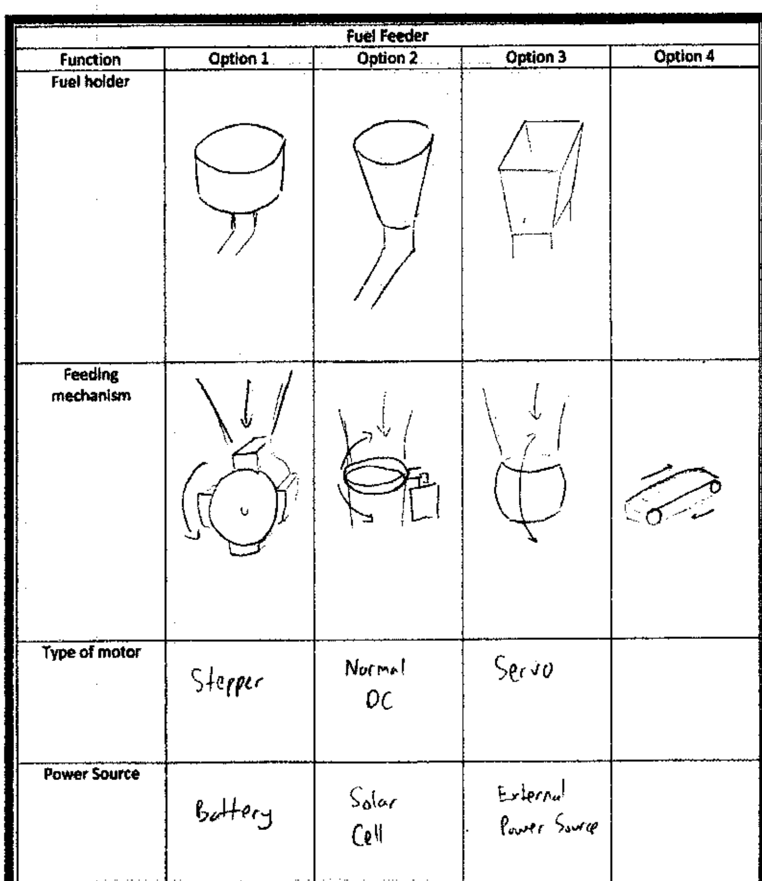

Figure 4.1 Morphological chart used in preliminary design

4.1.2 Design No.1

The first design used rotary valve which is connected to a stepper motor which will operate the valve. The degree of inclination of the feeder to the wall of the burner is set to be 35° to 45°. The high degree of inclination will help the free flowing solid particle to go into the burning chamber easily.

The feeder is designed so that it can be attach and detach. The purpose of this feature is to ease the maintenance of the feeder. The feeder will be connected by a flange type connector with 4 bolts and nuts.

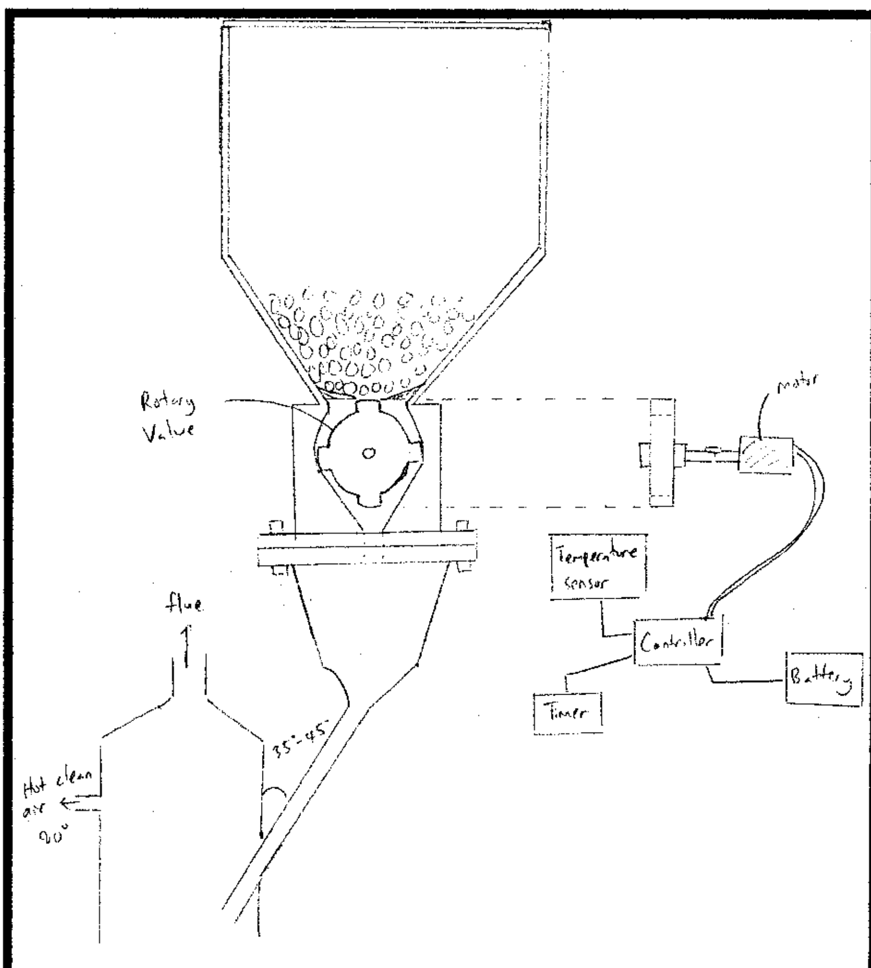

Figure 4.2 Sketched design

The rotary valve specifications are going to be as follow:

D_i, inside diameter: 40mm

D_o, outside diameter: 80mm

T, thickness: 40mm

The design adds another part to be attachable where the hopper and the valve are connected. The purpose of this feature is to ease the process of maintenance in case, the feeder got stuck or for schedule maintenance. For the front part of the feeder, it was decided to use a hard plastic cover to help monitor the condition inside of the rotating valve chamber.

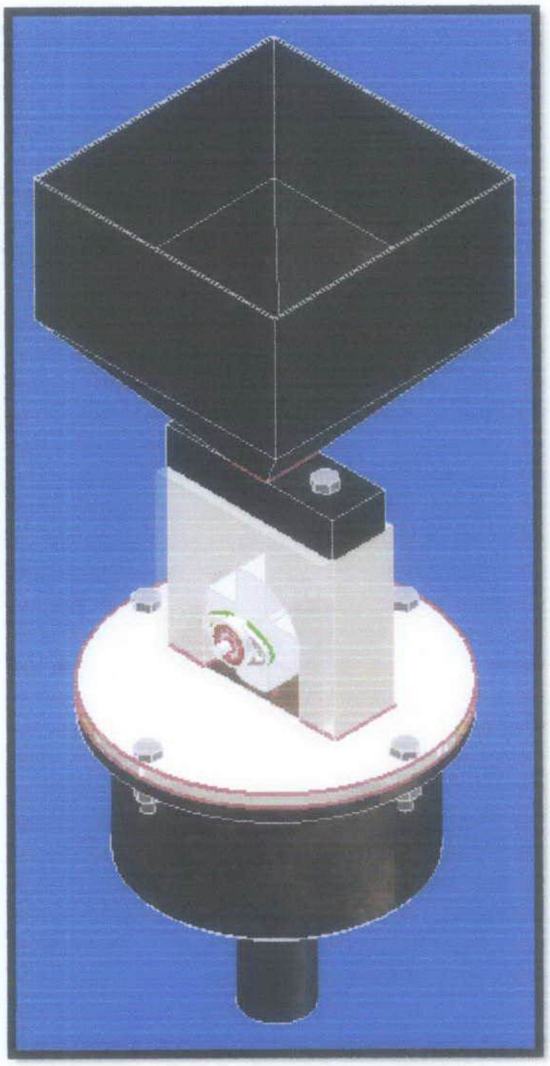

Figure 4.3 CAD Fuel Feeder with Rotary Valve

The motor chosen is the stepper motor. Because of the high precision needed for this design, stepper motor is the most suitable motor compare to normal dc motor.

After evaluation has been made, there is a critical drawback of the design.

- The point where the inlet of the valve meets the hopper. At this particular place, the fuel might stuck during the valve rotation and damage the system.
- The design is then reviewed and decided to be improve to fix this critical drawback.

4.1.3 Final Design

This design was an improvement from the first design. The idea of using rotary valve is removed and replaced by using a conveyor belt. The feeding will works like a conveyor feeding which the fuel will travel on a 200mm long conveyor belt before they enters the combustion chamber. This feature will make sure that there will be no fuel getting stuck during the feeding.

