INTELIGENT TOMOGRAPHY SYSTEM (ELECTRICAL CAPACITANCE TOMOGRAPHY)

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ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS

JUNE 2009

Intelligent Tomography System
(Electrical Capacitance Tomography)

By

Noor Fatiha Binti Mohd Azmi

Interim report submitted in partial fulfilment 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
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

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June 2009

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.

8/6/09

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ABSTRACT

Electrical Capacitance Tomography (ECT) is an intelligent tomography system that is used as a monitoring system for the industrial process. It is important to monitor specific process in industry so that we can get valuable information that may be used for visualization, monitoring, mathematical model verification and intelligent control of the process under investigation. ECT has several advantages over other tomography techniques in process industry such as low-cost, rapid response, portability, non-invasive and robustness. ECT capacitance sensor is made up of 8 electrodes that are arranged around a vessel. In order to obtain voltage measurements between electrode pairs for all 8 electrodes around the vessel, data acquisition system (DAS) is used to take the measurements simultaneously. These measurements are recorded in the computer program which is HyperTerminal. Image reconstruction of materials distribution in the vessel can be obtained by using the measurement values that can be developed in MATLAB. However, this project only covers a part of ECT which is DAS and capacitance sensor of ECT.

ACKNOWLEDGMENTS

My biggest appreciation to my Final Year Project Supervisor, Dr Taj Muhammad Baloch for his guidance throughout completing this project. He has been very patient to teach me and provide information regarding my project for better understanding. Without his help, the project will not be successful.

Last but not least, thank you to all lab EE department lab technicians for their assistance while I am doing laboratory works.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

In the 1980s, engineers began to investigate low-cost techniques to image the flows in pipes and vessels found in manufacturing industries. The term industrial process tomography refers to non-invasive visualization techniques, which is at that time, is still new and developing. Tomography techniques provide the understanding of visualizing the internal behavior of industrial processes.

The image reconstruction or cross-sectional images produced by tomography systems provide valuable information on the process, which can be used for visualization, monitoring, mathematical model verification and possibly for intelligent control. Tomography technology involves the acquisition of measurement signals from sensors located on the periphery of an object, such as a process vessel or pipeline. The basic components of any tomography instrument are divided into hardware and software. Hardware parts include sensors and signal/data control while for software parts include signal reconstruction, display and interpretation facilities and generation of output control signals to process hardware.

Electrical capacitance tomography (ECT) is regarded as a successful method for visualizing cross-sectional distribution and measuring multi-phase flows of the process. Image reconstruction for ECT is complicated because of the non-linear relationship between electrical measurements and the permittivity of the measured material. However, ECT offers some advantages over other tomography modalities, such as no radiation, rapid response, low cost, being non-intrusive and non-invasive, and the ability to withstand high temperature and high pressure.

1.2 Problem Statement

There are many types of tomography techniques, including ionizing radiation (e.g., x-ray and γ-ray), optical, positron emission (PET), nuclear magnetic resonance (NMR), acoustic (including ultrasound), electrical (i.e., capacitive, conductive and inductive) and microwave. Each of these techniques has its own advantages and disadvantages. Therefore, the choice depends on the subject under investigation.

We want to develop a system that can be used as an intelligent system to monitor specific process in the industry. This is important because with this monitoring system, we can get valuable information regarding the process. Therefore, tomography is one of the most suitable technologies that can be used for this purpose.

Electrical capacitance tomography (ECT) techniques have been investigated extensively during the past decades, as one of process tomography techniques that can be applied in process industry. ECT can generate cross-sectional images of the process being monitored to determine the permittivity distribution and material distribution by utilizing capacitance measurements. The reason why ECT system is chosen for further research for this project is because ECT has several advantages over other tomography techniques, such as low-cost, rapid response, portability, non-invasion and robustness. All of these elements are really important especially in manufacturing industry that always focus on low-cost technology but yet can provide the best results. In industrial area, ECT has found many applications, e.g. measurement of two-phase (gas/liquid and gas/solids) flows in pipelines and the analysis of dynamic processes in fluidized beds.

1.3 Objective and Scope of Study

The objective of this project is to develop a monitoring system for the industrial process by utilizing ECT system. Basically a basic ECT system consists of a sensoring system, a data acquisition system and a control computer as shown on Figure 1 below:

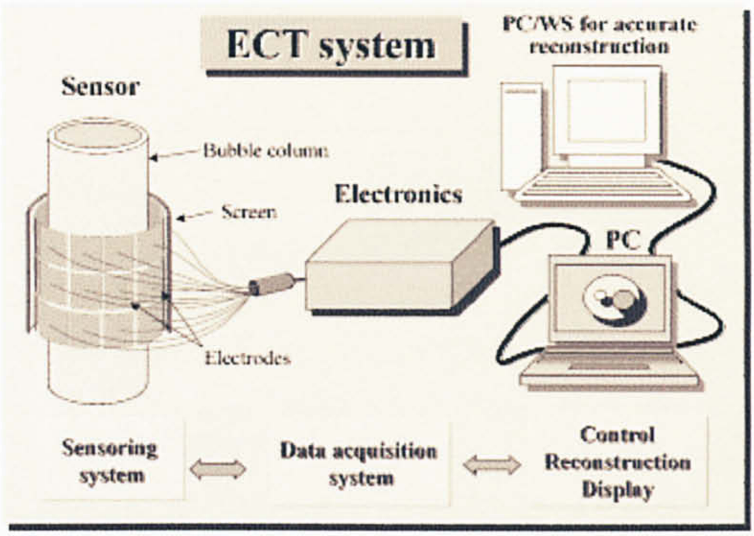

Figure 1: Schematic representation of ECT system [6]

There are two main parts in ECT system which is data acquisition and data processing. For data acquisition which is the hardware part of ECT system will include a capacitance sensor and a capacitance measuring unit. For data processing which is the software is to develop a software program in MATLAB to generate the controlled variable image on control computer as well as to be able to control the process. For this project, the author's interest will be on developing 8 electrodes capacitance sensor and Data Acquisition System (DAS) of ECT. DAS is a very important part of ECT system since it is used to get the values from the capacitance sensor.

CHAPTER 2
LITERATURE REVIEW

2.1 Electrical Capacitance Tomography (ECT)[8]

Electrical Capacitance Tomography (ECT) is a method for determination of the dielectric permittivity distribution in the interior of an object from external capacitance measurements. Potential applications include the measurement of flow of fluids in pipes and measurement of the concentration of one fluid in another or the distribution of a solid in a fluid. Although usually called tomography, the technique differs from conventional tomography methods, in which high resolution images are formed of slices of a material.

The measurement electrodes, which are metallic plates, must be sufficiently large to give a measurable change in capacitance. This means that very few electrodes are used and eight or twelve electrodes are common. An N-electrode system can only provide $M=N(N-3)/2$ independent measurements. This means that the technique is limited to producing very low resolution images of approximate slices. However, ECT is fast, and relatively inexpensive. Basic research on Capacitance Tomography is currently focusing on:

- New generation ECT system using an AC-based capacitance measuring circuit which has a signal-to-noise ratio improved by a factor of 10 compared with existing systems. This system can measure capacitance down to 0.1 femto Farads and is believed to be the world's most sensitive ECT system. A 16-electrode system is under development. For some applications the circuitry should also be able to measure the conductance component for deconvolution/correction purposes; measurement at a range of excitation frequencies may also be needed.

