Metered Multi-Moisture Detector

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2008

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.

MARNI BINTI MUHAMAD

ABSTRACT

This project explains the design of moisture detector with the use of microcontroller. Theory of resistivity and conductivity principles were implemented in this project. The metered multi-moisture detector used probes to detect the wetness or dryness of chosen substances; paddy, corn and red beans. The use of microcontroller was introduced in achieving the desired output. Microcontroller was programmed using C programming. It converted the voltage drop measured into moisture content (in percentage) and displayed the value through LCD. This metered multi-moisture detector is portable and cost effective device.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Moisture content of agricultural products is one of the most important characteristics for determining proper time for harvest and the potential for safe storage. It is also an important factor in determining the market price, because the dry matter of grain has more value than the water it contains.

The methods of determining moisture content can be divided into two broad categories: direct and indirect. Direct method determines the water content by removing the moisture. For examples, heating, distillation, infra red radiation and microwave radiation. Indirect method requires the measurement of an electrical property of grain, either conductance or capacitance. Resistance, capacitance and relative humidity are the examples of indirect measurement.

Moisture meters are designed to measure the moisture content of various substances. Moisture meters are used for quality control to ensure proper moisture levels. Operator needs to penetrate the material being tested if they use the electrical resistance approach [1]. They read the voltage drops across the two probes which become an input for microcontroller. Microcontroller will convert the input to percentage of moisture content and LCD displays the reading.

A microcontroller is a very powerful tool that allows designer to create sophisticated I/O data manipulation algorithms. Data is received from external input devices and stored in special compartments inside chip. It will process and sent out the data through external output devices.

1.2 Problem Statement

Currently, several methods have been developed to detect and measure the moisture content in substance such as woods, grains and soil. However, those devices can detect only for certain substance. Different substance may have different percentage of moisture content. Today, moisture meters in the market can detect the moisture content for grains only and some of them can sense wood-based materials only. Those devices cannot measure several substances and thus make it difficult and highly cost for users.

Standard method for determining moisture content in grain requires oven drying method for specific time periods at specified temperatures by prescribed methods. However, such methods are tedious and time-consuming, they are not suitable for general use in the grain grade, and other rapid testing methods have been developed.

The only definite way to determine moisture content is to use metered multi-moisture detector. These modern practical grain moisture detectors work on the principle of sensing electrical characteristics of grain, which are highly correlated with moisture content.

1.3 Objectives and Scope of Study

1.3.1 Objectives

The objectives of this project are listed as below:

- To determine the specific range of moisture content for paddy, corn and red beans.
- To design a low cost, portable multi-moisture detector
- To enhance the stability of moisture reading during the measurement

1.3.2 Scope of Study

This design is focused on measuring moisture content for several substances such as paddy, corn and red beans. All chosen substances are based on the availability of samples for laboratory experiments. The type of paddy have been used in this project is MR219. Specific moisture range of each substance was determined in order to design the circuit. Below are the limitations of the project [2]:

Table 1 Specific range of moisture content in percentage

Substance	Before Drying (%MC)	After Drying (%MC)
Paddy	20-25	14
Corn	20-22	15.5
Red beans	27	10

Before drying range refers to the harvesting percentage of MC range while after drying refers to percentage of MC for storage. The data in Table 1 had been used as a reference during the lab experiment in determining the moisture content.

The moisture meter's design uses a pair of probes to detect resistances and voltage drops across them. For microcontroller's design, PIC16F877A and an oscillator are used. The microcontroller has a 10-bit multi-channel Analog-to-Digital converter; which converts the analog input (voltage drop across probes) into digital output (by displaying the percentage of MC on LCD display).

CHAPTER 2

LITERATURE REVIEW

2.1 Conductivity

Conductance meter usually consists of two to four metal probes, or pins. Those probes are physically inserted into substance. They read the moisture content of the substance through the electrical resistance/conductance detected between the probes. As moisture levels goes higher, the electrical conductance also increased. There are two types of moisture level displays for the conductance meter; analog (needle indicator) and digital (alphanumeric indicator) displays. Liquid crystal display (LCD) or light-emitting diode (LED) technology was widely used for digital displays [3].

Conductance of a substance can be known by measuring the ability of a sample to conduct current relative to its moisture content. Water is a very good conductor when minerals from substances are added. Most materials are easily dissolved in water, and the easier it dissolves in water, more ionized atoms will be produced. Theoretically, wet sample has higher moisture content because it has more ions and thus conducts electricity well compared to dry sample. As the conductivity of substrate increases, the moisture content also increases [4].

2.2 Ohm's Law

Basically, lower percentage of moisture content has higher resistance and vice versa. Ohm's law will be a good fundamental in determining the relationship between the voltage drop and resistance. Based on Ohm's law (V=IR), as the resistance increases, the voltage drop also increases. The probes from the moisture meter will measure a high value of voltage drop if lower moisture content is measured. The voltage will be used as an input to microcontroller.

2.3 Gravimetric Technique

Gravimetric technique is used in laboratory experiment to determine the relationship between voltage and moisture content. It involves preparing a sample and determining the mass of water content in relation to the mass of dry sample. In other words, it can be done by weighing a sample before and after water is removed.

As a start, a sample of substance is weighed (minus the weight of container) to measure its wet weight. The sample is dried up to certain temperature and reweighed. This weight (minus the weight of container) is the dry weight. Then, the difference between the wet and dry weight is calculated to obtain the weight of water that the sample contained. Dividing the water weight by the wet weight gives the moisture content as a fraction [5].

2.4 Sensivity

A pair of probes was used as the sensing element to detect the moisture content in sample of substance. A pair of steel nails with 7cm long and 4mm diameter was used because it can conduct electricity well. The distance between probes is one of the most important criterions in designing the probes because it might affect the measurement result. Therefore, suitable distance is needed and a distance of one inch is held as constant for the probes [6].