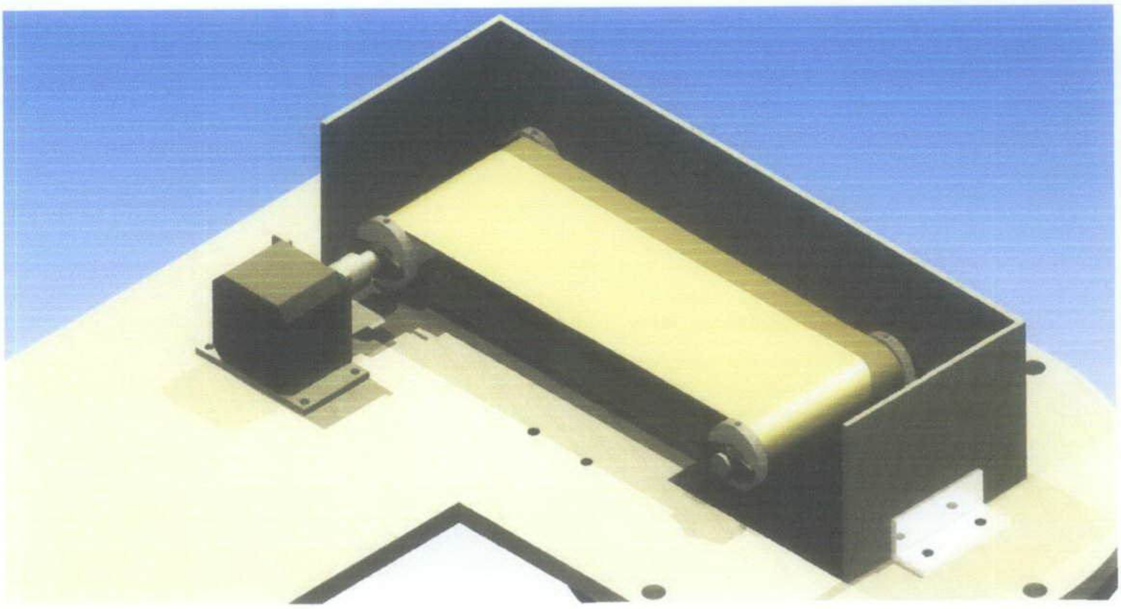

Figure 4.4 Conveyor Belt

Stepper motor will still be use for this design.

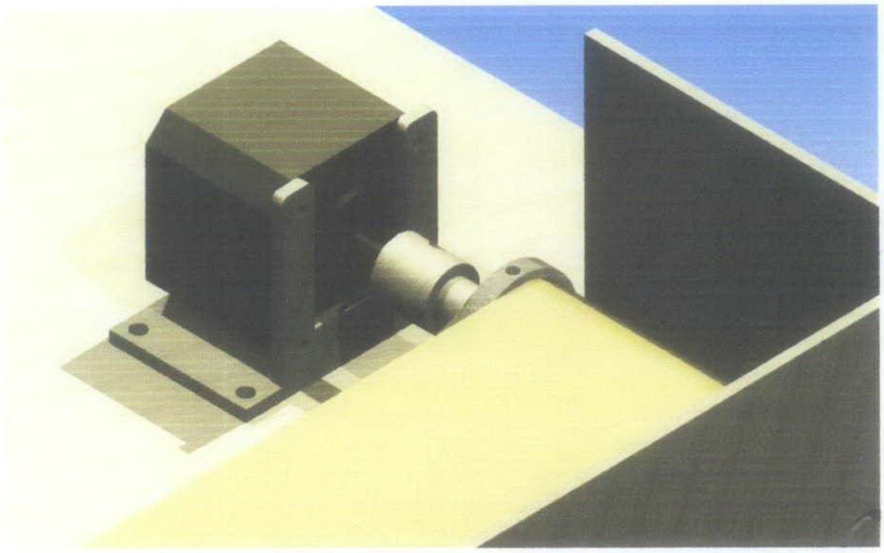

Figure 4.5 Stepper Motor

Below is the picture of the design from the side view. The fuel will enter from the hopper and drop onto the conveyor belt. It will then travel on the conveyor towards the burner.

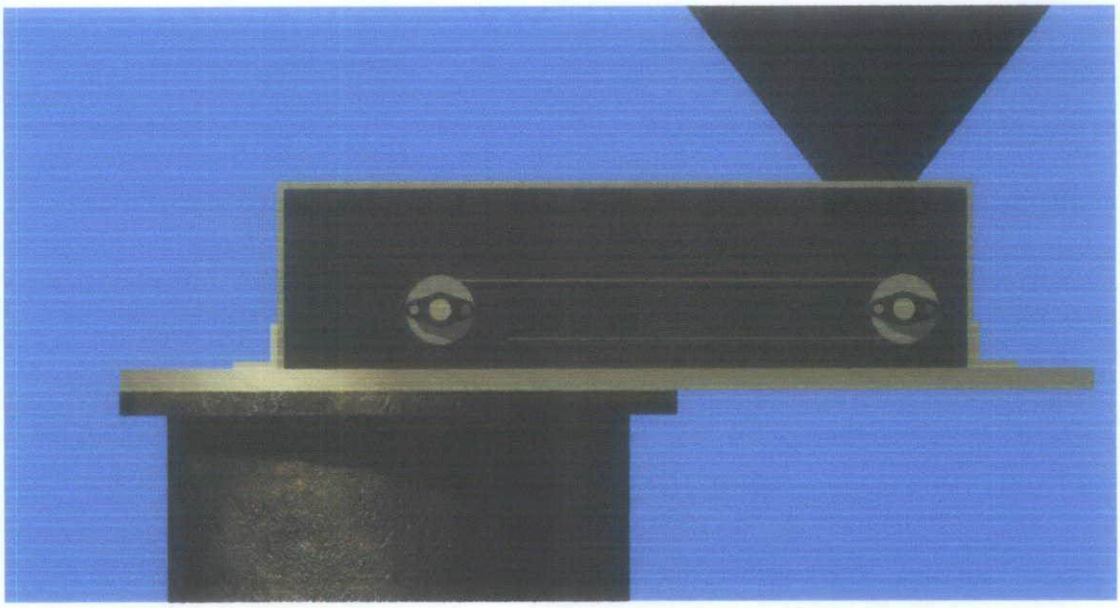

Figure 4.6 Side View

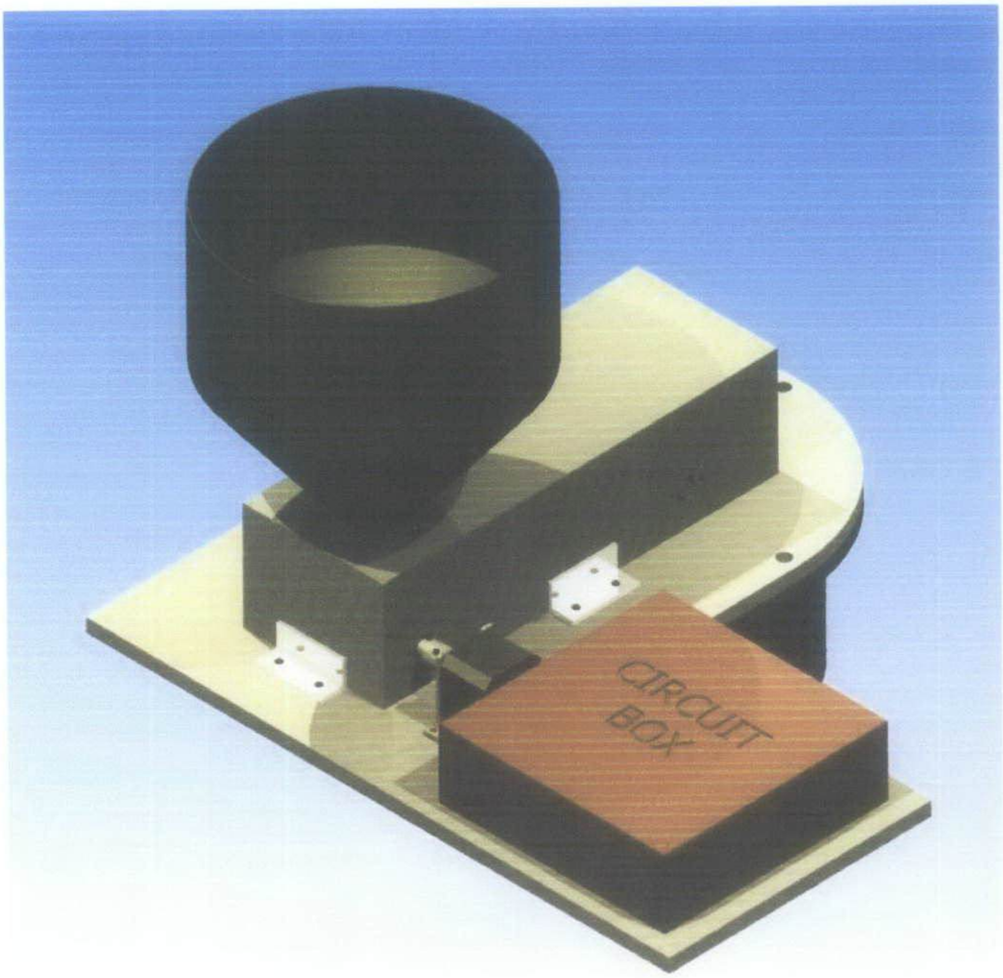

Figure 4.7 Full Assembly

4.2 Control System

A control system has been designed. The system consist of the controller with the present of temperature sensor, power supply (battery) and also a motor. Stepper motor has been chosen as the motor because it has high accuracy compare to other motors. After a series of discussions and research, the control system of the fuel feeder is the feedback system. This is because, each fuel have different period for reaching and maintaining the 80°C temperature.

