Chittagong University of Engineering and Technology

Department of Electrical and Electronic Engineering

Project Title: Capacitance meter (1nF to 100uF)

Group No.08

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Date of submission 17-08-2023

Abstract

"Capacitance Meter" is a device designed to accurately measure the capacitance of an unknown capacitor. Capacitance refers to the property of a capacitor where electric charge is stored in relation to a potential difference, utilizing two parallel plate conductors separated by a dielectric. Traditionally, capacitance measurements have been obtained using RLC meters that can determine the values of capacitance (C), resistance (R), and inductance (L).

Historically, the origin of capacitance meters traces back to 1960, as documented in the US Patents record [1]. The modern era of capacitors emerged in the late 1800s, coinciding with the practical utilization of electricity and the need for dependable capacitors with precise characteristics. The very first capacitor, referred to as the "Leyden Jar," can be traced back to 1745-46 when it was initially conceived by Edward Jargen.[**2**] Since then, numerous models and approaches have been devised to measure the capacitance of capacitors.

In this project, we present a capacitance meter based on the PIC16F628A microcontroller. This microcontroller provides the necessary functionality to implement a capacitance measurement system with high accuracy. By utilizing the PIC16F628A's built-in analog comparators and TIMER2 module, we can charge a capacitor through a series resistor, measure the time it takes to reach a specific voltage level, and calculate the capacitance using a simple mathematical formula.

The PIC16F628A microcontroller offers a cost-effective and efficient solution for building a digital capacitance meter. This project demonstrates the construction, performance evaluation, and usage analysis of the microcontroller-based capacitance measurement system, offering a reliable and versatile tool for various electronic applications.

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Chapter 1

Introduction

In the field of capacitance measurement, various techniques and methodologies have been explored to achieve precise and continuous measurements. Kolle [**9**] introduced a synchronous modulation and demodulation approach for accurately measuring the capacitance of capacitive transducers. Yang [**10**] proposed electrical capacitance tomography (ECT) as a means to measure capacitance in multi-electrode capacitive transducers. Matsumoto et al. [**11**]incorporated capacitance measurement as an integral part of the analog-to-digital conversion process.

However, previous systems often suffered from two main drawbacks: (1) a relatively slow rate of sensor readout, typically only a few conversions per second, and (2) dependence on the rate of sensor readout on the measured quantities. To address these limitations, Ashokkumar et al. [**12**], along with Reventer et al. [**13**], utilized a microcontroller-based approach to achieve continuous capacitance measurements. This design employed charging and discharging methodologies and offered the benefit of continuous measuring using a serial interface.

In 1998, a capacitance meter using an RLC circuit was developed [**3**], employing the device under test method. A recent paper demonstrated the construction of an RLC meter using an Arduino with a maximum error of 9 percent [**4**]. Other microprocessor-based capacitance meters achieved precision at a linear level, employing the RC discharge principle [**5**]. Some projects even achieved less than 0.7% error by utilizing an RC circuit with an Arduino [**6**]. Additionally, an op-amp integrated with an MCU provided an error below 5% [**7**]. These studies indicated that the use of comparators, op-amps, and other complex circuitry could enhance the quality of capacitance measurements. Furthermore, the selection of an appropriate IC with algorithmic analysis contributed to achieving high-quality results.

In summary, the literature review highlights the various approaches and techniques used to measure capacitance, with an emphasis on continuous measurements and enhancing measurement precision. While some methods relied on complex circuitry, recent studies have shown the potential of microcontroller-based designs to achieve accurate capacitance measurements. The present work aims to contribute to this field by utilizing the PIC16F628A microcontroller in a charging and discharging approach for capacitance measurement, offering a simple and effective solution with improved performance.

Chapter 2

Working and Design of Circuit

In this proposed methodology, we present a capacitance measurement technique based on the principle of charging a capacitor through a series resistor and utilizing the PIC16F628A microcontroller for control and data acquisition. The setup involves an analog comparator that plays a crucial role in determining when the capacitor reaches half of its full charge.