The probes were inserted into the substances to measure the electrical resistance/conductance between probes. As the exposed area of probes become larger, the sensitivity also increases. Higher moisture levels indicate better electrical conductance and thus higher moisture readings.

2.5 Microcontroller

A microcontroller is a compact standalone computer, optimized for control applications. Entire processor, memory and the I/O interfaces are located on a single piece of silicon so, it takes less time to read and write to external devices. A processor executes the programs digitally while program memory stores the program that has been compiled successfully by programmer. The Random-Access-Memory (RAM) stores the "variables". The function of I/O port is to connect sensor, keypad, LED, relay and so on. The use of timer in microcontroller is to count the time to execute some process [7].

PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 8 channels of 10-bit Analog-to-Digital (A/D) Converter, 2 additional timers, 2 capture/compare/PWM functions, the synchronous serial port can be configured. All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

The PWM helps to adjust the duty cycle (how long the output is high or low) of a square wave and adjust the frequency of the square wave by giving the PIC the information in the code [8]. The A/D converters can be used to "read" an analog voltage like the output voltage of the probes. Then, the voltage will be represented by PIC as a binary number.

CHAPTER 3

METHODOLOGY

3.1 Project Work Flow

Figure 1 shows the work flow for this project. It is divided into three main parts. Firstly, it starts with an ideation and then proceeds with the implementation; which involves the lab experiments, circuit and PCB design. Lastly, the refinements of prototype have been done from time to time.

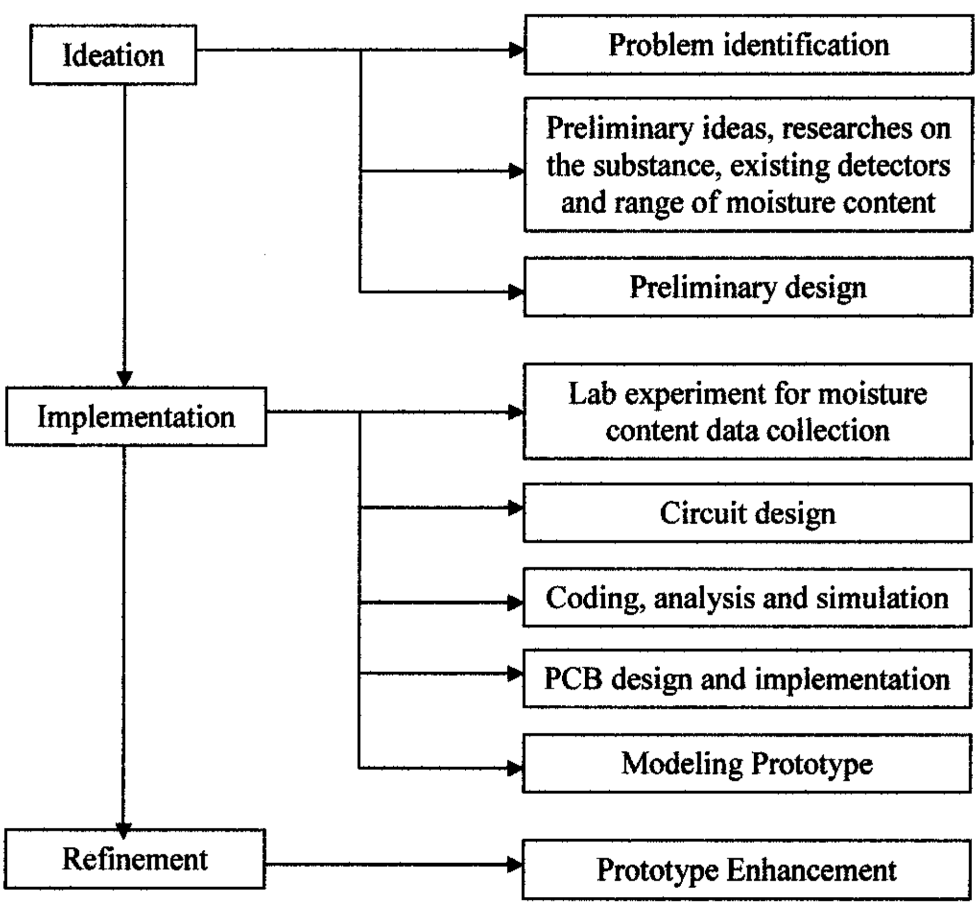


Figure 1 Plan and flow of project

A brief description about the project work flow is stated below:

1- Researches have been done from time to time in order to get enough information regarding the project. The information were focused on the following:
    - The substances (paddy, corn and red beans), specific range of percentage of moisture content for each substance and its characteristics.
    - Interview with officer at Institute of Agriculture for conducting the lab experiments (Gravimetric technique)
    - Existing devices in order to get some ideas in designing the circuit for the moisture meter.

2- Laboratory experiments were done to determine required data such as moisture content for chosen substances and relationship between moisture content and voltage drop across probes.

3- The microcontroller programming language has been developed part by part in the project. The steps involved in programming the PIC were:
    i. Writing the C programming
    ii. Compiling the program before proceeding to the next step
    iii. Burning the PIC chip using Warp13 Kit.

4- Circuit characterization. Component selection has been done, the type of microcontroller most suitable for this project, the initial circuit design and so on.

5- The circuit is implemented on bread board initially. Once the circuit troubleshooting is done, the project continued with PCB design. C programming was prepared and simulated until it gave the required output.

3.2 Operation Flow Chart

Figure 2 shows the detector operation flow chart. The process started with turning on the switch and output was displayed by LCD.