4.2.1 Feedback Control

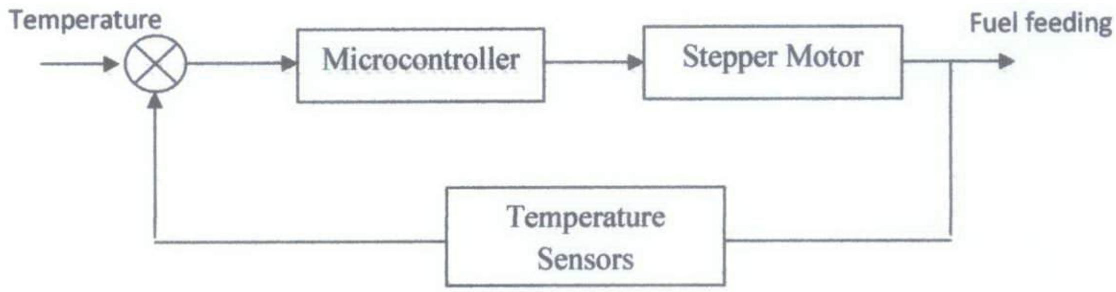

Figure 4.8 Final Control System Design

When using the feedback control, the operation starts with the temperature sensor detect the temperature. When the sensor detects the temperature to be below 80°C, it will give signal or input to the controller to process. Then, the controller will start the motor rotation and feeds the fuels to the burner. During the feedback, the sensor will continue measure the temperature. If the temperature reaches 80-90°C, it will stop the motor.

4.2.2 Constructed Circuit

Figure below shows the completed integrated circuit for the system. The full schematic diagram can be found in the Appendix.

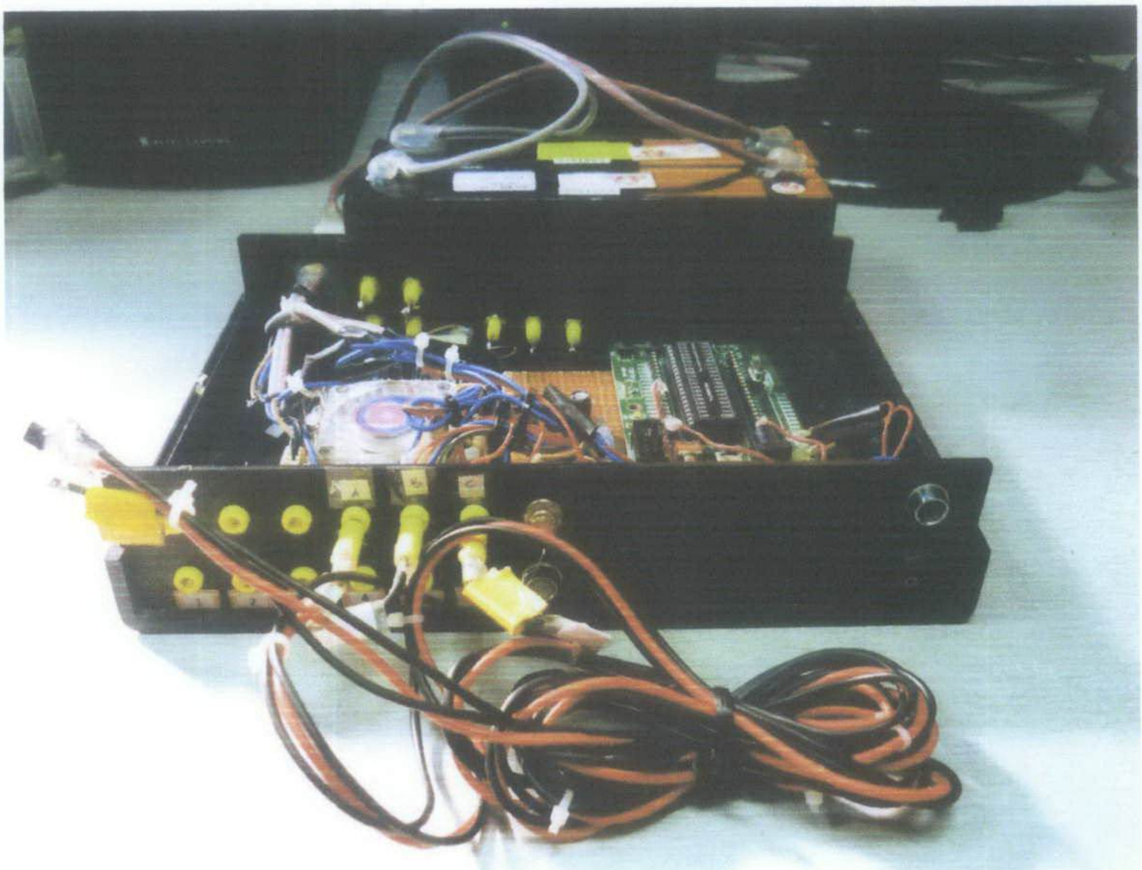

Figure 4.9 Integrated Circuit

The system was programmed using MPLAB IDE v.8.46. The complete programming coding can be found in the Appendix.

4.3 Fully Integrated System

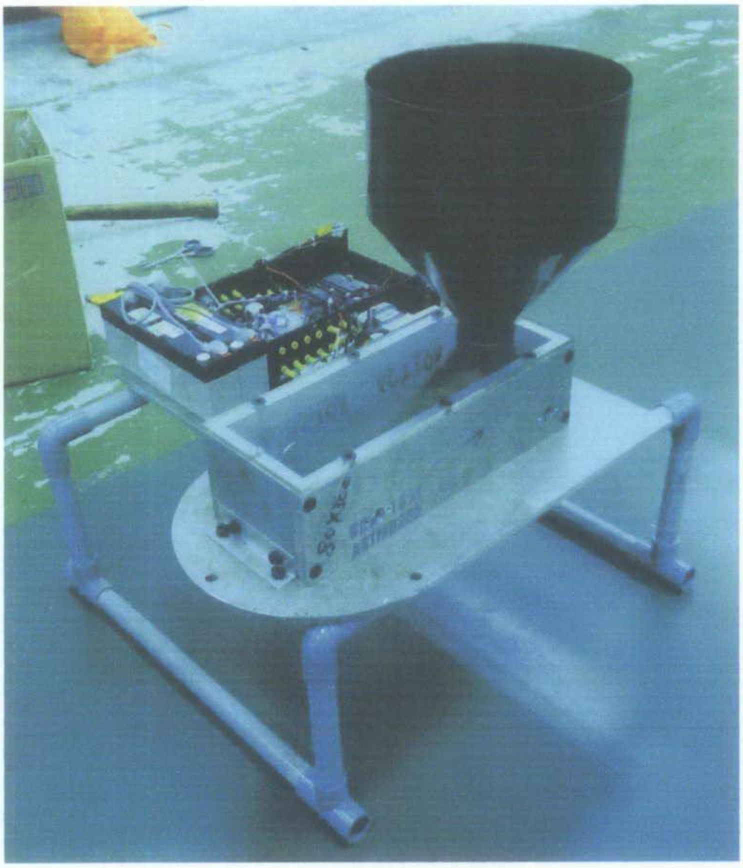

Figure 4.10 Fabricated Unit Ready

Main components of the system:

Components	Descriptions
SK40C 	SK40C is a 40 pins PIC microcontroller start up kit. It is designed for an easy to start board for PIC MCU. It uses the PIC16F877A for the microcontroller.
PIC16F877A 	A central processing unit for the system. Pre-programmed using MPLAB IDE v.8.46.

SD02B 	SD02B is a motor driver to drive the stepper motor. The board incorporates most of the components of the typical applications.
LM35 	The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. The range of the input is -55 to +150°C.
Battery 	Two 12V, 2.3A needed for the system to give 24V to the motor.
Stepper Motor 	A 6 wired stepper motor with 3.5kg.cm holding torque. A high torque and smooth running stepper motor for the system.

Table 4.1 Main Components of the System

CHAPTER 5

EXPERIMENTAL RESULTS

5.1 Experimental Data

The performance of the system was checked experimentally by means of calibration study. The speed of the motor was varied between 50 and 255 (PWM) during the calibration study for rice husk and wood chip particles. The calibration of the feeder was conducted by repeating the measurement of time required to feed 20 grams of particles at different speeds input. Table 5.1, 5.2 and Figure 5.1 shows the data gained from the experiments and graph generated from the experiments.