- 2D/3D mathematical modeling tools (e.g. Opera/Tosca/Maxwell packages for electromagnetic field modeling on PC or SUNsparc workstation) for primary sensor design, sensor performance prediction and algorithm development and/or implementation.
- Image reconstruction algorithms taking into account the field distortion caused by high loss or high permittivity components (e.g. saline water).
- Real-time implementation of image reconstruction algorithms (parallel data processing). A new image reconstruction algorithm based on iteratively solving an inverse problem has recently been developed which dramatically improves image quality. The image reconstruction software has been licensed to PTL and provided to users in several countries.
- Industrial applications of tomography techniques, including multiphase flow measurement, fluidized bed analysis, combustion flame monitoring and water hammer analysis.

2.2 Development of a Displacement Current-based Sensor for ECT Applications [2]

Electrical Capacitance Tomography (ECT) and is a common technique to examine the interior of a pipe by means of evaluating coupling capacitances of a multi-electrode assembly. ECT sensors are used in various industrial and laboratory applications in the field of multi-phase flow and feature a noninvasive determination of the cross-sectional permittivity distribution of the pipe content. ECT sensors typically comprise 8–16 electrodes, which are mounted on the outer surface of a non-conducting pipe. A measurement circuit is connected to each of the electrodes to obtain several inter-electrode capacitances, providing information about the permittivity and hence the material distribution in the pipe. A cross-sectional image of this distribution can be reconstructed by solving an inverse problem.

2.3 Electrical Capacitance Tomography Prototype Sensor [2]

To allow for a cost-effective sensor design, minor modifications on the sensors must be done. Less powerful microcontrollers and 16-bit analogue-to-digital converters are used for the 16 front-ends of the prototype sensor. For each time step the electrodes are operated as transmitters or receivers according to the control pattern. Measurement data from the sensor front-ends are collected by means of a preprocessing unit (μCLinux). The main controller is used to control all the front-ends and to provide a connection to the reconstruction PC. Since the sensitivity distribution in the pipe cross-section is predefined by the switching pattern, the permittivity distribution of the pipe content can be obtained and reconstructed. Figure 2 below shows the measurement setup, comprising the 16 electrodes on the outer pipe surface, the grounded shield, the front-end circuits, and the signal preprocessing unit:

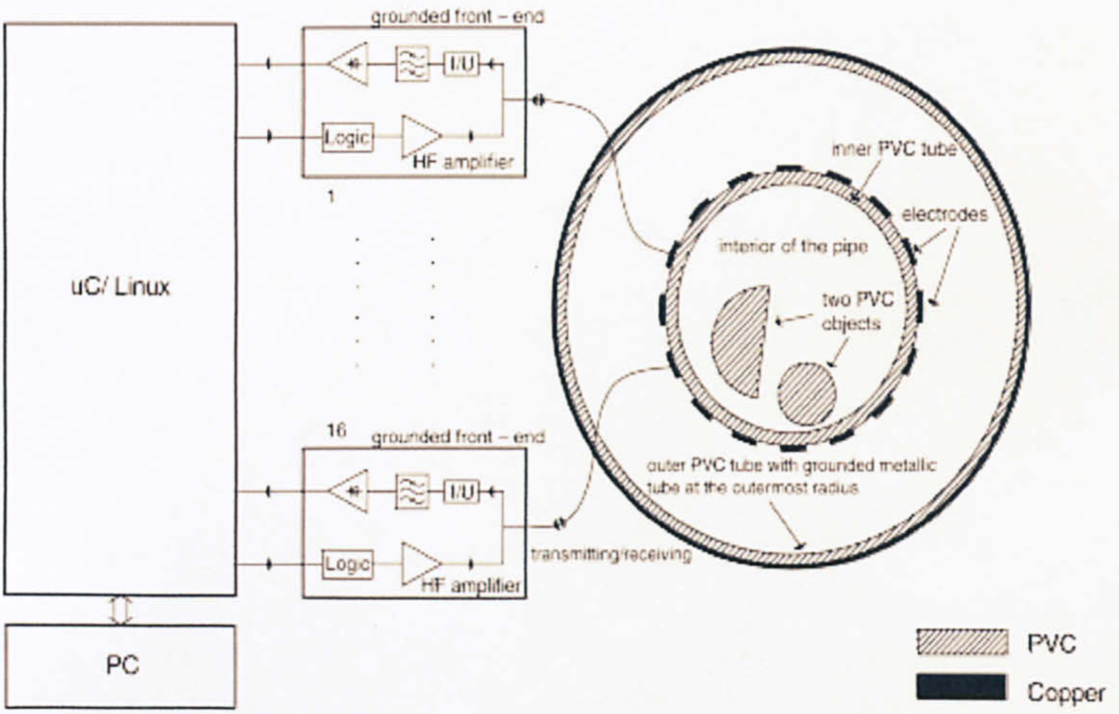

Figure 2: ECT measurement setup with 16 electrodes, sensor front-ends and preprocessing [2]

There are three simplifications are assumed to obtain a suitable model of the ECT sensor:

- Stray capacitances in longitudinal direction are not considered (due to the length of the electrodes) and therefore a 2D model is used.
- The model is assumed to be electrostatic. The carrier frequency is constant and the wavelength is large compared to the sensor geometry. Therefore, measured displacement currents correspond to charges in the model.
- The permittivity independent from the electric field strength.

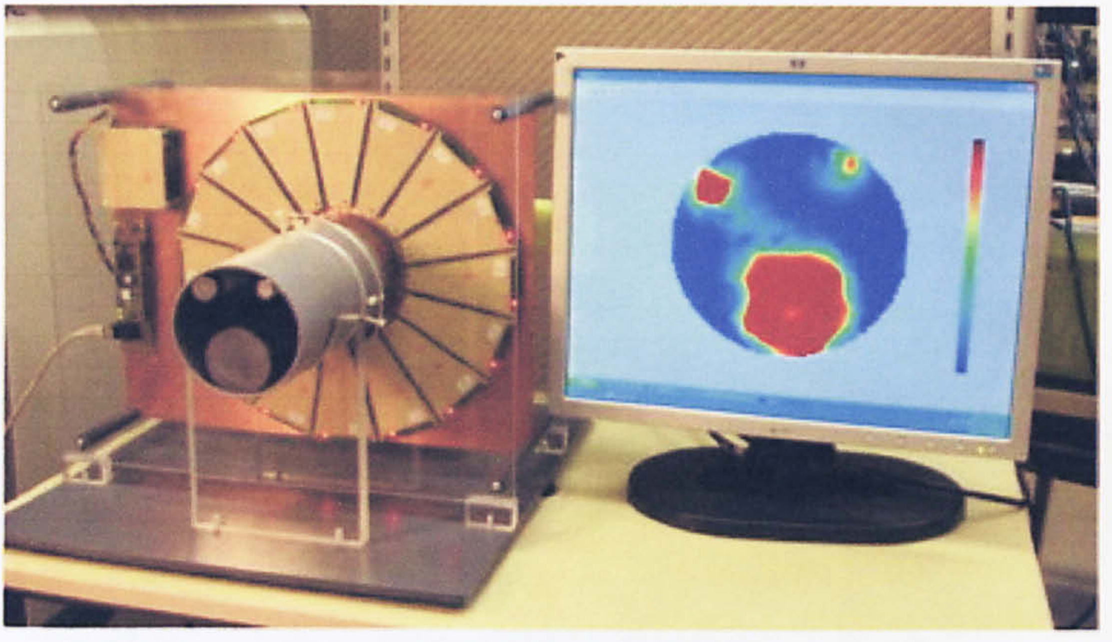

Figure 3: ECT prototype sensor and reconstruction of the pipe interior [2]