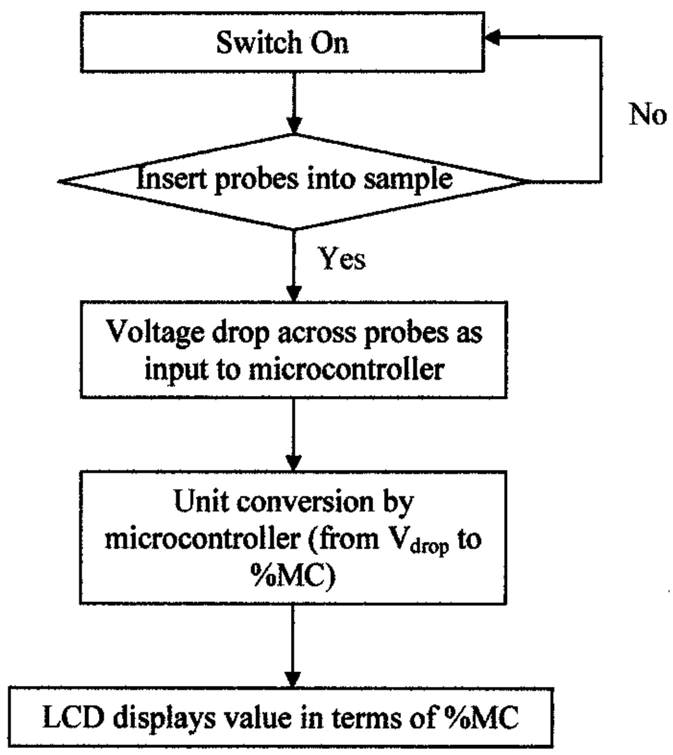


Figure 2 Detector operation flow chart

3.3 Laboratory Experiments

Laboratory experiments have been done for data analysis and calibration purposes. The laboratory experiment details can be found in Appendix B. The flow chart of experiment is shown in Figure 3.

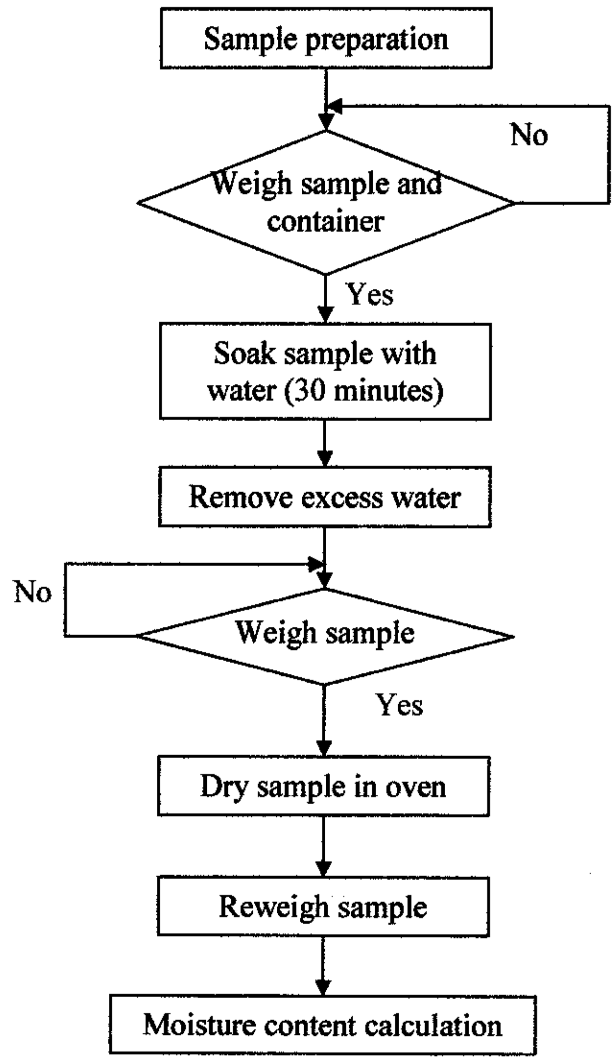


Figure 3 Lab experiment flow chart

3.4 Tools and Software

Tools (equipments, hardware and etc.) and software needed in this project are listed as shown in Table 2:

Table 2 Equipments needed for the project

Items	Description
1. Lab equipments	▪ 150 ml and 250 ml beakers ▪ Digital weighing scale (ae ADAM digital balance) ▪ Drying oven ▪ 100ml measuring cylinder
2. Electronic components	▪ A pair of probes ▪ Oscillator ▪ Microcontroller- PIC16F877A ▪ Battery (6V) ▪ 2x20 LCD display ▪ Resistors ▪ Voltage regulator, LM7805
3. Software	▪ PCW C Compiler IDE ▪ AutoCAD 2005 ▪ PSpice / Eagle software (PCB design)

Table 3 shows the list of electronic components with its cost.

Table 3 Estimated cost of electronics components

Component	Quantity	Cost/unit (RM)	Cost (RM)
PIC16F877A	1	20.00	20.00
2x20 LCD	1	60.00	60.00
PCB	1	10.00	10.00
Crystal oscillator 4MHz	1	1.50	1.50
Switch	4	1.00	4.00
Probes	2	0.30	0.60
Battery	4	1.00	4.00
Resistors	2	0.10	0.20
Voltage regulator, LM7805C	1	1.20	1.20
Total cost			RM101.50

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Interviews – Institute of Agriculture

First interview was done with Mr. Idris Sulaiman, Assistant of Agriculture in Paddy Processing Unit at Institute of Agriculture Titi Gantong, Perak. Second interview was done with Mrs. Fatimah Wati Tahir, lab assistant in the same unit. Below are the questionnaires for the interviews:

- What is the drying method used by the institute; for production and development paddy?

  The institute has used silo and LSU dryer for production while oven drying method for development (lab experiment). Even though it is a tedious and time-consuming process, however it is the most suitable way to ensure that the products have reached the standard moisture content level.