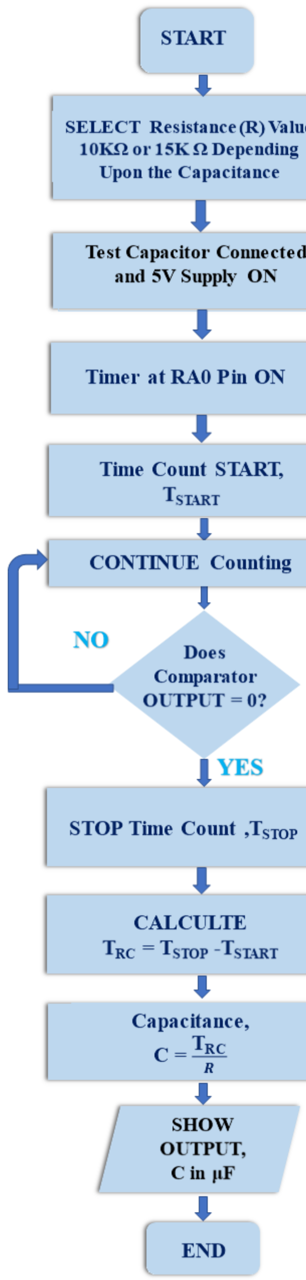
The measurement process begins with the capacitor fully discharged through a 10KΩ or 15KΩ resistor, depending on the range of capacitance being measured. For larger capacitance values, the 10KΩ resistor is used, while for smaller capacitance values, the 15KΩ resistor is employed. When the measurement starts, the RA0 pin of the microcontroller is set high, initiating the charging process through the corresponding resistor. As the capacitor charges, its voltage across the RA1 pin increases.

Once the voltage across the capacitor exceeds half of the voltage at the RA0 pin, the analog comparator's output flips from high to low. This change triggers the interrupt flag (CMIF), and the Timer2 module is used to calculate the time elapsed from the moment the RA0 pin is set high to the point when the comparator output goes low. This time constant, denoted as T_{RC}, represents the time required for the capacitor to charge to 63.2% of its maximum voltage.

With the known resistance (R) of 10KΩ or 15KΩ and the calculated time constant (T_{RC}), we can indirectly estimate the capacitance (C) of the unknown capacitor using the equation: $C = \frac{T_{RC}}{R}$.

By utilizing the analog comparator and TIMER2 modules of the PIC16F628A microcontroller, the capacitance meter achieves continuous measurements with improved accuracy. The proposed approach offers a simple and effective solution for measuring capacitance values ranging from 1nF to 100μF with a resolution of 1nF. This methodology enables the construction of a digital capacitance meter using easily available electronic components and microcontroller functionalities.