CHAPTER 3

METHODOLOGY

3.1 Project Flowchart

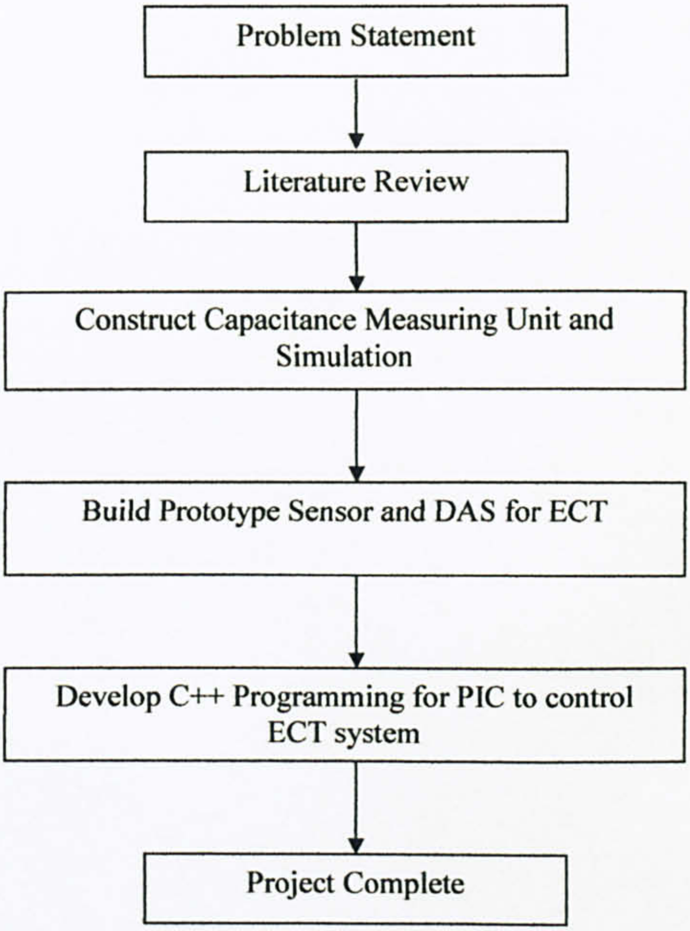

Figure 4: Project Flowchart

3.2 Vessel Prototype and ECT Sensors Design

The capacitance electrodes can be mounted either inside or outside the vessel. If the vessel wall acts as an electrical insulator such as plastic, then the electrodes are normally mounted on the outside surface of the pipe or vessel. In this project, a plastic bottle container is used as a vessel prototype. 8 electrodes which are made of aluminum are mounted outside the vessel. Each electrode is sheared with the measurement of 8cm x 2.5cm. The screws used are of size 0.4cm. Below are the pictures of capacitance sensor prototype:

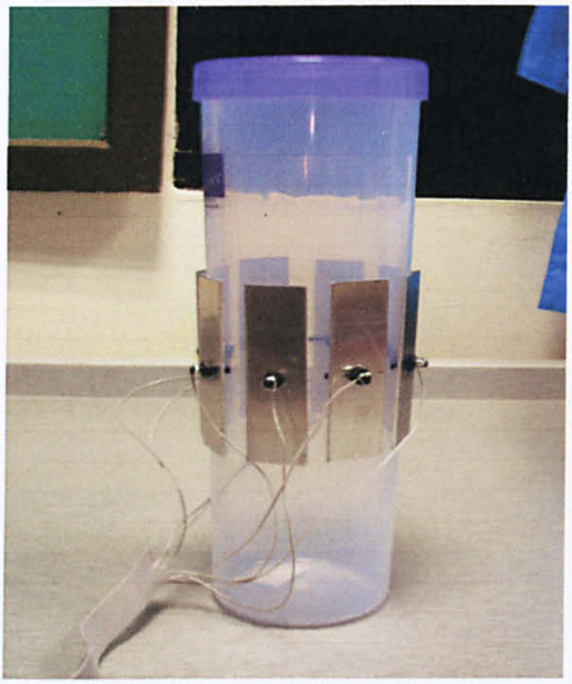

Figure 5: Side View of Capacitance Sensor Prototype

Figure 6: Top View of Capacitance Sensor Prototype

3.3 Construction of ECT Data Acquisition System Circuit

The sensor is considered to work for a broad field of industrial flow applications and shall feature reliable operation for a variety of different materials. Hence, the fundamental requirements of electronic circuits used for ECT systems are [7]:

- Possibility to use each electrode as transmitting as well as measurement (receiving) electrode.
- High dynamic range of the amplifying circuitry.
- Able to provide accurate capacitance measurements.
- Since the capacitance changes caused by permittivity variations inside the pipe are very small, the circuit needs to have high measurement resolutions.
- Shielding for all sensor circuits.
- Minimize external noise sources.
- Possibility to calibrate the transmitting and the receiving circuitry.

A functional data acquisition circuit needs to be developed in order to construct a tomographic image in an object. DAS will include the following circuits:

- Voltage-Controlled Voltage Source (VCVS)
- Multiplexer Circuit
- Voltage measurement
- Central Control Unit Design

These circuits will be connected together to obtain the voltage measurements at the output of the microcontroller and will be displayed at HyperTerminal program.

3.3.1 Voltage-Controlled Voltage Source (Voltage Generation)

A single Voltage-Controlled Voltage Source (VCVS) is built to generate voltage. An operational amplifier LM833N is used in VCVS in order to reduce effect from stray capacitance since it has a very low input noise which is relatively low input noise of 4.5nV / √Hz. Output voltage, V_0 is controlled by input voltage, V_I. In this project, the VCVS is used to produce constant voltage as a supply to the system. Figure 7 below is the schematic diagram of VCVS simulated in Multisim Version 8.

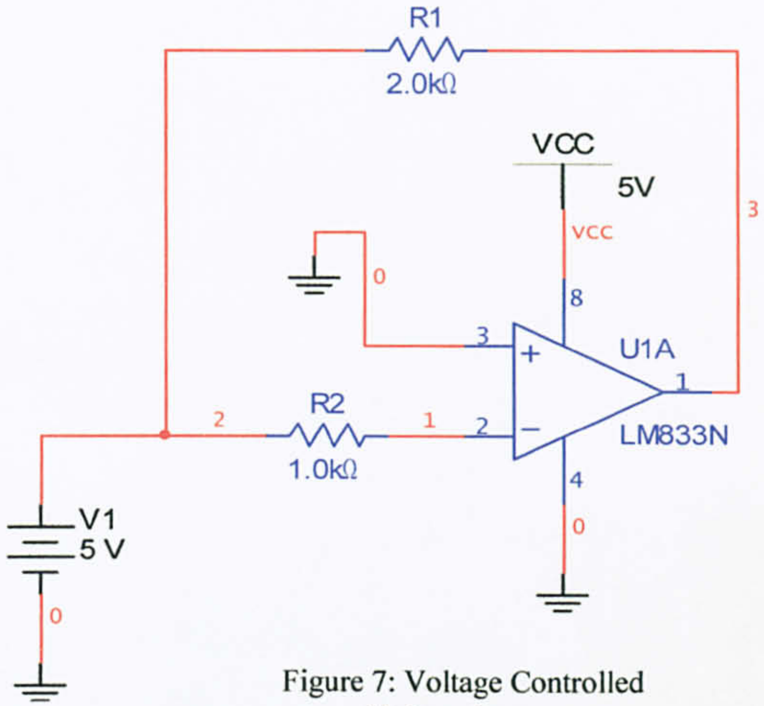

Figure 7: Voltage Controlled Voltage Source

In previous traditional ECT systems, high frequency sinusoidal waveform is used as the excitation source, which in turns introducing signal demodulation circuits such as low pass filters. These extra circuits decrease the speed performance of the whole system. Therefore, bi-directional current pulse is used to excite the electrodes in order to improve the measurement speed. Analog CMOS switch HCF4016BE is used in the circuit to generate the bi-directional current. This IC consists of 4 bi-polar switches which let the current flows through when the switch (control pin) is held at a high voltage level. Otherwise, the switch will open and no voltage will flow.