- For lab experiment, how the institute conducts the experiment?

  They also applied Gravimetric technique and oven drying method. The sample is dried up in oven for 2 hours with temperature 130°C and cooled down for 45 minutes after the drying process.

- Why do we need to cool it down after drying process?

This is because the weight of hot sample from oven is different with the one in room temperature. Therefore, before we reweigh the sample, it must be kept in dessicator cabinet for 45 minutes.

- <u>How long the harvested paddy can last before fungi development?</u>

The harvested paddy can only be in best quality just for 2-3 days. After that, fungi development occurs due to high percentage of moisture content in sample.

4.2 Moisture Content Calculation

Below is the formula used to determine the moisture content in unit of percentage:

$$\text{MC} = \frac{\text{Weight of moisture in wet sample}}{\text{Weight of wet sample}} \times 100\%$$

or

$$\text{MC} = \frac{(\text{Weight of wet sample - weight of dry sample})}{\text{Weight of wet sample}} \times 100\%$$

During drying process, sample has lost several weights due to loss of moisture content. The formula to calculate the final weight of sample is:

$$\text{Final weight of sample} = \frac{\text{Initial weight x } (100 - \%\text{MC Initial})}{(100 - \%\text{MC Final})}$$

4.3 Results of Experiment

Oven drying method is used for the experiment; with Gravimetric technique. This method was tedious and time-consuming, but very important in order to calibrate and design the circuit. This project used oven-drying method to dry sample; which is basically reverse process from actual oven-drying method. The purpose is to verify that the amount of moisture content from experiment is similar to the actual amount of moisture content discussed in Chapter 1 (scope of study).

Once sample water content was removed, the amount of remaining water was determined and used to calculate the percentage of moisture content in sample. Several trials were done for sample of paddy, corn and red beans. The results of the experiment are summarized in **Appendix D**. Based on the experiment; the average of percentage of moisture content can be calculated and summarized in Table 4:

Table 4 Average of percentage of moisture content

Substance	%MC			
	1	2	3	Avg
Paddy	18.75	21.88	18.75	19.79
Corn	20.22	20.00	19.40	19.87
Red beans	25.93	28.57	25.00	26.50

Based on the results, for example, the average percentage of MC for paddy is 19.79%MC. In the scope of study discussed earlier, the %MC before drying is approximately 20-25%MC. Table 5 below is developed to compare between the experiment values with actual values. Therefore, it is verified that the value is closer to the actual value.

Table 5 Comparison between actual and experiment value of %MC

Substance	Experiment	Actual (%MC)
Paddy	19.79	20-25
Corn	19.87	20-22
Red beans	26.50	27

Table 6 below shows relationship between voltage drop and moisture content.

Table 6 Voltage drop versus moisture content

	V	%MC		V	%MC		V	%MC
PADDY	3.135	5	CORN	3.254	5	RED BEANS	2.881	5
	3.021	7		3.198	7		2.764	7
	2.986	10		3.067	10		2.535	10
	2.821	12		2.943	12		2.442	12
	2.538	15		2.691	15		2.269	15
	2.311	17		2.415	17		2.132	17
	1.825	20		1.923	20		1.752	20
	0.869	25		0.919	25		0.653	25
	0.532	27		0.628	27		0.411	27

The graphs represent the measured values of voltage drop versus moisture content for paddy, corn and red beans.