2.1 Flow Chart



2.2 Circuit Diagram

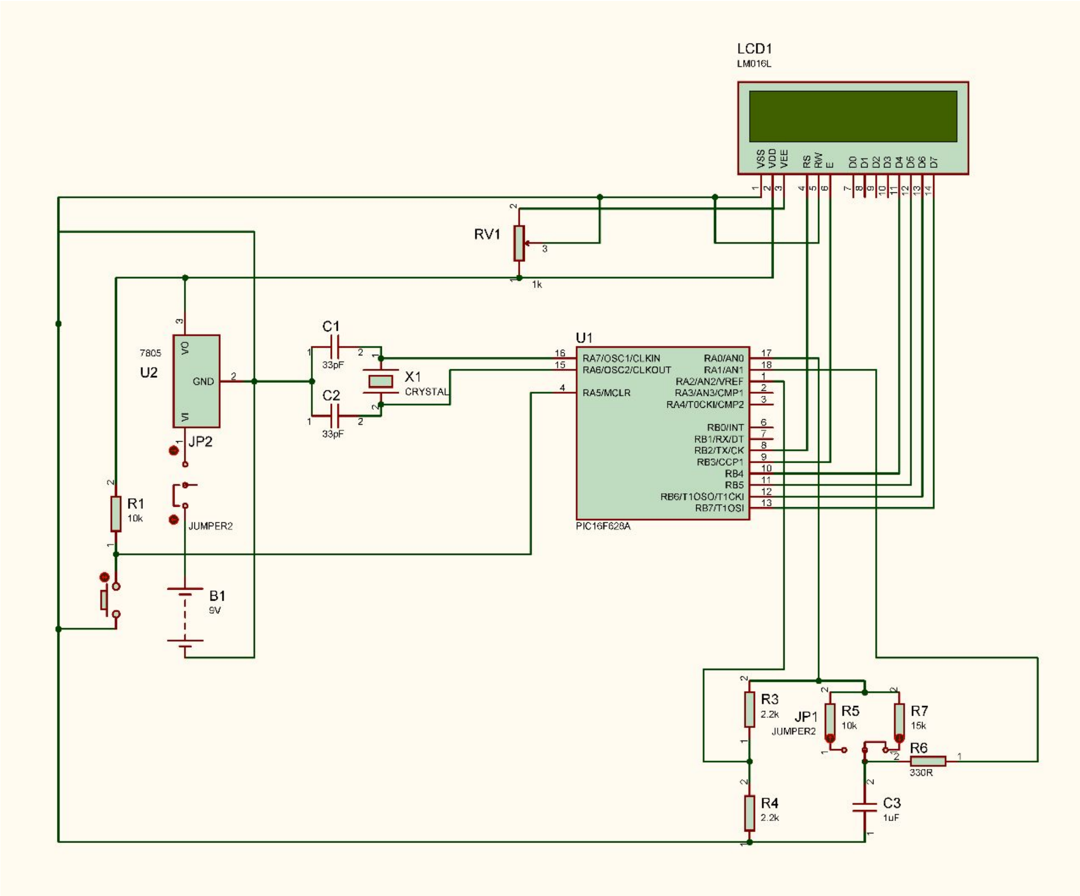


Figure 2.1: Capmeter Circuit

2.3 Components

Breadboard The term "breadboard" refers to a rectangular board having numerous tiny holes in it. On a breadboard, temporary circuits are created.

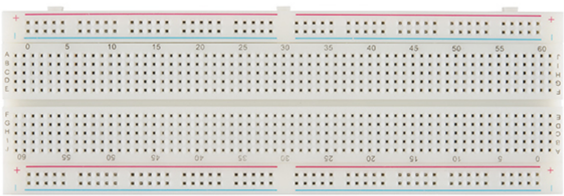


Figure 2.2: Breadboard.

33 pf ceramic capacitor

A 33pF ceramic capacitor is a small electronic component used to store and release electrical energy in circuits. It has a capacitance of 33 picofarads (pF), which is a measure of its ability to store charge. Ceramic capacitors are commonly made from ceramic materials and are known for their compact size, high stability, and wide frequency response. They are often used in high-frequency circuits, signal filtering, and noise suppression applications.

Figure 2.3: Ceramic capacitor

Crystal Oscillator

A 4 MHz crystal, a specific sort of resonator, is used to generate an oscillating signal at a frequency of 4 MHz. The crystal's signal can be used to measure time or as a dependable clock signal for digital circuits. Electronic gadgets like computers, mobile phones, and radios employ crystal oscillators.

Figure 2.4: A 4 MHz Crystal oscillator

Voltage Regulator

A voltage regulator is an electronic component or circuit that maintains a consistent and stable output voltage despite changes in input voltage or load conditions. It is used to ensure that devices receive a steady and reliable supply of voltage, preventing potential damage or malfunction due to voltage fluctuations. Voltage regulators are commonly employed in various electronics, from power supplies to integrated circuits, to maintain proper operation and protect sensitive components.

Figure 2.5: LM7805 Voltage regulator

Table 2.1: Voltage Regulator Pin

Pin no	Pin name	Description
1	Input(V+)	Unregulated input Voltage
2	Ground(Gnd)	Connected to Ground
3	Output(Vo)	Outputs regulated +5

B10k Potentiometer

A B10k potentiometer, also known as a ”10k ohm linear potentiometer,” is an electronic component with a resistance of 10,000 ohms (10k ohms) that can be adjusted using a knob or slider. It has three terminals: two outer terminals connected to the ends of the resistance track and a middle terminal connected to a movable contact. By turning the knob or sliding the control, the middle terminal’s connection point along the resistance track changes, allowing for variable resistance and precise voltage control in electronic circuits. B10k potentiometers are commonly used for tasks like volume control in audio devices or adjusting settings in electronic systems.

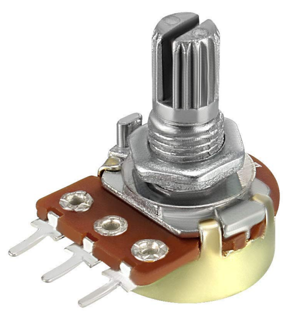


Figure 2.6: B10k Potentiometer

PIC 16F628A Micro-controller

The PIC 16F628A is a widely used microcontroller manufactured by Microchip Technology, belonging to their popular PIC (Peripheral Interface Controller) family. It serves as a versatile and robust 8-bit microcontroller, well-suited for a variety of embedded system applications.

Highlighted attributes of the PIC 16F628A comprise:

1. **8-bit Architecture:** Operating on an 8-bit architecture, the microcontroller processes data in 8-bit segments, enabling efficient control and data manipulation.