In the positive half cycle, switches S1 and S3 are closed, while switches S2 and S4 are open. In this case, the current flows from electrode 1 to electrode 2. In the negative half cycle, S1 and S3 will open while S2 and S4 are closed. Now, the current is reversed, flowing from electrode 2 to electrode 1. The sequence of the switches is summarized in Table 1 below:

Table 1: Bi-directional Current Pulse Sequence

Cycle	S1	S2	S3	S4
Positive	Closed	Opened	Closed	Opened
Negative	Opened	Closed	Opened	Closed

3.3.2 Multiplexer

Since we are using 8-electrodes data acquisition system, a multiplexer circuit must be used to accordingly switch the current source and voltage measurement components between electrode 1, 2, 3, 4, 5, 6, 7 and 8. In this project, the multiplexer unit circuit consists of four 74LS151 analogue multiplexers. Two multiplexers are used for current injection and the other two for multiplexers for voltage measurement. The multiplexers select which pairs of electrodes will be used and measured. In one particular time, two electrodes which is one pair will be used for current injection while the other electrode pairs will be used for voltage measurement. Current then supplied through another pair of electrodes and the voltage measurements for other electrode pairs are repeated until the full rotation of electric field of the object/materials inside the vessel is obtained. The multiplexers' outputs are fed to PIC microcontroller to be processed. The multiplexer unit circuit can be found in Appendix B.

The number of measurements taken or multiplexer sequence depends on the number of electrodes used. Since 8 electrodes are used in this project, the total number of voltage measurements will be 20 according to the formula shown below:

$$\textbf{Total number of measurements, } M = N\,(N-3)/2$$
$$= 8\,(8-3)/2$$
$$= 20$$

In order to obtain overall 20 measurements, the multiplexer unit circuit is designed and connected as shown in the Table 2 where MUX1 and MUX2 are multiplexers used for current injection while MUX3 and MUX4 are multiplexers used for voltage measurement.

Table 2: The Sequence of Multiplexers

Sequence	Current Injection		Voltage Measurement	
	MUX1	MUX2	MUX3	MUX4
1	Electrode-1	Electrode-2	Electrode-3	Electrode-4
2			Electrode-4	Electrode-5
3			Electrode-5	Electrode-6
4			Electrode-6	Electrode-7
5			Electrode-7	Electrode-8
6	Electrode-2	Electrode-3	Electrode-4	Electrode-5
7			Electrode-5	Electrode-6
8			Electrode-6	Electrode-7
9			Electrode-7	Electrode-8
10			Electrode-8	Electrode-1
11	Electrode-3	Electrode-4	Electrode-5	Electrode-6
12			Electrode-6	Electrode-7
13			Electrode-7	Electrode-8
14			Electrode-8	Electrode-1

15	Electrode-4	Electrode-5	Electrode-6	Electrode-7
16			Electrode-7	Electrode-8
17			Electrode-8	Electrode-1
18	Electrode-5	Electrode-6	Electrode-7	Electrode-8
19			Electrode-8	Electrode-1
20	Electrode-7	Electrode-8	Electrode-8	Electrode-1

The multiplexers switching for current injection and voltage measurement are controlled via control logic by using microcontroller PIC16F877. The truth table shown in Table 3 indicates the sequence of every multiplexer during certain time duration.

Table 3: Truth Table of Multiplexers

Sequence	**Current Injection**			**Voltage Measurement**		
	MUX1 & MUX2			**MUX3 & MUX5**		
1	0	0	0	0	1	0
2				0	1	1
3				1	0	0
4				1	0	1
5				1	1	0
6	0	0	1	0	1	1
7				1	0	0
8				1	0	1
9				1	1	0
10				1	1	1
11	0	1	0	1	0	0
12				1	0	1
13				1	1	0
14				1	1	1

15				1	0	1
16	0	1	1	1	1	0
17				1	1	1
18				1	1	0
19	1	0	0	1	1	1
20	1	0	1	1	1	1

3.3.3 Analogue to Digital Converter (ADC)

The measured analogue voltages obtained from the multiplexer circuit must be converted to digital values. This is done by using PIC16F877 that has a built in ADC function which can perform the conversion process.

3.3.4 Central Control Unit (PIC 16F877)

PIC 16F877 is used to control and synchronize data acquisition system (DAS). It can be referred to as central control unit of DAS. Microcontroller has major functions in DAS such as:

- To generate and inject the current signal into the circuit.
- Multiplexer switching circuit for both current injection and voltage measurement.
- Analog to digital conversion.
- Connected to PC interface circuit to view the voltage measurement in digital values.

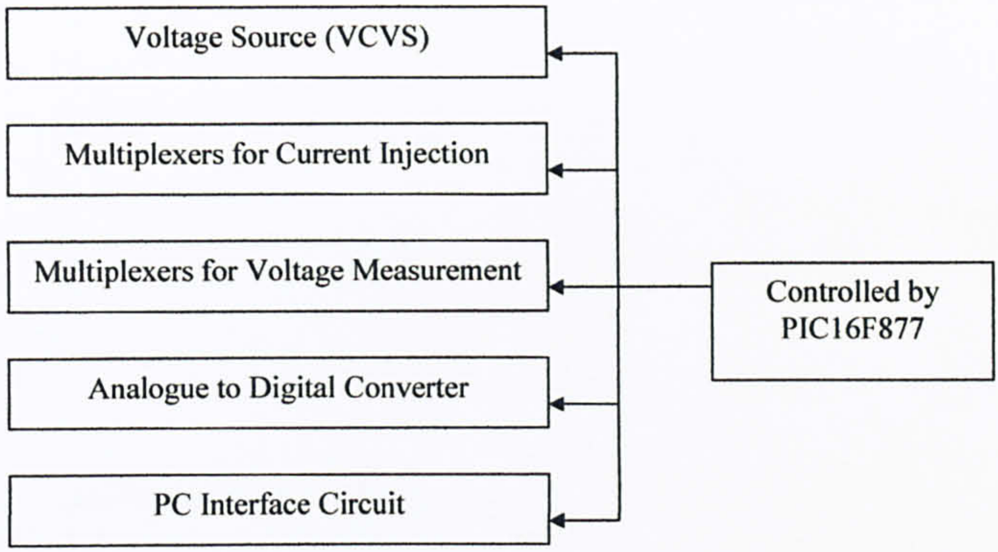

Figure 8: DAS controlled by PIC16F877

Figure 8 below shows the pin arrangement of PIC16F877:

Figure 9: PIC16F877 Pin Arrangements

To build data acquisition system, there are several input pins and output pins connections are used as follow:

- **Power Supply and Grounding**

  Power which is +5V and ground (GND) are connected to the PIC through pins Vdd and Vss. The dd and ss refer to the drain and source notation used in the PIC. Vdd = 5V and Vss = 0 (GND).

- **The Master Clear Pin (MCLR)**

  This is an active low pin that provides a reset feature. Grounding this pin causes the PIC to reset and restart the program stored in the FLASH ROM. At any other time (to run microcontroller), the MLCR pin should be made logic 1 by connecting it to a +5V supply through a pull-up resistor.