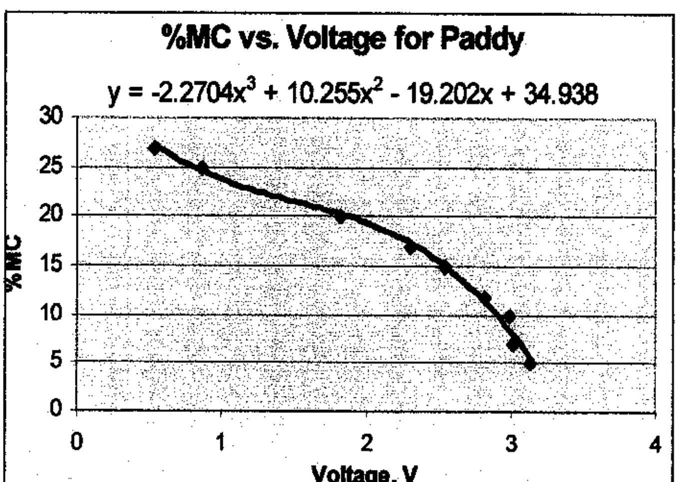


Figure 4 MC vs. voltage drop for paddy

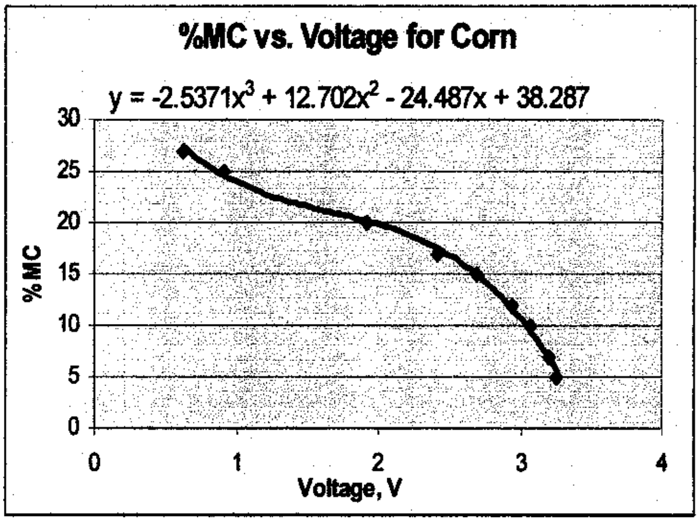


Figure 5 MC vs. voltage for corn

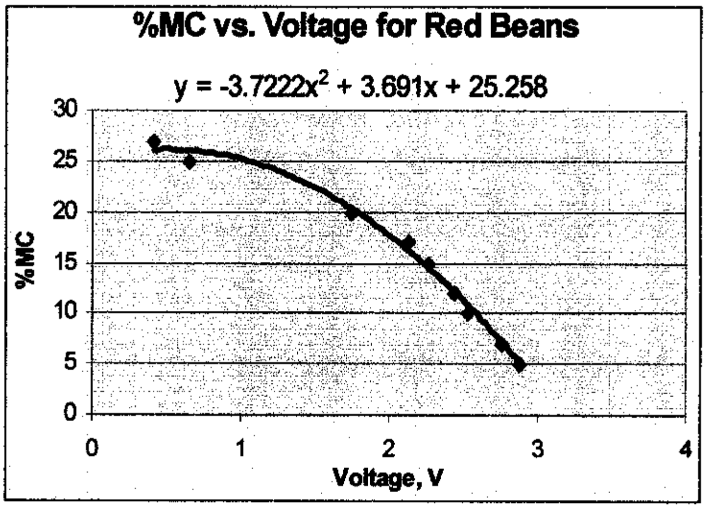


Figure 6 MC vs. voltage for red beans

The voltage drop across probes was measured using a known value of moisture content sample. From the results obtained, the trend line for paddy and corn are quite similar to each other; which is a third order polynomial. Both samples have high value of voltage drops with low percentage of moisture content. Based on Ohm's law, the voltage drop increased when the value of resistance also increased. For red beans, the graph corresponded to a second order polynomial.

4.4 Component Selection

As mentioned earlier in Chapter 3, PIC16F877A has been used in the project. For the microcontroller moisture detector, there was an output; the LCD display and an input; the probe circuit.

When an analog input (voltage drop in this case) exists, there is a need to convert them into digital input because PIC can only process in digital form, either 1 (voltage exists) or 0 (no voltage).

Figure 7 Microchip PIC16F877A

An external oscillator was connected to the OSC1 input. Crystal (XT) oscillator was chosen in this project because the mode was designed to give a compromise between high frequency operation and modest power consumption, and also more stable than resonators and RC networks. It is also recommended for operation at up 4MHz. For XT mode, two capacitors are needed. Figure 8 shows the minimum PIC configuration.

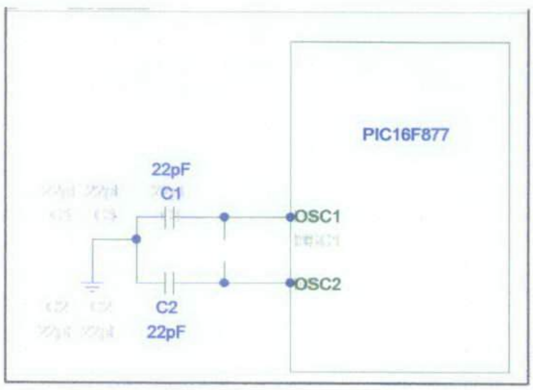


Figure 8 Minimum PIC configuration with XT mode

Table 7 below shows the types of mode for PIC configuration for the project and types of capacitor values.

Table 7 Capacitor selection for crystal operation

Mode	Frequency	C1, C2
LP	32 kHz	68-100pF
LP	200 kHz	15-33pF
XT	100 kHz	100-150pF
XT	2 MHz	15-33pF
XT	4 MHz	15-33pF
HS	4 MHz	15-33pF
HS	10 MHz	15-33pF

An LCD display has made a microcontroller much more user-friendly as it enables numeric values to be an output in a more versatile manner than 7-segment display. Basically, there are 2 types of LCD display; parallel and series. Parallel LCD; which has 2 lines x 20 characters has been chosen for the project. It is connected to the microcontroller circuitry and then transferred to the LCD unit using more than one data line.

4.5 Voltage Range and Resolution

By implementing the line #device ADC=8 in C programming, the analog to digital conversion is set to 8 bit resolution. The range of the ADC of PIC16F877A is 0V to 5V and the ADC conversion is 8 bits. Hence, the resolution is $2^8-1=255$. The formula for built-in A/D converter is given below:

$$V_{in} = \frac{X}{255} \times V_{fullscale}$$

where X represents the digital output.

Using the formula within a program which had X, the voltage being applied was known and used to display the actual voltage on an LCD readout.

For programming, the examples of commands are as follows:

```
adcvalue = read_adc();
Vin = 5*adcvalue/255;
```

4.6 Design of Multi-Moisture Detector

Figure 9 below shows the design of the multi-moisture detector.