2. **Flash Memory:** With a reasonable flash memory capacity, developers can directly program and store their applications on the microcontroller.

3. **RAM and EEPROM:** It presents both volatile RAM (Random Access Memory) for temporary data storage and non-volatile EEPROM (Electrically Erasable Programmable Read-Only Memory) for retaining data even in power-off scenarios.

4. **Built-in Peripherals:** The PIC 16F628A integrates various essential peripherals, including timers, UART serial communication interfaces, analog-to-digital converters (ADC), and digital I/O ports, enhancing versatility and practicality.

5. **Power Efficiency:** Engineered for energy efficiency, the microcontroller is well-suited for battery-operated devices and applications prioritizing low power consumption.

6. **Clock Speed Options:** Developers can adjust the microcontroller's clock speed to strike a balance between performance and power usage.

7. **Interrupt Capability:** Featuring a flexible interrupt system, the microcontroller can promptly respond to external events and time-critical tasks.

8. **I/O Connectivity:** Ample input and output pins facilitate seamless connections to external devices and sensors, making it optimal for interfacing with the physical world.

9. **Development Support:** Microchip delivers a comprehensive suite of development tools, encompassing compilers and integrated development environments (IDEs), streamlining programming and debugging processes.

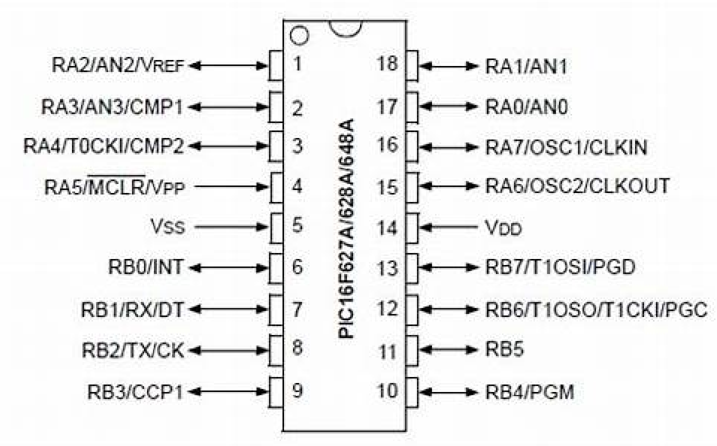


Figure 2.7: PIC 16F628A Micro-controller

Resistor

A resistor is an electrical component which limits or restricts the flow of electricity that are passing across a circuit in an electronic device. A certain level of voltage can be supplied via resistors to an active component.Here, we used 15K ohm and 10K ohm resistor.

Figure 2.8: Resistor

LCD

Liquid Crystal Display, or LCD.We used a 16×2 character LCD module in this instance.It has a two-line, 16-character display capacity. A 16×2 LCD in 8 Bit mode can be connected to a microcontroller. LCD commands are transmitted using character data in the 8 Bit mode over data lines D0 to D7. The LCD's E port provides a data strobe, and 8 bit data is delivered at a time.

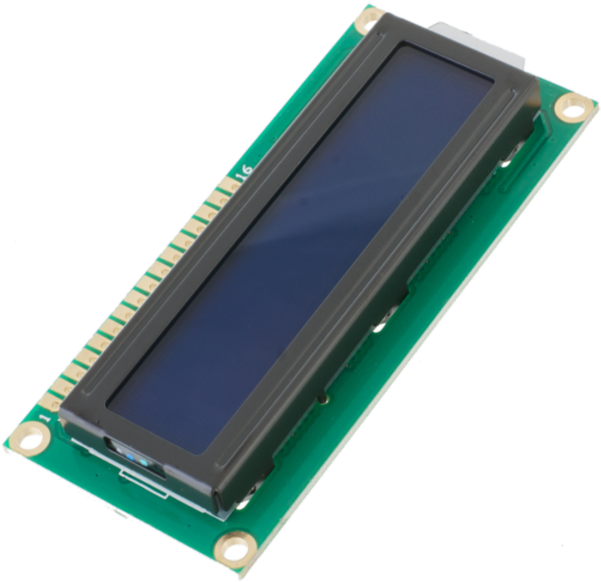


Figure 2.9: 16×2 character LCD module

SPDT Slide Switch

An SPDT slide switch is a type of switch that lets one choose between two different pathways for electric current by sliding a contact. It's used in electronics to control circuits and is reliable for basic switching tasks. In this project two of these kinds of switch have been used: one to control power input and another to control the switching between 15Kohm and 10Kohm.