- **Oscillator/External Clock Source Input**

  Pin OSC1/CLKIN will be used to connect with external clock input to generate frequency used in this project.

- **Signal Generation**

  The analogue CMOS switch HCF4016BE is connected to pin RD3 and RD4 to synchronize all the measurement circuits. Port D is used for this purpose because it is bi-directional I/O port, which means it can be configured as an input or as an output.

- **Multiplexer Switching**

  Port C and Port D are used for multiplexing addressing for current injection and voltage measurement respectively. Port C and Port D are bi-directional I/O port. RC0, RC1 and RC2 are connected to the control pins A, B, and C of 2 multiplexers 74LS151 for current injection. RD0, RD1 and RD2 are connected to the control pins A, B and C of other 2 multiplexers 74LS151 for voltage measurement. The output of microcontroller port is a 3 bit address from 000 to 111 to control the multiplexers.

- **Analog to Digital Conversion**

  The pins in Port A can be used as analog inputs. These analog inputs can be converted to digital output with the build-in analog to digital converter in PIC16F877. Pin RA0 to RA7 can be used for multiple analog input or single analog output. The ADC used in this project is 10 bits ADC.

- **USART asynchronous receiver and transmitter**

  Pins RC6 and RC7 can be used as USART asynchronous transmitter and receiver respectively.

3.3.5 Serial data communication between hardware and computer

In PIC16F877, the USART (Universal Synchronous/Asynchronous Receiver Transmitter) is utilized for asynchronous serial communication. The most common protocol used for asynchronous communication in microcontroller is the RS232 protocol. The PIC16F877 does not transmit the signals at RS232 directly but does it through a driver called MAX232 which is an IC. MAX232 helps protecting the processor from possible damage by static that may come from people handling the serial port connectors. Pins RC6 and RC7 can be used as USART asynchronous transmitter and USART asynchronous receiver. In this project, RS232 communication circuit is used to read the voltage values measured at the electrodes. Pins T1OUT and R1IN of MAX232 will be connected to 9 pin connector of RS232 in order to be connected to PC to display the measured voltage. The data will be displayed at HyperTerminal program.

3.3.6 Complete Data Acquisition System (DAS) and Capacitance Sensor

By using all the components described in methodology, a complete data acquisition system (DAS) and capacitance sensor system is designed and built successfully. In order to take voltage measurements between all the electrode pairs of capacitance sensor automatically, C programming is created for DAS system and loaded into PIC16F877. The complete schematic diagram for DAS can be found in Appendix B and the codes for C programming can be found in Appendix C.

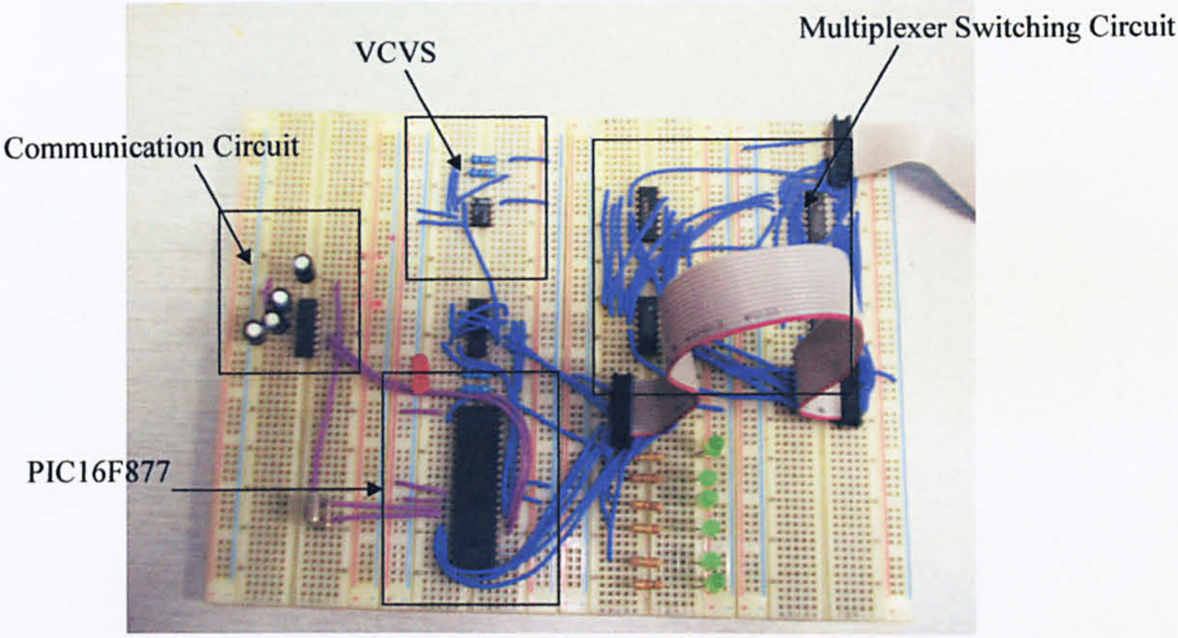

Figure 10: DAS Measuring Unit

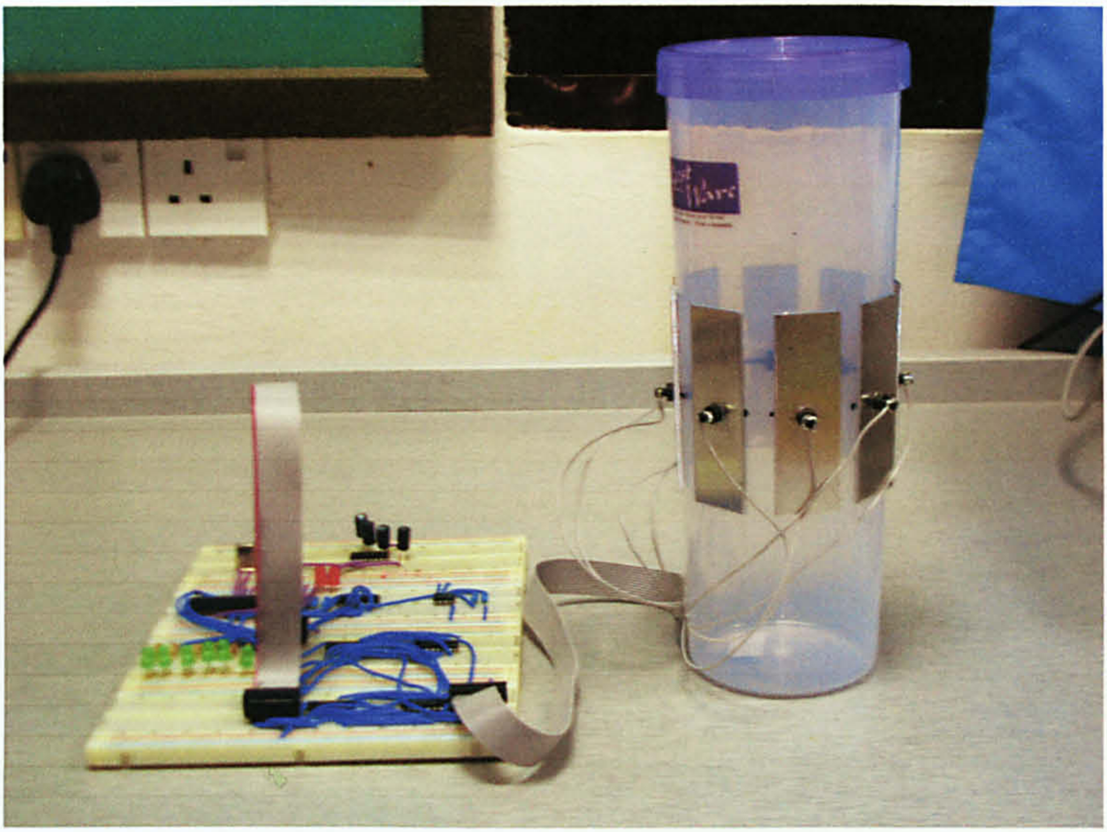

Figure 11: Data Acquisition System and Capacitance Sensor

CHAPTER 4

RESULTS AND DISCUSSION

In order to obtain data from data acquisition system, an experiment is carried out by using capacitance sensor prototype. Rice grains are used as the medium of the experiment. 2/3 of the vessel prototype is filled with rice grains. The objective of the experiment is to obtain voltage measurements between electrode pairs. These voltages are measured by using the data acquisition system that has been developed before.