1. Rice Husk

   Mass = 20 grams

Speed (PWM)	50	100	150	200	255
Time (s)	62.5	53.15	46.45	41.37	35.3
Feed Rate (g/s)	0.32	0.376	0.431	0.483	0.567

Table 5.1 Data using Rice Husk

2. Wood Chip

Mass = 20 grams

Speed (PWM)	50	100	150	200	255
Time (s)	67.12	57.42	51.24	44.31	40.52
Feed Rate (g/s)	0.298	0.348	0.39	0.451	0.494

Table 5.2 Data using Wood Chip

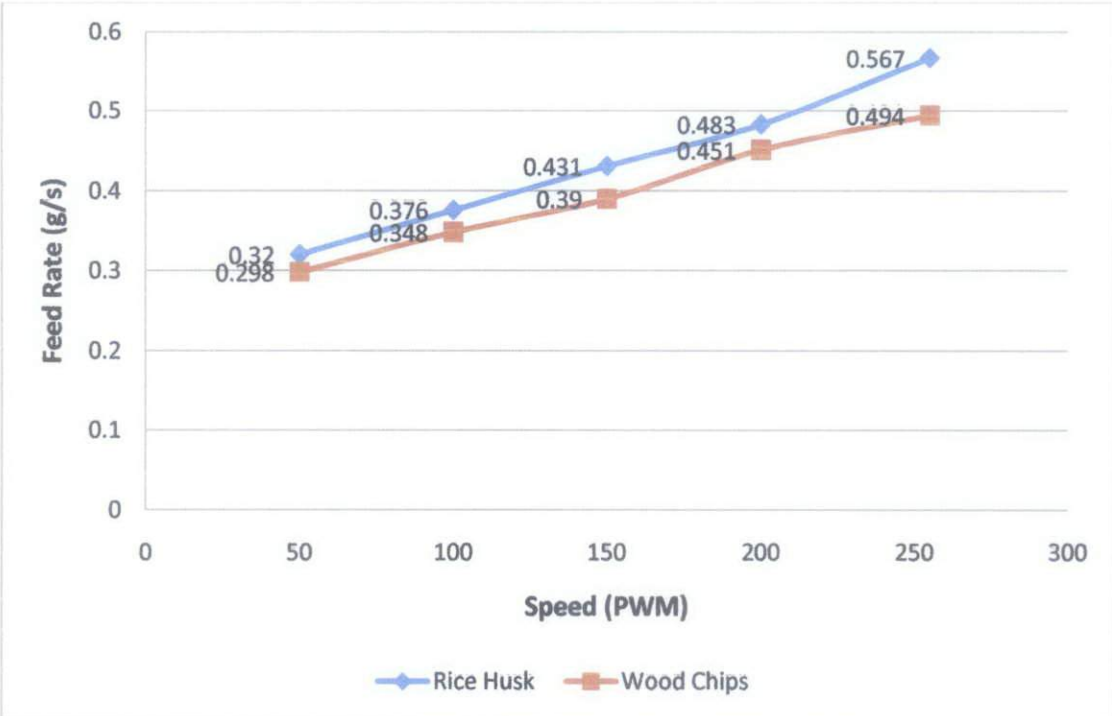

Figure 5.1 Variation of feeding rate with motor speed for respective particles

5.2 Discussions

Figure 5.1 shows that the mass feeding rates of both Rice Husk and Wood Chips increase directly proportional with increasing motor speed. However the data does not have a constant incremental rate with respect to the speed. This was due to the unexpected problems encountered during the experiments. The problems are:

1. The hopper design

   Rice husk can easily flow onto the conveyor but not in the case of wood chips which have bigger particle size than that of rice husks. To ease the experiment, during the feeding, the hopper needs to be stirred continuously to aid the particles to flow onto the conveyor.

2. Empty gaps inside the feeder

   There are gaps along the side of the conveyor which the particles can fall into. The particles that fell can make the conveyor stuck during the feeding process. This happened during the feeding of the wood chips. Because of the size of the particles, the feeder got jammed and maintenance was done to remove the particles. To continue the experiment, I add temporary features inside the feeder to close all the gaps along the side of the conveyor.

3. Position of hopper

   The hopper inlet position is too near with the edge of the conveyor. Some of the particles can fall into the edge and jammed the conveyor.

Aside from these problems, the feeding system works fine as the control system accurately operates according to the program as in the Appendix. It was difficult to have a temperature source of 80°C so I changed it to stop when it reach 45°C and continue operating if the temperature is below 45°C.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The calibration studies on the new feeder showed that the feeder could be used to feed biomass particles mores steadily than the previous manual conventional feeder. The control system also worked according to the pre-programmed microcontroller. It will operate if the temperature detected is below ±80°C and stop when it reach ±90°. The system is best to operate at the maximum speed as it will make the feeding faster and in the actual combustion process, the required temperature needed will be achieved faster. The experimental study for the design of the new feeder is yet to achieve perfection. Some of recommendations that can be useful:

1. More detailed study on the design of a hopper that can feed particles onto the conveyor. Random shape particles like wood chips are not suitable for this kind of hopper. A bigger diameter of inlet might solve the problem or a design with an automatic stirrer can aid the particle flows.
2. Design the conveyor chamber to be gaps free as possible to prevent obstruction during the feeding. The conveyor must be as close as it can with the wall with a tolerance that the particle cannot slip into.
3. Ratio of the hopper inlet to the conveyor belt width is now 1:2. The ratio was not enough to prevent the particles from spilled out of the conveyor. A ratio of 1:4 might a least prevent that from happening.
4. Based on the first design with the rotary valve. The design can still be implemented by adding a shaking mechanism to solve the particles getting stuck during the feeding.

It can be finally concluded that the control system for the new feeder worked and can be used for future development. The design of the feeder has to be improved with the stated recommendations for it to achieve a perfect feeding mechanism. It meets the objective of the project to have an automated feeding system that can operate without continuous monitoring.

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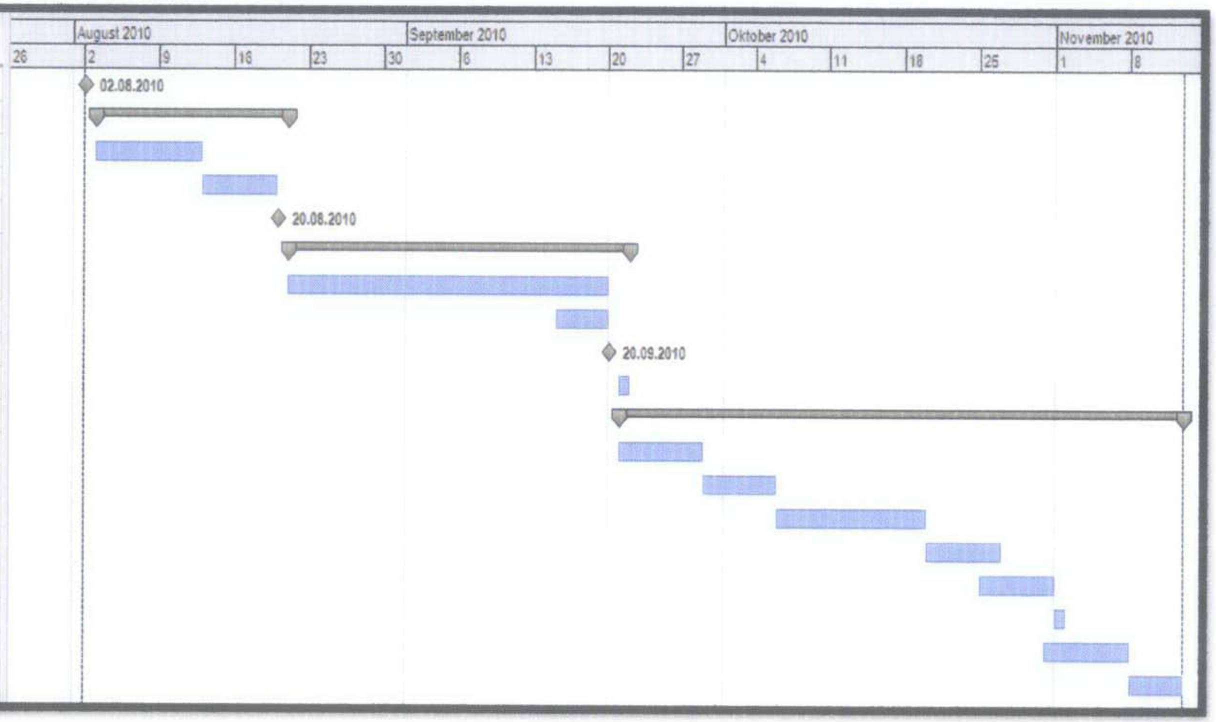
Appendix 1