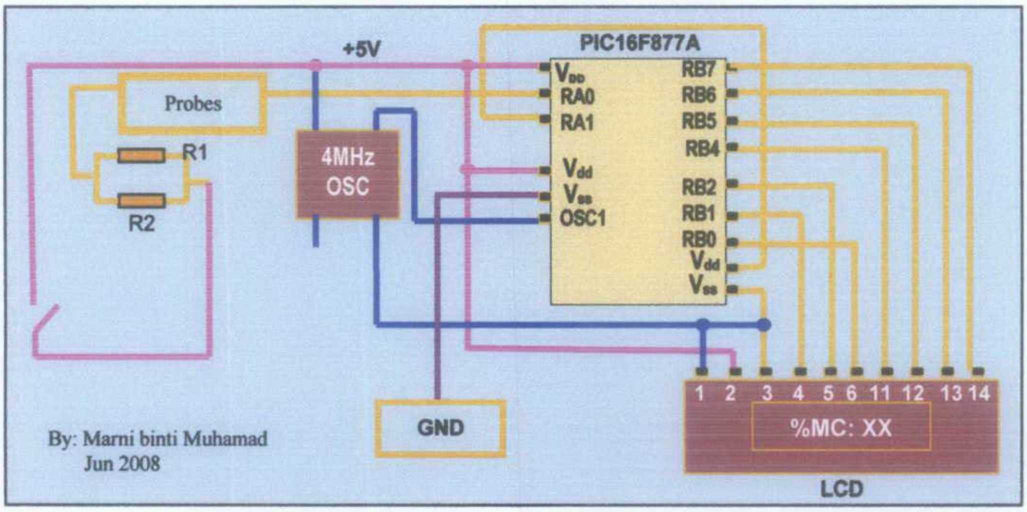


Figure 9 Initial design of moisture detector

The input of microcontroller is an output from the probes. In this project, PIC16F877A and an oscillator have been used. The output port is known as port B, which is set to pin 33 to 40. All these pins are connected to the output, which is the 2x20 LCD display. A power supply of 5V is connected to LCD. The function of oscillator in this project was for clocking purposes since it is the most stable operation for microcontroller. Based on the C programming, the LCD displayed the moisture content in terms of percentage of moisture content.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

There are several kinds of moisture detectors; where one detector is only suited for one kind of substance. The output for this project is designed for detecting the wetness or dryness of paddy, corn and red beans. Gravimetric technique is applied during the lab experiment in order to calculate the percentage of moisture content and for calibration purposes. The moisture content is reflected by a meter reading and displayed on the Liquid-Crystal display (LCD) using microcontroller.

As conclusion, the objectives of this project have been met. The Author is able to demonstrate specific range of moisture content for paddy, corns and red beans and fabricate a portable and cost effective moisture detector.

5.2 Recommendations

Further improvements can be done to the fabricated device. As for future works, the use of moisture sensor or dual type of moisture meter (probes and pin-less) can make the implementation of detector much easier. A moisture sensor with higher sensitivity will make the detector functions more accurately. For pin-less meter, it uses capacitance technology to detect moisture. The sensor pad, which makes surface contact with the material being tested, sends a radio frequency signal into the material. Ideally, using a pin and pin-less meter together will give the fastest and most accurate results.

Besides that, it is important to determine the reliability of the reading displayed by LCD. It can be done by conducting more experiments to model the mathematical equations for each substance. An alarm also can be added to this detector to indicate high moisture level; which is out of the control limits. Hence, the user will directly know the moisture level in the measured substances.

REFERENCES

[1] Cole-Parmer Technical Library, "What moisture meter should I use?" 2nd August 2007, <http://www.coleparmer.com/techinfo>

[2] Mr. Idris Sulaiman, 2007, Institute of Agriculture, Titi Gantong, Perak.

[3] Building Envelope Research, "Moisture Detection Equipment-Manufacturers", 15th August 2007, <http://alcor.concordia.ca/~raojw/crd/essay/essay000141.html>

[4] M.M Haslinda, J.B. Janier, "Multipurpose Moisture Content Detector", Final Year Project Thesis, Universiti Teknologi PETRONAS.

[5] Robert Rynk, 20th October 2007, "Monitoring Moisture in Composting Systems", http://www.environmental-expert.com/magazine/biocycle/october2000/article1.htm

[6] M.Maliki, J.B. Janier, "Moisture Detector for Paddy", Final Year Project Thesis, Universiti Teknologi PETRONAS, December 2005

[7] Dr.Oh, "PIC16F877 Microcontroller Tutorial Rev.A", 16th February 2008, <http://www.pages.drexel.edu/~cy56/PIC.htm>

[8] Dogan Ibrahim, 2002, *Microcontroller-Based Temperature Monitoring and Control*, Newnes

[9] Rice Quality Workshop 2003, "Measurement of Grain Moisture", 30th August 2007, <http://www.plantsciences.ucdavis.edu/uccerice/QUALITY/rqw2003/C-14MoistureMeasurement2003.pdf>

[10] Tutorial for Microcontroller Beginner Kit, Retrieved 12th January 2008, <http://www.iguanalabs.com/mbktut>

APPENDICES

Appendix A Gantt Chart FYP 1 July 2007

Week Number / Activities	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16
FYP briefing															
Topic selection															
Research on topic															
Gantt chart submission															
Preliminary report submission				17/8											
Material selection															
Seminar (verbal report)							TBA						TBA		
Software selection															
Progress report submission								21/9							
Design															
Draft report submission											10/1 0				
Interim report submission														29/1 0	
Oral presentation															TBA

Appendix B Gantt Chart FYP 2 Jan 2008

Week Number / Activities	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16
FYP briefing															
Circuit design															
Progress report 1				15/2											
Seminar						TBA							TBA		
Other programming and circuit troubleshooting															
Progress report 2								21/3							
Continue work (PCB, poster, miscellaneous)															
Draft report											17/4				
Final report (soft cover)															5/5
Technical report															5/5
Oral presentation															TBA
Submission of dissertation															20/6

Appendix C Laboratory Experiment

Apparatus:

1. 3 beakers (150ml)
2. Digital weighing scale
3. Drying oven
4. 100ml measuring cylinder
5. 3 containers

Sample:
25g of dry paddy per trial

Procedure:

1. Switch on the weighing scale and measure the weight of beaker.
2. Put 25g of dry sample into a beaker and weigh again.
3. Weigh the tap water (with beaker)
4. Soak the sample with 100ml of tap water for 30 minutes. Weigh the sample (with tap water)
5. After that, filter the sample to get rid of the excessive water in the beaker and weigh again the wet sample
6. Dry the sample in the drying oven for 2 hours with 130°C.
7. After drying, cool down the sample in room temperature for 45 minutes.
8. Place the sample in beaker and reweigh.