There are 2 conditions applied in completing the experiment. First, the voltages are measured when the vessel is empty. Second, the voltages are measured when the vessel is filled with rice grains. The difference of the voltage values for both measurements is shown in Figure 12 and the voltages measured are tabulated in Table 4 as followed:

Table 4: Voltage Measurements with Empty Vessel and with Vessel Filled With Rice Grains

Sequence	Current Injection		Voltage Measurement		Voltage (mV) (Empty Vessel)	Voltage (mV) (Vessel Filled Rice Grains)
1	1	2	3	4	545	560
2			4	5	535	550
3			5	6	532	545
4			6	7	543	548
5			7	8	548	550

6	2	3	4	5	538	540
7			5	6	535	537
8			6	7	528	530
9			7	8	531	532
10			8	1	526	528
11	3	4	5	6	524	525
12			6	7	532	534
13			7	8	535	537
14			8	1	521	524
15	4	5	6	7	521	525
16			7	8	532	533
17			8	1	538	539
18	5	6	7	8	535	537
19			8	1	534	536
20	6	7	8	1	523	525

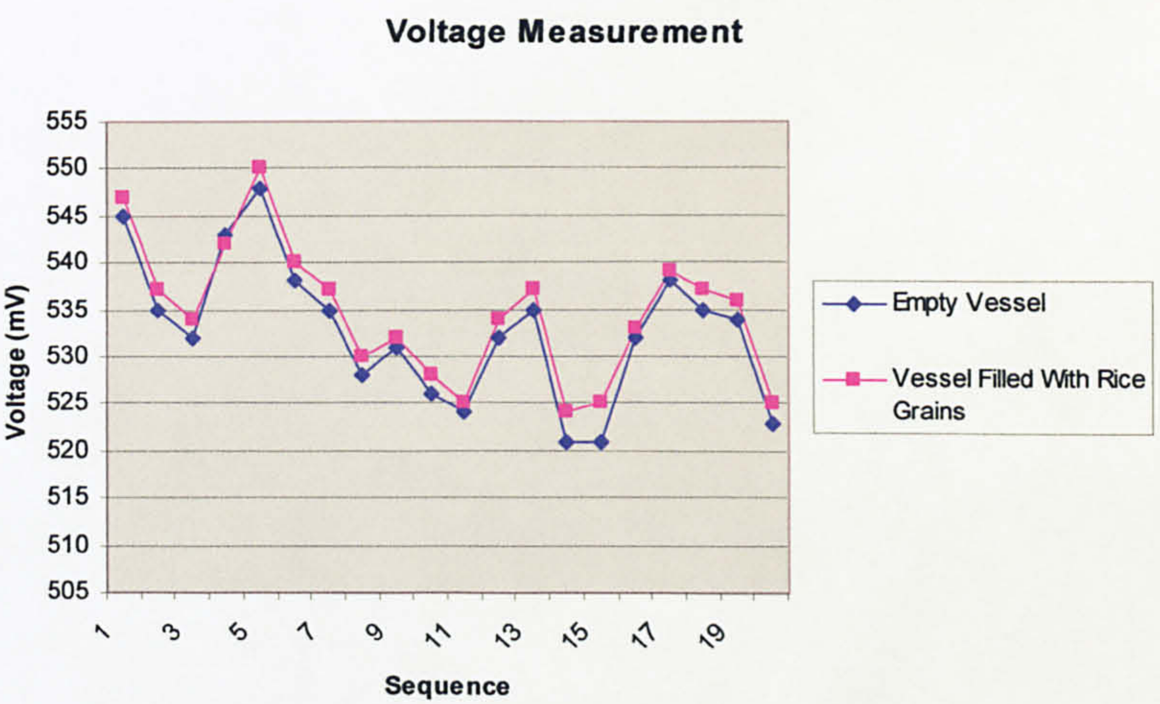

Figure 12: Voltage Measurement Difference

As we can see from Table 4 and Figure 12 above, there is slightly difference in voltage measurements when the vessel is empty and when the vessel is filled with rice grains. It can be concluded that output voltage is higher when the vessel is filled with rice grains. This shows the effect of the materials in the vessel.

Another experiment is carried out by using capacitance sensor and DAS. But this time instead of using rice grains as the medium, the author's uses steel ruler as the medium in the vessel. The voltages are measured when there is a steel ruler in the vessel and when there is no steel ruler in the vessel. The difference of the voltage values for both measurements is shown in Figure 13 while the values for both measurements are tabulated in Table 5 as follow:

Table 5: Voltage Measurements with Empty Vessel and with Vessel Contained Steel Ruler

Sequence	Current Injection		Voltage Measurement		Voltage (mV) (Empty Vessel)	Voltage (mV) (Vessel Contained Steel Ruler)
1	1	2	3	4	30	32
2			4	5	23	23
3			5	6	20	22
4			6	7	24	26
5			7	8	35	37
6	2	3	4	5	33	34
7			5	6	24	26
8			6	7	13	14
9			7	8	25	25
10			8	1	32	32
11	3	4	5	6	31	32
12			6	7	26	27

13			7	8	18	20
14			8	1	25	27
15	4	5	6	7	32	34
16			7	8	25	26
17			8	1	13	15
18	5	6	7	8	35	38
19			8	1	22	24
20	6	7	8	1	35	36