FYP 1 Project Activities

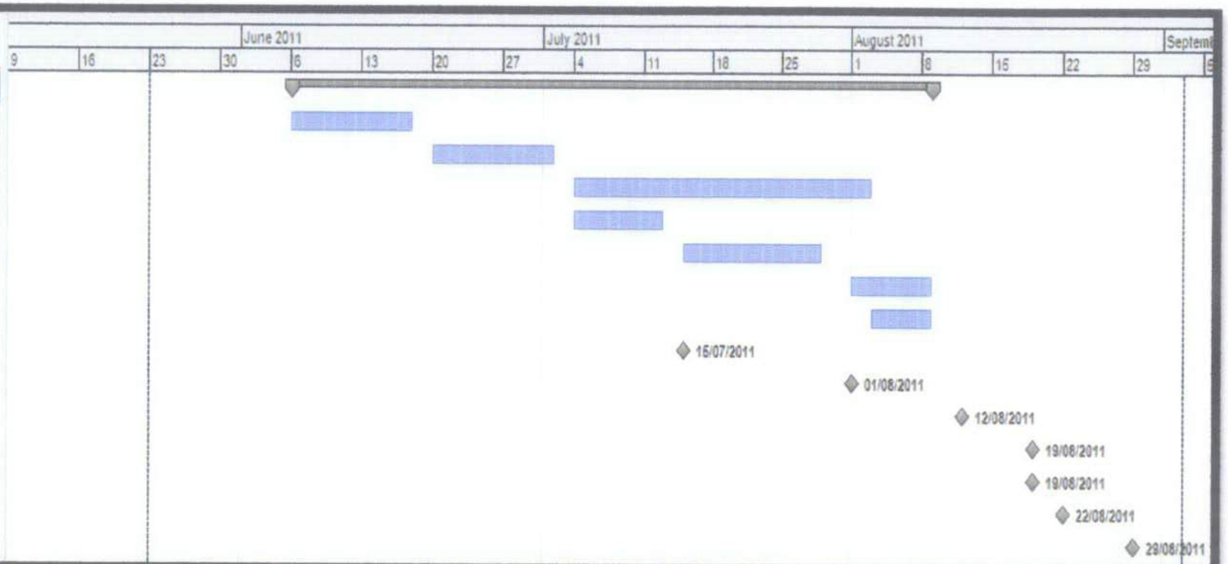
	Task name	Length	Start	Finish
1	Project Title Award	1 d	02.08.2010	02.08.2010
2	⊟ **Preliminary Research**	**18 d**	**03.08.20...**	**20.08.2010**
3	Searching for referances for literature review	10 d	03.08.2010	12.08.2010
4	Preliminary report writing	7 d	13.08.2010	19.08.2010
5	Preliminary report submission	1 d	20.08.2010	20.08.2010
6	⊟ **Project Works**	**32 d**	**21.08.20...**	**21.09.2010**
7	Research on designs of control system for fuel feeding	30 d	21.08.2010	19.09.2010
8	Progress report writing	5 d	15.09.2010	19.09.2010
9	Progress report submission	1 d	20.09.2010	20.09.2010
10	Seminar	1 d	21.09.2010	21.09.2010
11	⊟ **Continuation of Project**	**53 d**	**21.09.20...**	**12.11.2010**
12	CAD designing	8 d	21.09.2010	28.09.2010
13	Analysis of design	7 d	29.09.2010	05.10.2010
14	Fabrication of model	14 d	06.10.2010	19.10.2010
15	Dry tests	7 d	20.10.2010	26.10.2010
16	Interim report writing	7 d	25.10.2010	31.10.2010
17	Interim report submission	1 d	01.11.2010	01.11.2010
18	Preparation for oral presentation	8 d	31.10.2010	07.11.2010
19	Oral presentation	5 d	08.11.2010	12.11.2010



Appendix 2

FYP 2 Project Activities

	Task name	Length	Start	Finish
1	Continuation of Project	46 d	06/06/2011	08/08/2011
2	Re-evaluate design	10 d	06/06/2011	17/06/2011
3	Analysis of design	10 d	20/06/2011	01/07/2011
4	Fabrication of model	22 d	04/07/2011	02/08/2011
5	Control system finalization	7 d	04/07/2011	12/07/2011
6	Circuitary and Programming	10 d	15/07/2011	28/07/2011
7	Control system testing	6 d	01/08/2011	08/08/2011
8	Full System Test	4 d	03/08/2011	08/08/2011
9	Progress Report Submission	1 d	15/07/2011	15/07/2011
10	Pre-EDX	1 d	01/08/2011	01/08/2011
11	Draft Report Submission	1 d	12/08/2011	12/08/2011
12	Soft bound dissertation	1 d	19/08/2011	19/08/2011
13	Technical Paper Submission	1 d	19/08/2011	19/08/2011
14	Oral Presentation	5 d	22/08/2011	26/08/2011
15	Hard Bound Dissertation	5 d	29/08/2011	02/09/2011



Appendix 3

```
//====================================================
=================================

//

//        Author                    : Mohamad Adib bin Ishak

//        Project                   : Design and Implementation of Control System for Fuel
Feeding

 //       Project description       :

//        Date                      : 2011

//

//====================================================
=================================


//====================================================
=================================

// Include file

//====================================================
=================================

#include <pic.h>



//====================================================
=================================

// Configuration

//====================================================
=================================

__CONFIG(0x3F32);
```

```
//============================================================
=====================================

//Define
//============================================================
=====================================
#define ADC_DATA    ADRESH                      //define adc port
#define LED1        RB5                         //define LEDs
#define LED2        RB6
#define LED3        RB7
//============================================================
======================================
// Function Prototype
// User can write all the necessary function here
//============================================================
======================================


void delay(unsigned long data)
{
        // this is a delay function for user to use when the program need a delay
        // this function can be call by type : delay(xxxx),
        // user can replace the 'xxxx' with a value to determine how long the program
        // should delay for, the bigger the value, the longer the time of the delay
        for( ;data>0;data-=1);
}
```

```
void init(void)                         // subroutine to initialize

{

        TRISA = 0b11111111;

        TRISB = 0b00011111;

        SPBRG=129;                              // set baud rate as 115200 baud

        BRGH=1;

        TXEN=1;

        CREN=1;

        SPEN=1;

}


void display(unsigned char c)           // subrountine to display the text on the screen

{

        while (TXIF == 0);

        TXREG = c;

}


unsigned char receive(void)             // subrountine to receive text from PC

{

        while (RCIF == 0);

        a = RCREG;

        return a;

}
```

```
void setup_adc ( void )
{
        ADCON0 = 0b10000000;          //Left justified, RA0, RA1 and RA3 as ADC input
        ADCON1 = 0b01000100;          //Fosc/32, channel 0, ADC not active, ADC off
}

unsigned char read_adc ( unsigned char channel )
{
        switch (channel)
        {
                case 1:
                ADCON0 = 0b10000001;
                break;
                case 2:
                ADCON0 = 0b10001001;
                break;
                case 3:
                ADCON0 = 0b10011001;
                break;
                default:
                ADCON0 = 0b10000000;
        }

        delay(5);                     // delay for a while
        ADGO = 1;                     // start conversion
```

```
        while (ADGO) continue;
        ADON = 0;                       // Off ADC module
        return ADRESH;          // return ADC result

}

//=========================================================
======================================
//      Main Function
//      This is the main function where program start to execute
//=========================================================
======================================
void main(void)
{
        int analogs;
        init();

        LED1=1;
        LED2=0;
        LED3=1;

        while(1)
        {

                analogs = read_adc(1);
```

```
avrg = avrg+analogs;

if(analogs>23)                  //set temperature set point to 45 degrees Celsius
{
LED2=1;
LED3=1;
display ('B');                  //Commands for Stepper Motor
display ('O');
display ('<');                  //Direction For Stepper
display ('O');
display ('S');                  // Command Stop Motor when Temperature is 45
degrees
display("0");

}

if((analogs<23)&&(analogs>22))
{
LED2=0;
LED3=0;
display ('G');
display ('O');
display ('<');
display ('O');
display ('S');
display("1");           //Command Speed Motor To lowest speed when temp about 45
degrees
delay(20000);
```

```
        LED2=1;
        LED3=1;
        delay(20000);
        }

        if(analogs<22)
        {
        LED2=0;
        LED3=0;
        display ('G');
        display ('O');
        display ('<');
        display ('O');
        display ('S');
        display("255");            // Command Speed Maximum when temperature is lower than
40 degree
        delay(10000);
        LED2=1;
        LED3=1;
        delay(10000);

        }

        }

}
```

Appendix 4

Table: Sensor and PIC Calibration:

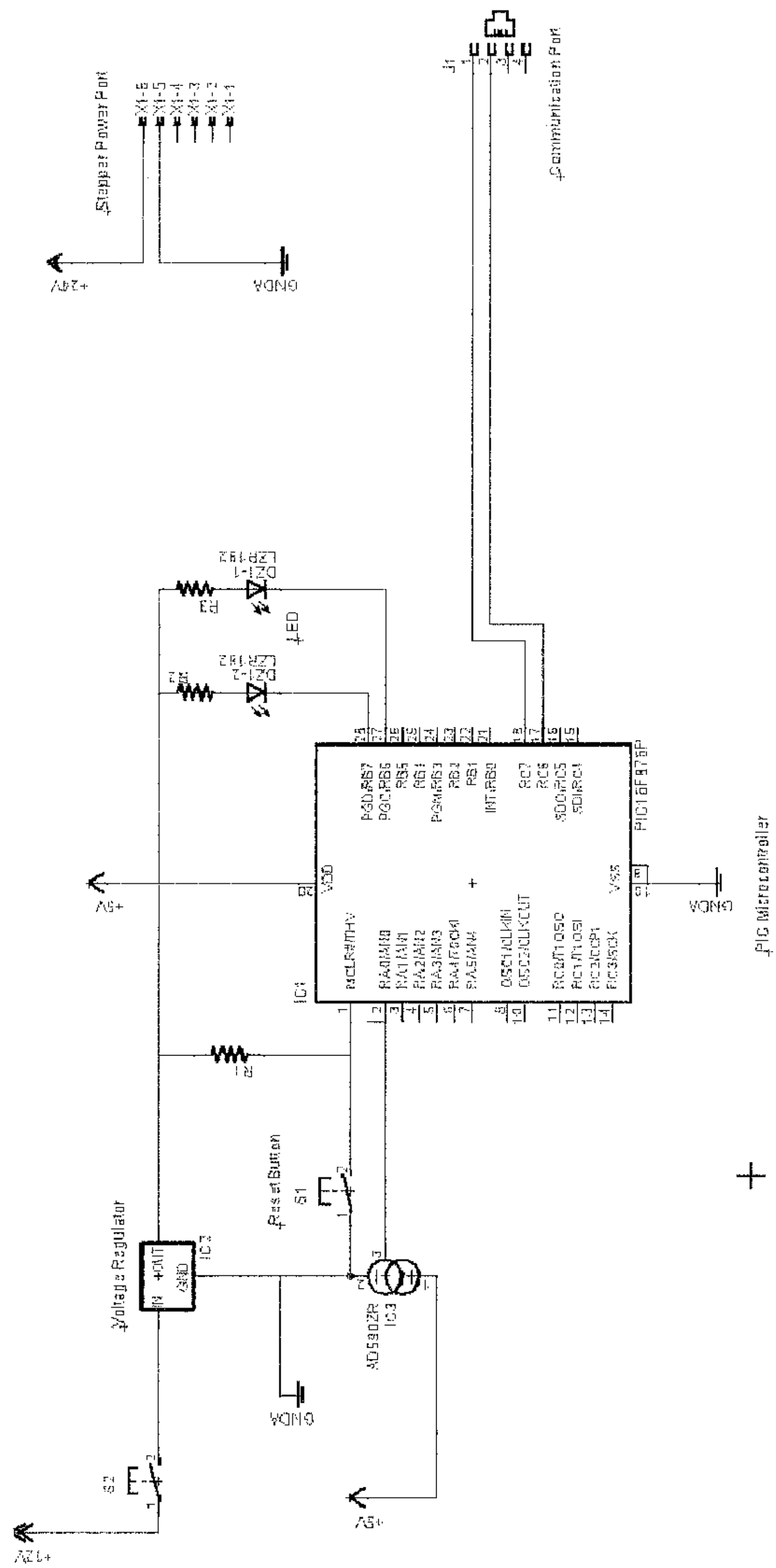
PIC ADC Value	Temperature (degree)
0	0
1	1
2	3
3	5
4	7
5	9
6	11
7	13
8	15
9	17
10	19
11	21
12	23
13	25
14	27
15	29
16	31
17	33
18	35
19	37
20	39
21	41
22	43
23	45
24	47
25	49
26	51
27	53
28	55
29	57
30	59
31	61
32	63
33	65
34	67
35	69
36	71
37	73
38	75

39	77
40	79
41	81
42	83
43	85
44	87
45	89
46	91
47	93
48	95
49	97
50	99
51	101
52	103
53	105
54	107
55	109
56	111
57	113
58	115
59	117
60	119
61	121
62	123
63	125
64	127
65	129
66	131
67	133
68	135
69	137
70	139
71	141
72	143
73	145
74	147
75	149

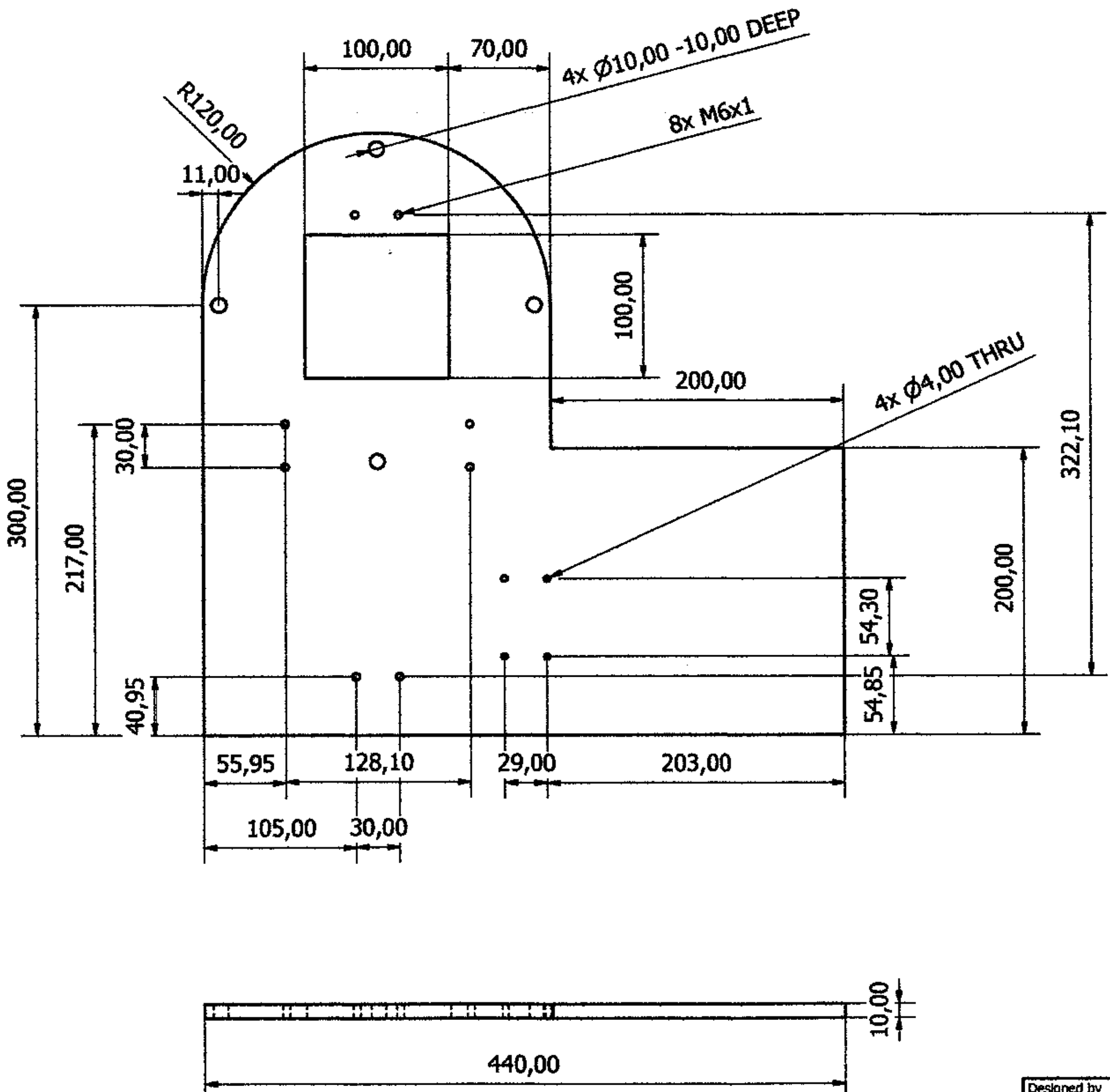
PIC ADC resolution bits = 8bits

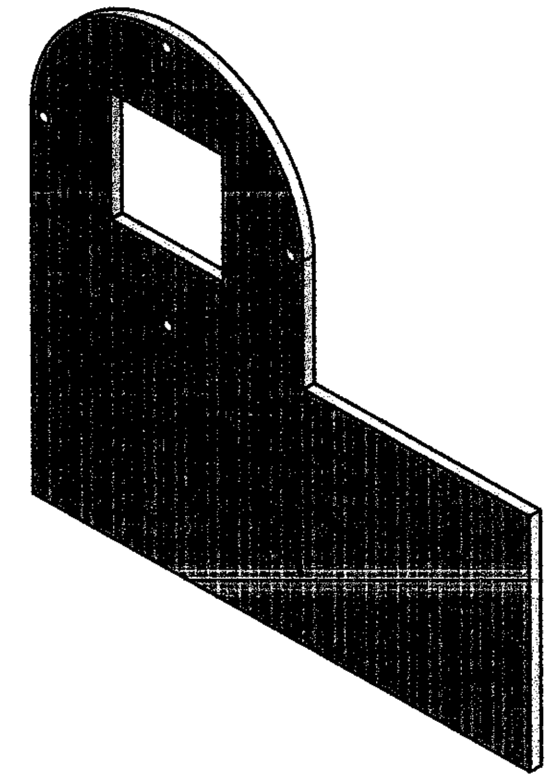
since 2^8 = 256. The values can represent the ranges from 0 to 255.