Figure 2.10: SPDT Slide Switch

2.4 Mamthematical Formula

1. Time Constant Calculation: The time constant, T_{RC}, is calculated using the formula:

$$T_{RC} = R \times C$$

where R is the known resistance in ohms `10K`Ω (for large size of capacitance) or `15K`Ω (for small size of capacitance) and C is the unknown capacitance in farads.

2. Capacitance Calculation: The capacitance of the capacitor under test (C) can be calculated using the time constant T_{RC} and the known resistance R through the formula:

$$C = \frac{T_{RC}}{R}$$

2.5 Program code

```
sbit LCD_RS at RB2_bit;
sbit LCD_EN at RB3_bit;
sbit LCD_D4 at RB4_bit;
sbit LCD_D5 at RB5_bit;
sbit LCD_D6 at RB6_bit;
sbit LCD_D7 at RB7_bit;
sbit LCD_RS_Direction at TRISB2_bit;
sbit LCD_EN_Direction at TRISB3_bit;
sbit LCD_D4_Direction at TRISB4_bit;
sbit LCD_D5_Direction at TRISB5_bit;
sbit LCD_D6_Direction at TRISB6_bit;
sbit LCD_D7_Direction at TRISB7_bit;
sbit Va at RA0_bit;
char message1[] = "Capacitance";
char message2[] = "Meter";
unsigned int T_Value, Num;
float x,cap,y;
unsigned short i, j, TimerValue, OverRange = 0;
char Capacitance[] = "00.000  ",txt[20];
void interrupt(){
  if(PIR1.TMR2IF){
  TMR2 = TimerValue;
  Num ++;
  if(Num > 9999) OverRange = 1; // Range is 99.99 uF
  PIR1.TMR2IF =0; // Clear TMR0 interrupt flag
  }
}
void Display_Cap(unsigned int n){
 Capacitance[0] = n/10000 + 48;
 Capacitance[1] = (n/1000)%10 + 48;
 Capacitance[3] = (n/100)%10 + 48;
 Capacitance[4] = (n/10)%10 + 48;
 Capacitance[5] = (T_Value*10)/153 + 48;
 Lcd_Cmd(_Lcd_Clear);
 Lcd_Out(1, 1, "C(uF):");
 x=n+(T_Value/20);
 cap=(0.002357*x-0.00205);
 FloatToStr(cap , txt);
 if(!n)
 Lcd_Out(2, 1, Capacitance) ;
 else
 Lcd_Out(2,1, txt);
}
void reset(){
 TRISA = 0b00000100;
 CMCON = 7;
 RA1_bit = 0;
 Delay_ms(2000);
 TRISA = 0b00000110;
 CMCON = 5;
}
void main(){
  char cap_size;
  TRISB = 0b00000001;
  PORTB = 0;
  TRISA = 0b00000110;
  OPTION_REG.TOCS = 0;
  INTCON.GIE = 1; //Enable global interrupt
  INTCON.PEIE = 1; //Enable peripheral interrupt
  // Configure Timer2 module
  PIE1.TMR2IE = 1;  // Enable Timer2 interrupt
```

```
  T2CON = 0;         // Prescaler 1:1, and Timer2 is off initially
  PIR1.TMR2IF =0;    // Clear int bit
  CMCON = 5;         // Independent comparator between RA1 (-) and RA2(+)
  Lcd_Init();
  Lcd_Cmd(_Lcd_Clear);
  Lcd_Cmd(_LCD_CURSOR_OFF);
  Lcd_Out(1, 1, message1);
  Lcd_Out(2, 1, message2);
  delay_ms(2000);
  Lcd_Cmd(_Lcd_Clear);
  Lcd_Out(1, 1, "C = ");
  Va = 0;
  TimerValue = 112;  // 104 + 4 clock delay on branching to ISR and others
  while(1){
   Num = 0;
   OverRange =0;
   Lcd_Cmd(_Lcd_Clear);
   Lcd_Out(1, 1, "Testing.");
   Lcd_Out(2, 1, "...");
   TMR2 = TimerValue;       // Initial value of Timer2 for 30us delay
   Va = 1; //apply voltage
   T2CON.TMR2ON = 1; // start timer
   while(CMCON.C2OUT) {
    if(OverRange) ;
   }
   T2CON.TMR2ON = 0; // stop timer
   T_Value = TMR2 - TimerValue;
   Va = 0;
  //--------------------------------
  if(!OverRange){
    Display_Cap(Num*10);
  }
  else{
    OverRange = 0;
    Lcd_Cmd(_Lcd_Clear);
    Lcd_Out(1, 1, "Out of Range!");
   }
   reset();
  }
}
end
```