Calculation:

$$MC = \frac{(\text{Weight of wet sample} - \text{weight of dry sample})}{\text{Weight of wet sample}} \times 100$$

$$\text{Initial weight} = \frac{\text{Final weight} \times (100 - \text{MC initial }\%)}{100 - \text{MC final }\%}$$

Discussion

1. Did each of your samples contain approximately the same amount of moisture content?

2. What was the average moisture of all three samples?

Appendix D Laboratory Experiment Results

1. Moisture content of paddy

	Sample	1	2	3	4	5	Average
Dry	Beaker, g	71	71	71	71	71	71
	Sample, g	26	25	25	26	24	25
	Sample + beaker, g	97	96	96	97	95	96.2
Wet	Beaker, g	71	71	71	71	71	71
	Sample, g	32	32	31	31	31	31.4
	Sample + beaker, g	103	103	102	102	102	102.4
	%MC	18.75	21.88	18.75	16.13	22.58	20.38

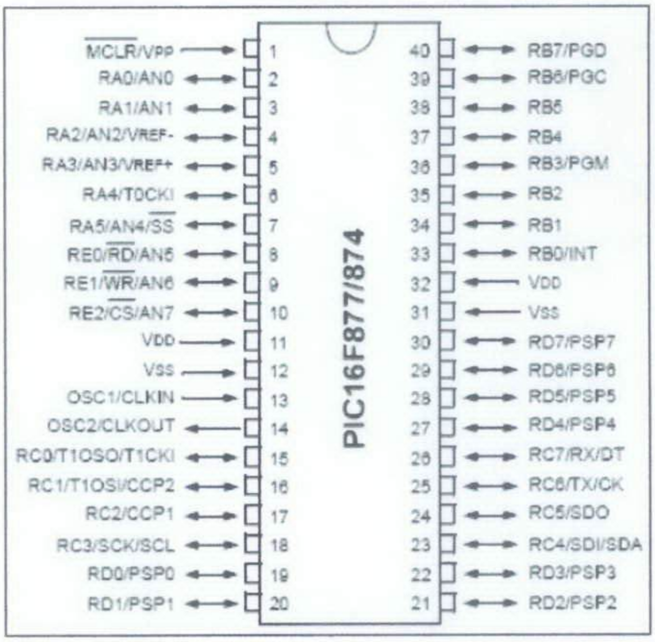
2. Moisture Content of Corns

Item	Remarks	Sample	Corns		
			1	2	3
1	Before soaking	Weight of beaker, g	71	67	67
2		Weight of sample, g	25	25	25
3		Weight of sample + beaker, g	96	92	92
4	During soaking	Weight of beaker, g	71	71	71
5		H2O+beaker, g	124	125	122
6		Sample + H2O, g	149	145	141
7	After soaking	Sample + beaker, g	107	102	103
8		Remaining H2O	114	115	110
9	After drying	Sample + beaker, g	103	98	99

3. Moisture Content of Red Beans

Item	Remarks	Sample	Red Beans		
			1	2	3
1	Before soaking	Weight of beaker, g	69	68	69
2		Weight of sample, g	25	25	25
3		Weight of sample + beaker, g	94	93	94
4	During soaking	Weight of beaker, g	71	71	71
5		H2O+beaker, g	122	123	122
6		Sample + H2O, g	144	145	143
7	After soaking	Sample + beaker, g	96	96	97
8		Remaining H2O	119	120	118
9	After drying	Sample + beaker, g	93	94	94

Appendix E PIC16F877A Data Sheet



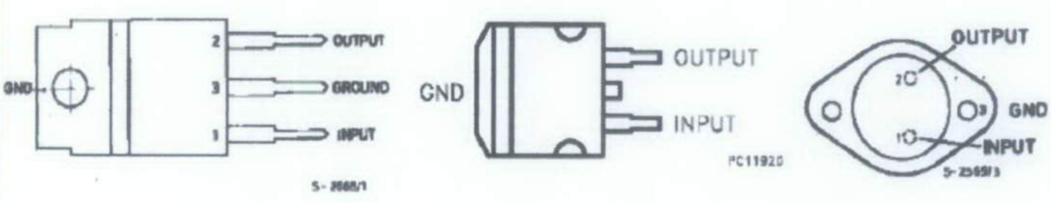
MCLR/VPP	1	1	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	2	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	4	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	5	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/SS/AN4	7	7	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	21	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3/PGM	24	24	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	25	25	I/O	TTL	Interrupt-on-change pin.
RB5	26	26	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	27	27	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	28	28	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

VSS	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
VDD	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

Appendix F LM7805C Data Sheet

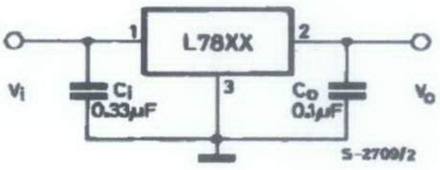
ELECTRICAL CHARACTERISTICS FOR L7805C (refer to the test circuits, T_j = 0 to 125 °C, V_i = 10V, I_o = 500 mA, C_i = 0.33 μF, C_o = 0.1 μF unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
V_o	Output Voltage	T_j = 25 °C	4.8	5	5.2	V
V_o	Output Voltage	I_o = 5 mA to 1 A $P_o \leq$ 15 W V_i = 7 to 20 V	4.75	5	5.25	V
ΔV_o*	Line Regulation	V_i = 7 to 25 V T_j = 25 °C V_i = 8 to 12 V T_j = 25 °C		3 1	100 50	mV mV
ΔV_o*	Load Regulation	I_o = 5 to 1500 mA T_j = 25 °C I_o = 250 to 750 mA T_j = 25 °C			100 50	mV mV
I_d	Quiescent Current	T_j = 25 °C			8	mA
ΔI_d	Quiescent Current Change	I_o = 5 to 1000 mA			0.5	mA
ΔI_d	Quiescent Current Change	V_i = 7 to 25 V			0.8	mA
$\frac{\Delta V_o}{\Delta T}$	Output Voltage Drift	I_o = 5 mA		-1.1		mV/°C
eN	Output Noise Voltage	B = 10Hz to 100KHz T_j = 25 °C		40		μV
SVR	Supply Voltage Rejection	V_i = 8 to 18 V f = 120 Hz	62			dB
V_d	Dropout Voltage	I_o = 1 A T_j = 25 °C		2		V
R_o	Output Resistance	f = 1 KHz		17		mΩ
I_{sc}	Short Circuit Current	V_i = 35 V T_j = 25 °C		750		mA
I_{scp}	Short Circuit Peak Current	T_j = 25 °C		2.2		A