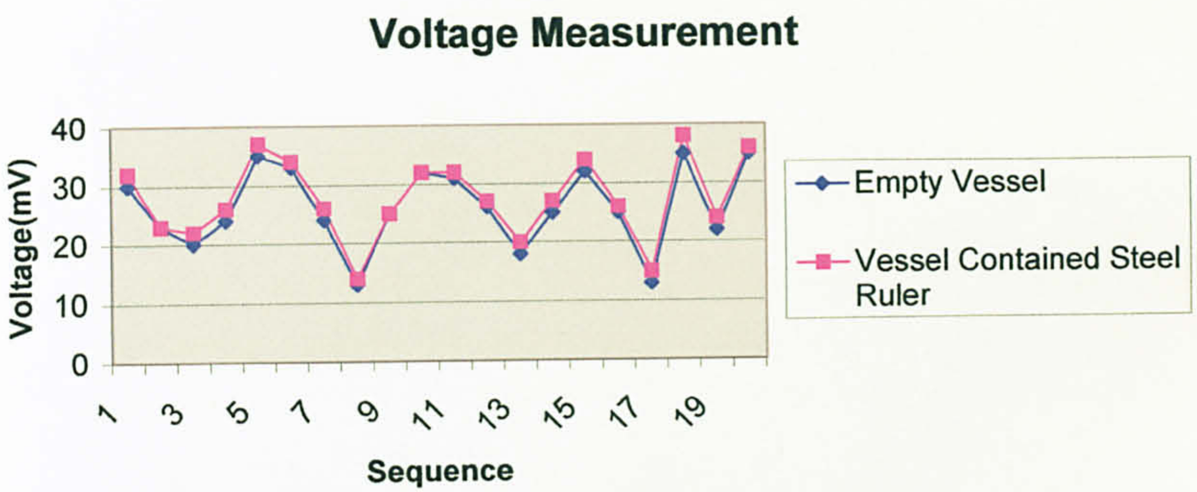

Figure 13: Voltage Measurement Difference

As we can see from Table 5 and Figure 13, there is slightly difference value of voltages between empty vessel and vessel contained steel ruler. This indicates the effect of steel ruler in the vessel. From the measurement, it can be concluded that the voltage is highest at electrode pair that is closest to current injection electrode pair. The voltage decreased when electrode pair is away from current injection electrode pair. Voltage is lowest at electrode pair which has longest distance from current injection electrode pair.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this project, 8-electrode capacitance sensor and data acquisition system (DAS) are successfully designed for Electrical Capacitance Tomography (ECT). A series of experiments have been done to test the functionality and accuracy of DAS as well as the capacitance sensor prototype.

As for recommendations for this project, the ECT system can be made more sensitive by using more electrodes for capacitance sensor such as 16 or 32 electrodes so that the data obtained from data acquisition system will be more accurate and able to generate better image reconstruction. However, in this project I managed to build 8 electrodes capacitance sensor only due to limited time. Although another part of ECT system which is image processing is not included in this project, but from voltage measurements obtained, we can see the difference of voltage values when the vessel is empty and when materials which is rice grains and object which is steel ruler are used as medium in the vessel. This indicates the effect of materials and object in the vessel which the capacitance sensor and data acquisition system can sense.

As mentioned earlier in results and discussion, we can only see slightly difference in voltage measurements. This is because the current injection to the data acquisition system (DAS) is too small. We can avoid this by injecting higher current as current injection is the power source of DAS and with this the voltage difference will be much more significant.

Data acquisition system is the major part of this project. A full understanding on how the system should work to obtain the data is very important so that we can get accurate results. The DAS measuring unit must be designed such that it can control the whole system automatically. In order to achieve this intelligent ECT system, C programming is used so that we can get the data automatically without having to measure the voltage manually between all electrode pairs. This is important because ECT is very sensitive to environment and it must be handled without too much disturbance from the outside environment including the person that handles the experiments.

In conclusion, a simple data acquisition system for ECT system has been developed successfully. However, the system can be upgraded to a more intelligent and sophisticated design in the future.

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APPENDICES

APPENDIX A

FINAL YEAR PROJECT GANTT CHART

SEMESTER 1

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
	-Review on selected topic	■													
	-1st meeting with Dr Taj		■												
2	Preliminary Research Work														
	-Introduction to the project		■												
	-Decide main objective and short term target		■												
	-Research/study on basic knowledge and principles														
	• Electrical Capacitance Tomography (ECT		■	■											
	• Development of a displacement current-based sensor for ECT applications		■	■											
	• ECT prototype sensor		■	■											
3	Submission of Preliminary Report				●										
4	Project Work														
	- Vessel prototype and ECT sensor design				■	■	■	■							
	- Research on ECT data acquisition circuit				■	■	■	■							
	- Research on ECT				■	■	■	■							

	system hardware and software				■	■	■	■							
5	Submission of Progress Report								●						
6	Project work continue														
	- Research on image reconstruction algorithm								■	■	■	■			
	-Learn how to use MATLAB for ECT image reconstruction and MATLAB programming								■	■	■	■			
7	Submission of Interim Report Final Draft													●	
8	Submission of Interim Report														●
9	Oral Presentation														●

Suggested milestone ●   Process ■

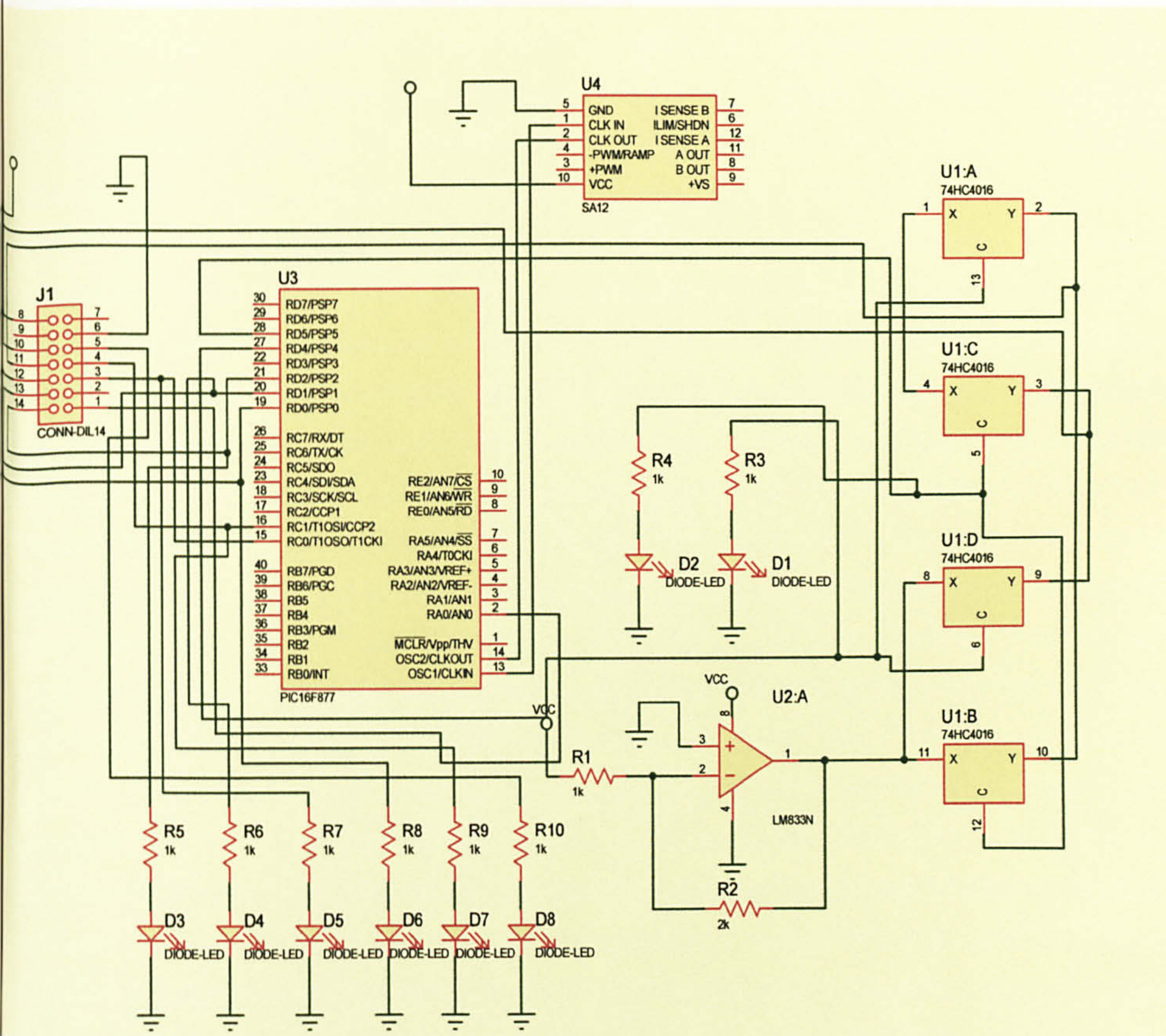
SEMESTER 2

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue														
	-DAS Construction	■													
	-C Programming Code		■												
2	Submission of Progress Report 1			●											
4	Project Work Continue														
	- Build Capacitance Sensor Prototype				■	■	■	■							
	- Circuit Construction				■	■	■	■							
5	Submission of Progress Report 2								●						
6	Project work continue														
	- Testing and Troubleshooting DAS								■	■	■	■			
7	Submission of Dissertation Final Draft													●	
8	Oral Presentation														●
9	Submission of Project Dissertation (Hard Bound)														●