Chapter 3

PCB layout

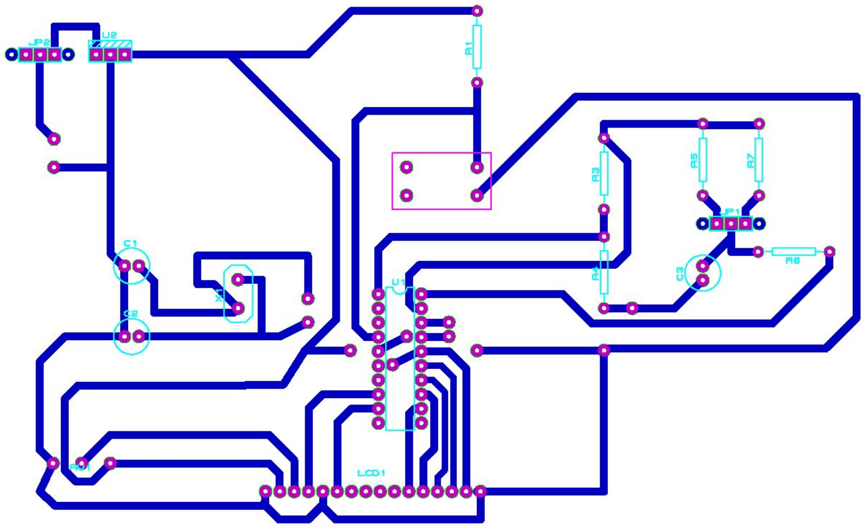


Figure 3.1: PCB Layout

The PCB layout created using Proteus for the capacitance meter project is designed to accommodate the components and connections necessary for accurate capacitance measurements. It follows a compact and organized arrangement to optimize space utilization and minimize signal interference. The layout features appropriate placement of the PIC16F628A microcontroller, resistors, capacitors, and other supporting components. Special attention is given to the routing of traces to ensure signal integrity and avoid noise-induced inaccuracies. The layout also includes designated areas for power supply connections and an LCD display, making it easy to interface with the microcontroller. Overall, the PCB layout in Proteus is well-structured, facilitating a functional and efficient capacitance meter design.

Chapter 4

Breadboard Implementation

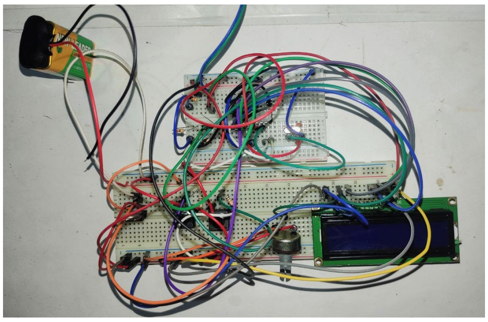


Figure 4.1: Breadboard Implementation

Before implementing the project on a PCB, we first prototyped our capacitance meter on a breadboard. The breadboard implementation allowed us to quickly and easily test and verify the circuit's functionality. This breadboard prototype served as a practical platform for troubleshooting and making any necessary adjustments to the circuit design. It provided a flexible and cost-effective way to ensure the feasibility of our capacitance meter before proceeding with the more permanent PCB implementation.

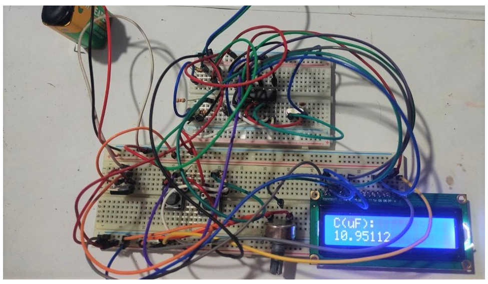


Figure 4.2: Capacitance Test and Outcome.

Chapter 5

PCB Implementation

After successful testing and refinement on the breadboard, the project moved to the next phase – designing and manufacturing the Printed Circuit Board (PCB). The PCB implementation involves translating the breadboarded circuit into a more compact and permanent form. The components are soldered onto the PCB, which offers several advantages including increased reliability, reduced size, and improved electrical performance.