TO-220 & ISOWATT220 D²PAK TO-3

APPLICATION CIRCUIT



Appendix G Main Program for One Substance

```
/////////////////////////////////////////////////////////////////
//      METERED MULTI-MOISTURE DETECTOR                        //
//                                                             //
//      The program is to display the moisture content of     //
//      paddy and corn                                         //
//                                                             //
//      When toggle switch is ON (channel 0), it will          //
//      calculate the MC for paddy and corn                    //
//                                                             //
//                                                             //
//      Written by: MARNI BINTI MUHAMAD                        //
//      Date:   26th May 2008                                  //
//                                                             //
/////////////////////////////////////////////////////////////////


// Preprocessor Directives//

#include <16F877A.h>            // use the PIC16F877A as the microcontroller
#device ADC=8                   // 8 bit analog to digital converter
#fuses XT, NOWDT, NOPROTECT, NOPUT, NOBROWNOUT, NOLVP       // XT- crystal oscillator
#use delay(clock = 4000000)     // 4MHz oscillator
#include <LCD.C>                // lcd.c included to display the moisture content
#include <stdio.h>

void main()
{

//      Local Definitions

   lcd_init();          // lcd initializations
   set_tris_b(0x00);    // set port b as output for lcd

   setup_adc_ports(ALL_ANALOG);       // set port a as analog input
   setup_adc(ADC_CLOCK_INTERNAL);     // using adc internal clock

// Statements
   while(1)
   {

      float calcmc;
      float finalmc;            // define variable for calmc1 and finalmc1
      set_adc_channel(0);       // set pin a0 as input

      delay_ms(50);
      calcmc = read_adc();      // read data using the ADC

      finalmc=38.287-24.487*calcmc+12.702*calcmc*calcmc-2.5371*calcmc*calcmc*calcmc;

      output_b(finalmc);       //use port b to output the digital word

      delay_ms(100);       // delay 100 ms
      lcd_gotoxy(1,1);  // lcd requirement for initial display

      lcd_putc('\f');
      printf(lcd_putc,"MC:%6.3f", finalmc);    // display 'MC:'

      delay_ms(100);       // delay 100 ms

   }

} //main//
```

Appendix H Main Program for Three Substances

```
//////////////////////////////////////////////////////////////
//      METERED MULTI-MOISTURE DETECTOR                     //
//                                                          //
//      The program is to display the moisture content of   //
//      paddy and corn                                      //
//                                                          //
//      When toggle switch 1 is ON (channel 0), it will     //
//      calculate the MC for paddy and corn                 //
//                                                          //
//      When toggle switch 2 is ON (channel 1), it will     //
//      calculate the MC for red beans                      //
//                                                          //
//      Written by: MARNI BINTI MUHAMAD                     //
//      Date:   26th May 2008                               //
//                                                          //
//////////////////////////////////////////////////////////////


// Preprocessor Directives

#include <16F877A.h>            // use the PIC16F877A as the microcontroller
#device ADC=8                   // 8 bit analog to digital converter
#fuses XT, NOWDT, NOPROTECT, NOPUT, NOBROWNOUT, NOLVP      // XT- crystal oscillator
#use delay(clock = 4000000)     // 4MHz oscillator
#include <LCD.C>                // lcd.c included to display the moisture content
#include <stdio.h>

// Global Declarations

float sub_1();
float sub_2();
float finalmc;

void main()
{

//      Local Definitions

   lcd_init();              // lcd initializations
   set_tris_b(0x00);        // set port b as output for lcd

   setup_adc_ports(ALL_ANALOG);      // set port a as analog input
   setup_adc(ADC_CLOCK_INTERNAL);    // using adc internal clock

// Statements
   while(1)
   {
      sub_1();              // go to function sub_1()
      sub_2();              // go to function sub_2()

      delay_ms(100);        // delay 100 ms
      lcd_gotoxy(1,1);      // lcd requirement for initial display

      lcd_putc('\f');
      printf(lcd_putc,"MC:%6.3f", finalmc);

      delay_ms(100);        // delay 100 ms

   }

} //main//


// This function is to calculate the %MC in paddy n corn

float sub_1()
{
   float calcmc, finalmc;      // define variable for calmc2 and finalmc2
   set_adc_channel(0);

   delay_ms(50);
   calcmc = read_adc();
```

```
   finalmc=38.287-24.487*calcmc+12.702*calcmc*calcmc-2.5371*calcmc*calcmc*calcmc;

   output_b(finalmc);

}  //sub_1//

// This function is to calculate the %MC in red beans
float sub_2()
{
   float calcmc, finalmc;
   set_adc_channel(1);

   delay_ms(50);
   calcmc = read_adc();

   finalmc=25.258+3.691*calcmc-3.7222*calcmc*calcmc;

   output_b(finalmc);

}  //sub_2//

/////////////////////////END OF PROGRAM////////////////////////////////////////////
```

Appendix I Metered Multi-Moisture Detector Circuit and Prototype