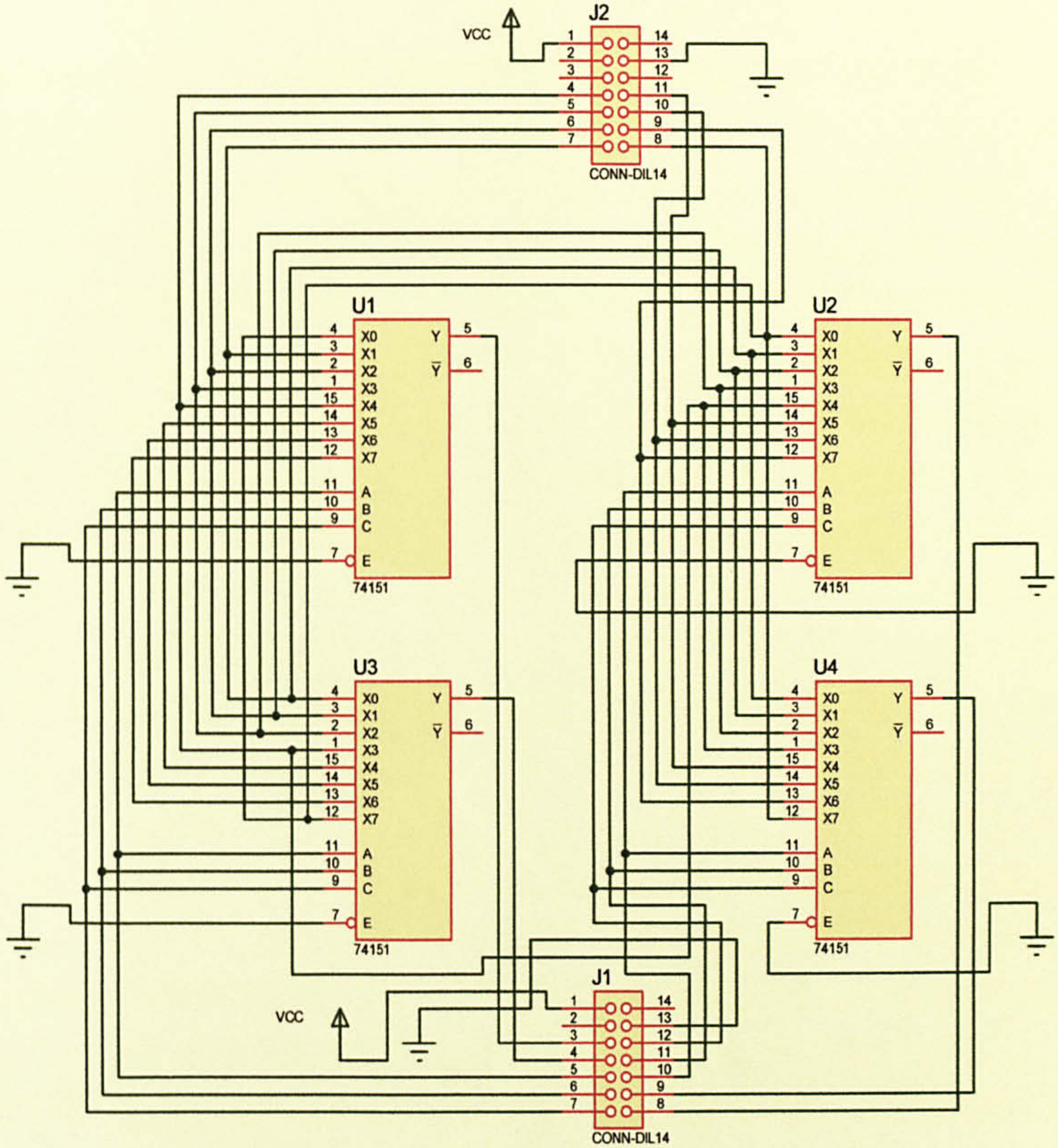
Suggested milestone ● Process ■

APPENDIX B

SCHEMATIC DIAGRAM OF ECT DATA ACQUISITION SYSTEM



CIRCUIT A: PIC16F877 AND VCVS



CIRCUIT B: MULTIPLEXER UNIT CIRCUIT

APPENDIX C

(C PROGRAMMING CODE)

```
#include <16F877.h>
#device ADC=10
#USE DELAY(CLOCK=4000000)
#FUSES XT,NOWDT,NOPROTECT,NOPUT,NOBROWNOUT,NOLVP
#USE RS232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)



    int i,j;
    unsigned int8 adcValue;
    set_tris_c(0x00);
    set_tris_d(0x00);
    float voltage;



    void main(void)
    {
    //adc
    setup_adc_ports(ALL_ANALOG);
    setup_adc(ADC_CLOCK_INTERNAL);
    {
    while(1)
    {
    for(i=0;i<=0;i++)
    {
    output_d(i);
    {
    for(j=2;j<=6;j++)
    {
    output_c(j);
    {

     output_high(PIN_D4);
     output_low(PIN_D5);


     delay_ms(1000);
```

```
output_high(PIN_D4);
output_low(PIN_D5);


delay_ms(1000);


output_high(PIN_D4);
output_low(PIN_D5);


delay_ms(1000);


output_high(PIN_D4);
output_low(PIN_D5);


delay_us(50);//Delay for sampling cap to charge
set_adc_channel(0);
adcValue=read_adc();//Get ADC reading


while(1)


{
printf("\033[2J");//Clear hypertermianl screen
 {
for(i=0;i<12;i++)
{


delay_us(50);//Delay for sampling to charge
adcValue=read_adc();//Get ADC reading
voltage=1.000*adcValue/1023.000;


printf("\033[2J");//Clear Hyperterminal screen
printf("\n\n");
printf("%u\n",adcValue);
printf("Pair Voltage %d:%f V\n",i,voltage);
delay_ms(500);
```

```
      }
     }
     }


    delay_ms(1000);
   }
  }
 }
}


for(i=1;i<=5;i++)
{
output_d(i);
{
for(j=i+2;j<=7;j++)
{
output_c(j);
{
output_high(PIN_D4);
output_low(PIN_D5);


delay_ms(1000);


output_low(PIN_D4);
output_high(PIN_D5);


delay_ms(1000);


output_low(PIN_D4);
output_high(PIN_D5);


delay_us(50);//delay for sampling cap to charge
set_adc_channel(0);
adcValue=read_adc();//Get ADC reading


while(1)
```

```
{
printf("\033[2J");//Clear Hyperterminal screen
{
for(i=0;i<12;i++)

{

delay_us(50);//Delay for sampling cap to charge
adcValue=read_adc();//Get ADC reading
voltage=1.000*adcValue/1023.000;


printf("\033[2J");//Clear Hyperterminal screen
printf("\n\n");
printf("%u\n",adcValue);
printf("Electrode Pair Voltage %d:%f V\n",i,voltage);
delay_ms(500);



}
}
}


delay_ms(1000);
}
}
}
}
}
}
}
```