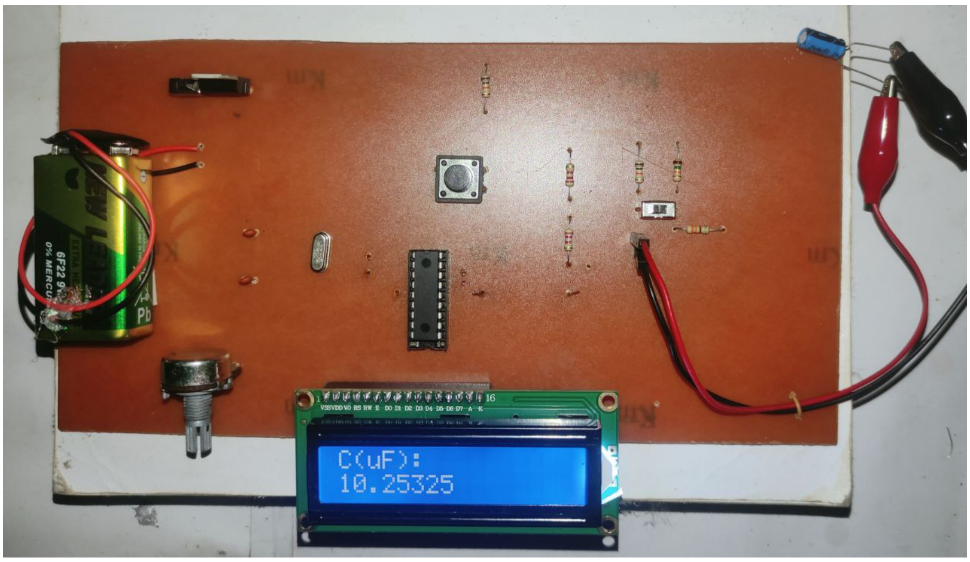


Figure 5.1: PCB Implementation and Measuring a Test Capacitance

Chapter 6

Price Table

Table 6.1: Components Quantity and Pricing

Component Name	Quantity	Price
PIC 16F628A	01	180
Breadboard	01	80
9V battery(with cap)	01	80
LCD	01	200
Push Switches	01	5
SPDT switch	02	10
PCB Board, Clip, Header		65
IC Holder	01	5
Capacitors	09	20
PCB Print	01	50
$FeCl_3$	100g	30
Crystal Oscillator	01	15
7805 Voltage Regulator	01	10
1k Potentiometer	01	20
Resistors	06	10
Total	———	**780**

The cost analysis provides a breakdown of the expenses associated with the implementation of our project. It includes the quantities and prices of various components essential for building the capacitance meter. The list covers items such as the microcontroller, breadboard, battery, LCD, switches, PCB components, capacitors, and other essential elements. The total estimated cost for all components amounts to 780 Taka.

Chapter 7

Result

We conducted measurements on various capacitors using both our implemented meter and a standard reference meter. The obtained values were then compared to the capacitance data measured using a multimeter.

Table 7.1: Comparison of Capacitance between Measured, LC Meter, and Labeled Values

Label (uF)	Multimeter Measure (uF)	Capacitance Meter Measure (uF)	Error wrt Multimeter Measure (%)
0.001	0.001	0.001	0
0.1	0.104	0.106	1.923076923
0.1	0.115	0.1181	2.695652174
1	1.04	1.037	0.288461538
10	10.15	10.25561	1.040492611
47	42	42.4263	1.015
100	112	113.7091	1.525982143

A comparison is made between the data obtained from a standard LC meter and our capacitance meter, as presented below:

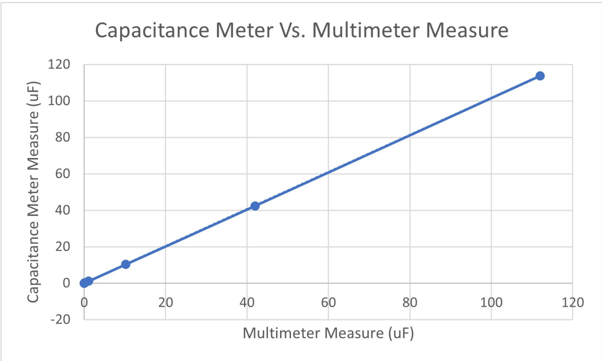


Figure 7.1: Capacitance meter vs multimeter measurement

Below is the comparison between the capacitance data written on the label and the data measured by our capacitance meter:

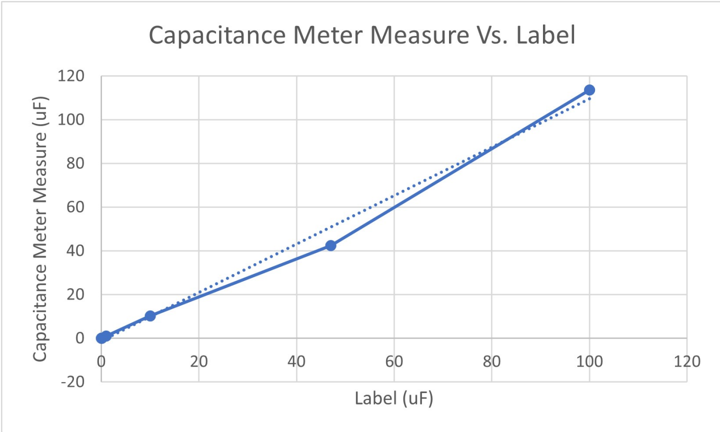


Figure 7.2: Capacitance meter measurement vs label

The data illustrates that the measurements obtained from our capacitance meter displayed fluctuations within the range of 0% to 3% when compared to the values acquired from the multimeter. This variance indicates a high level of consistency and accuracy in our capacitance measurement technique. The observed minor fluctuations fall comfortably within an acceptable margin and affirm the reliability of the proposed measurement method.

Chapter 8

Limitations & Future Improvement

Limitations: The capacitance meter developed using the PIC16F628A microcontroller has certain limitations. One major limitation is the restricted measurement range, with values ranging from 1nF to 100uF being the most suitable for accurate measurements. Values beyond this range cannot be reliably tested using this specific setup. Furthermore, the capacitance values tend to exhibit fluctuations during the measurement process, which can introduce some uncertainty in the recorded results. These limitations suggest that while the meter offers a straightforward and cost-effective approach to capacitance measurement, it may not be suitable for applications requiring precise measurements in a broader capacitance range or demanding high accuracy under fluctuating conditions.

Future Improvements: While the current implementation of the capacitance meter using the PIC16F628A microcontroller has shown promising results, there are several avenues for future improvements and enhancements. Firstly, to further enhance measurement accuracy, more precise resistors and capacitors can be used in the circuit. Additionally, implementing calibration routines and compensating for any potential offset errors can help reduce measurement discrepancies. Integrating a temperature compensation mechanism could also improve the meter's performance under varying environmental conditions. Furthermore, exploring advanced algorithms and filtering techniques can contribute to noise reduction and provide even more accurate capacitance measurements. Lastly, incorporating a graphical user interface (GUI) or wireless connectivity, such as Bluetooth or Wi-Fi, could enhance the usability and accessibility of the capacitance meter.

Chapter 9

Conclusion

In conclusion, we have successfully developed a low-cost digital capacitance meter utilizing the PIC16F628A microcontroller. The meter demonstrated reliable and precise capacitance measurements within 95%accuracy. The simplicity of the design allows for easy integration into laboratory settings, making it suitable for a wide range of precise measurements. Although there is room for improvement in terms of precision, considering the limited resources and primary components used, this project represents a practical and effective approach to capacitance measurement.

This work lays the foundation for potential future improvements to the capacitance meter. The flexibility of the PIC16F628A microcontroller and the extensibility of the design paves the way for various enhancements, such as IoT integration for online data storage and display. With further refinement and calibration, the meter's accuracy can be improved, making it a valuable tool for both educational and industrial applications. Overall, this project serves as a stepping stone toward increased accessibility and affordability of capacitance measurement solutions. By continuously refining and building upon this foundation, we can unlock new possibilities for capacitance measurement in diverse fields and contribute to advancements in electronic testing and instrumentation.

Chapter 10

Plagiarism Declaration

We hereby declare that the project report titled "**Capacitance meter (1nF to 100uF)**" submitted by us for **EEE 354 Measurement and Instrumentation Sessional** is entirely our own work. We have properly acknowledged and referenced all sources of information, including research papers, and websites. Any ideas, findings, or content taken from external sources have been appropriately cited in the report.

We have made every effort to avoid copying from any source. While we sought assistance from the Internet, we ensured that the work remains original. We are well aware of the consequences of plagiarism. This project report accurately represents our research, efforts, and understanding of the subject.

Chapter 11

Acknowledgement

We express our heartfelt gratitude to our esteemed course instructors, Md. Manjurul Gani, Diba Das, and Samiha Ahmed, for their unwavering support, invaluable guidance, and continuous encouragement throughout the duration of this project.

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