Appendix 5



Stepper Power Port
Communication Port
PIC Microcontroller
LED
Reset Button
Voltage Regulator
GNDA
+5V
+24V
+12V





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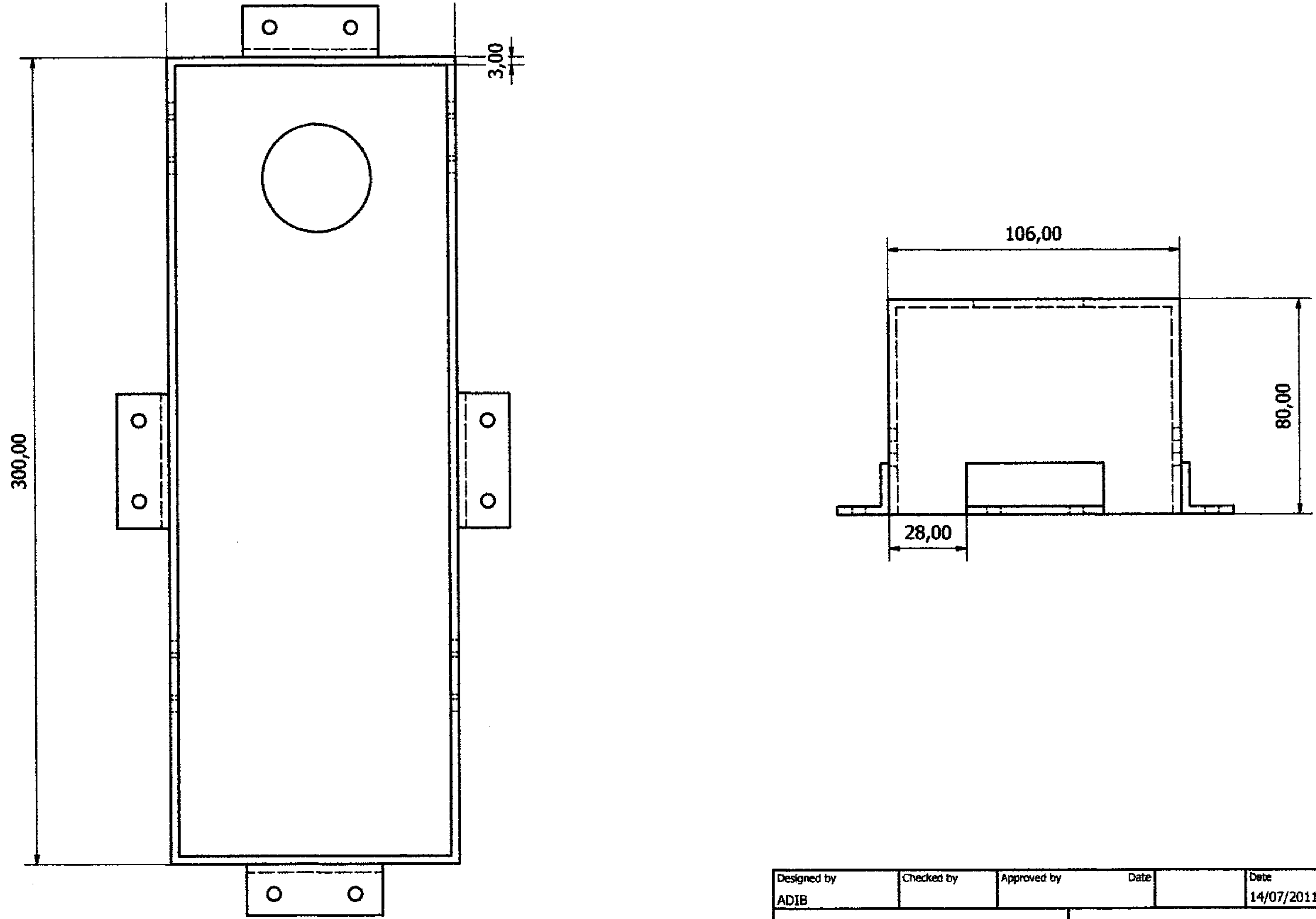
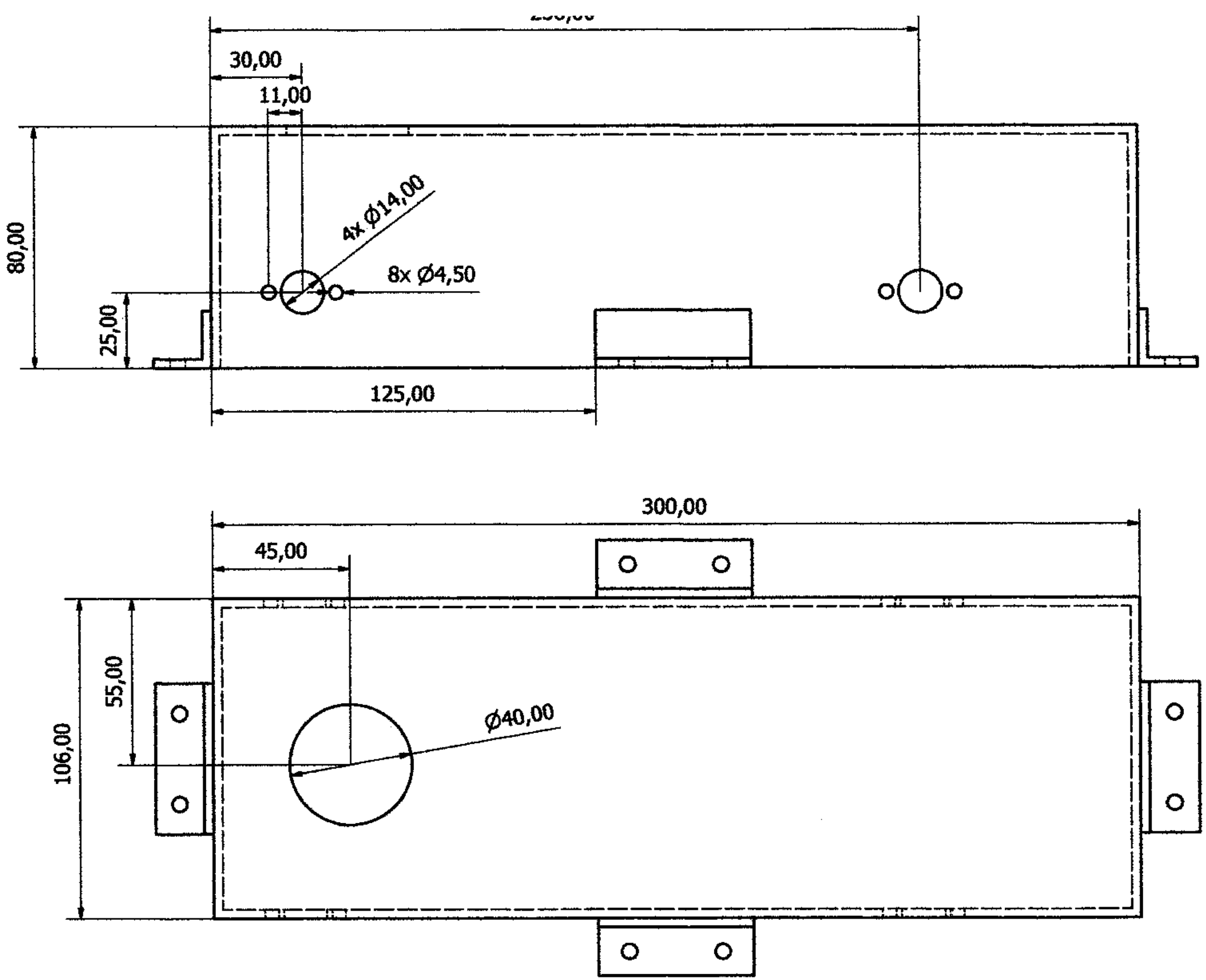
ADIB				14/07/2011
	Base			
	Base	Edition	Sheet 1 / 1	



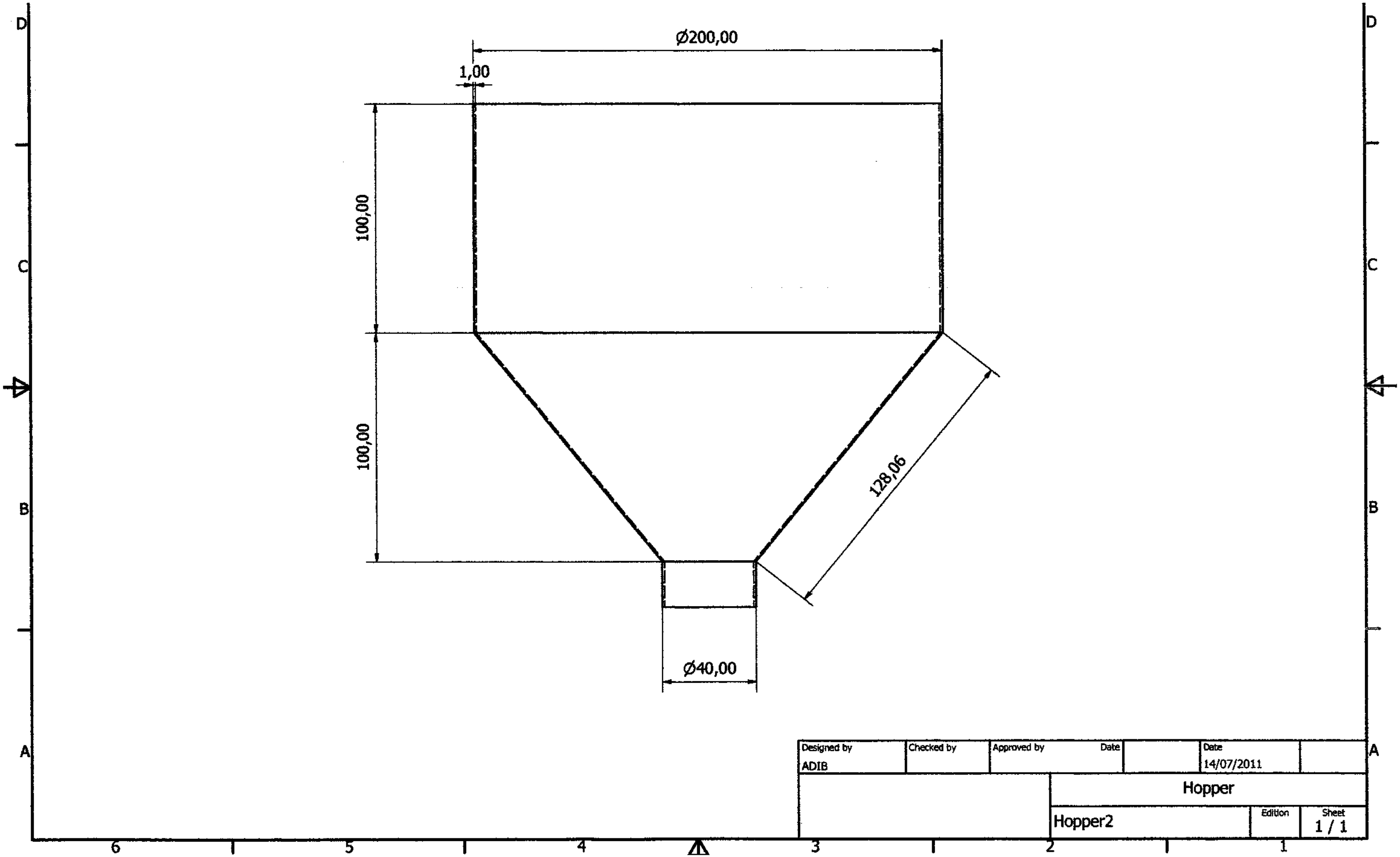
Designed by	Checked by	Approved by	Date	Date
ADIB				14/07/2011

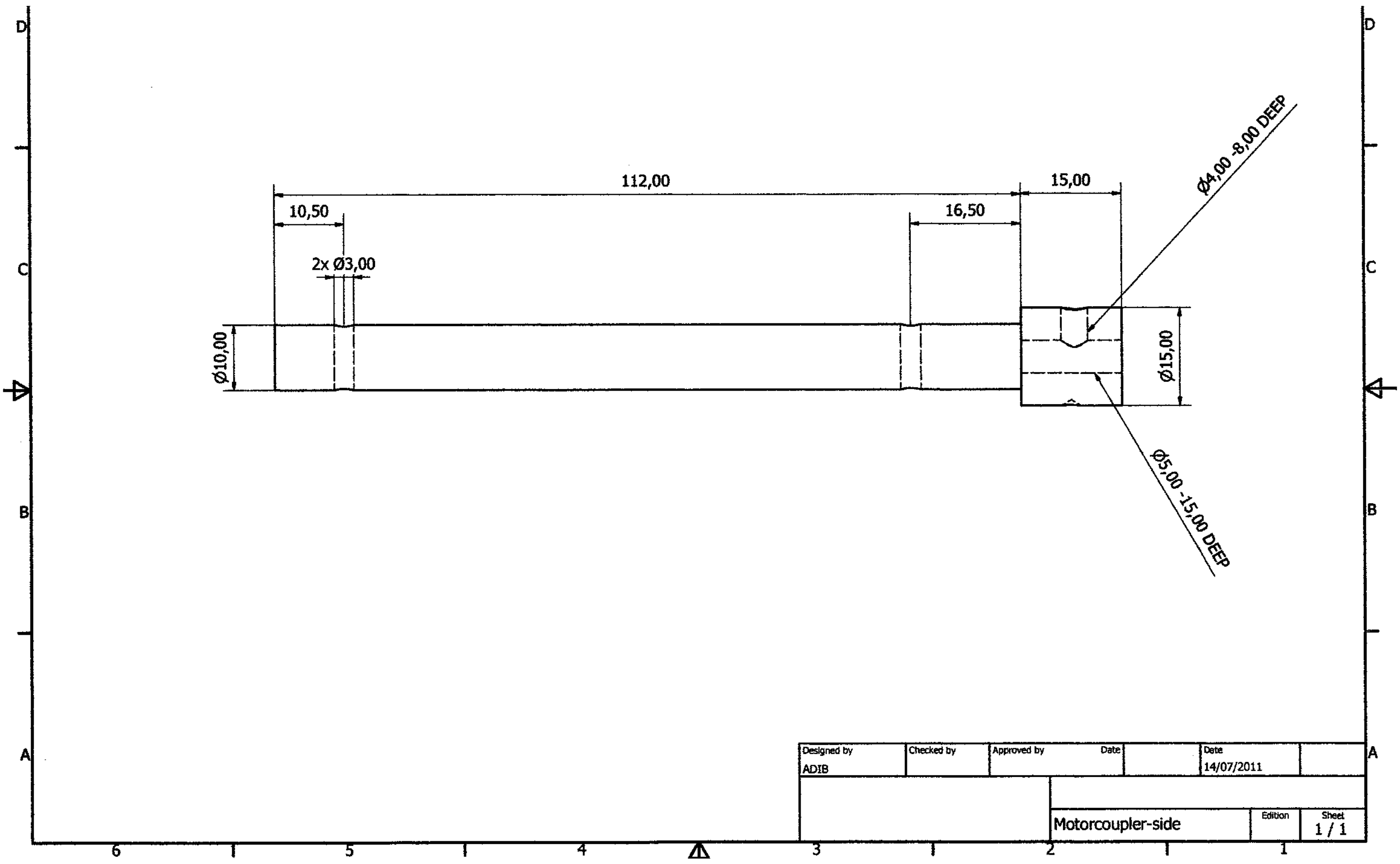
Side & Bottom		
Body-Side&Bottom	Edition	Sheet 1 / 1



Designed by	Checked by	Approved by	Date	Date
ADIB				14/07/2011

Top & Front		
Body-Top&Side	Edition	Sheet 1 / 1


Ø200,00
1,00
100,00
100,00
128,06
Ø40,00
Designed by
ADIB
Checked by
Approved by
Date
Date
14/07/2011
Hopper
Hopper2
Edition
Sheet
1 / 1


112,00
10,50
16,50
15,00
2x Ø3,00
Ø10,00
Ø15,00
Ø4,00 -8,00 DEEP
Ø5,00 -15,00 DEEP
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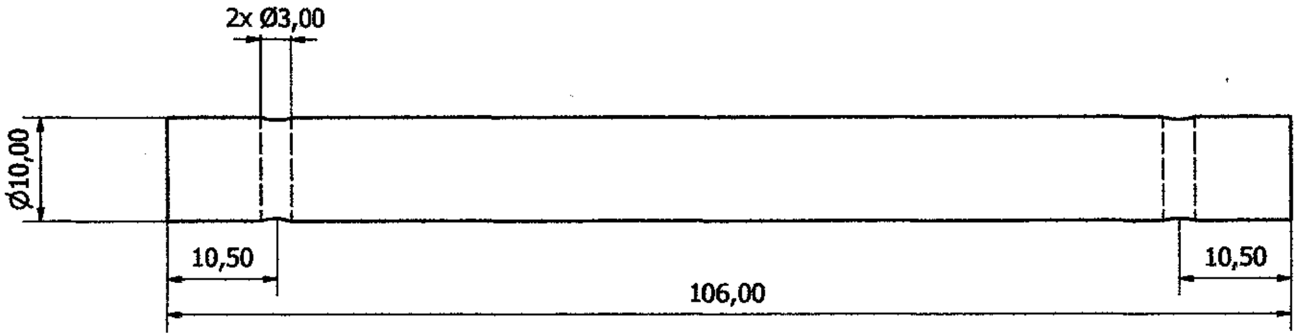
Date
Date
14/07/2011
Motorcoupler-side
Edition
Sheet
1 / 1



Designed by	Checked by	Approved by	Date	Date
ADIB				14/07/2011

Shaft2		
shaft2	Edition	Sheet 1 / 1