Design and Implementation of a Digital Capacitance Meter

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***Abstract*—Capacitance measurement has been a practice among researchers and engineers with different types of methods. A digital capacitance meter precisely determines the capacitance of an unknown capacitor. Utilizing parallel plate conductors and a dielectric, it measures electric charge stored relative to potential difference. This project showcases an ATmega328P-based capacitance measurement system, exploring its design, components, and performance evaluation.**

***Index Terms*—ATmega328P, Capacitance meter, Time constant**

I. Introduction

A tool known as a "digital capacitance meter" is capable of precisely determining the capacitance of an unknown capacitor. When two parallel plate conductors are utilised and a dielectric is maintained between them, the electric charge stored with regard to the potential difference is referred to as capacitance in this context. RLC metres are typically used to measure capacitance since they can also measure resistance and inductance, respectively, along with capacitance. The capacitance metre concept was patented in 1960, according to the US Patents database [1]. The "Leyden Jar," the earliest and most fundamental type of capacitor used today, was created in 1745–1746 by Edward Jargen, and Pieter van Musschenbroek subsequently demonstrated a functional model the following year [2]. The capacitance metre in the device under examination was constructed in 1998 utilising an RLC circuit [3]. A recent research [4] showed how we may quickly and simply construct an RU metre using the Arduino, with a maximum inaccuracy of 9 percent. Another small microprocessor-based capacitance metre that also employs the RC discharge technique has been developed [5]. It has linear precision. In this project, an ATmega328P based capacitance measurement will be demonstrated along with its performance evaluation.

II. Literature Review

The capacitance metre was put together [3] in the device under test technique in 1998 using an RLC circuit. A recent study [4] showed how to simply construct an RLC metre with an Arduino, recording an error rate of up to 9%. Other microprocessor-based capacitance metres that employ the RC discharge mechanism have also been demonstrated to have linear precision [5]. Even employing an RC circuit with the Arduino, certain applications were able to achieve less than 0.7% inaccuracy [6]. Another example of an op-amp and MCU combination produced error levels under 5% [7].

III. Apparatus

A. List of Components

- ATMega328P
- Crystal Oscillator (16MHz)
- Capacitors(22pF, 100µF, 10µF)
- Resistor (10K ohm, 220 ohm)
- Push Buttons
- 16 x 2 LCD display
- Voltage Regulator (LM 7805)
- Potentiometer (10K)
- 9V Battery

B. Details of Components

- ATMega328P Micro-controller: ATmega328 is used here, which is an 8-bit microcontroller built on the AVR Architecture with 32 registers that are built for general-purpose. It operates around 2 to 5 volts with a ±0.5V variation. It has 1 kilobyte of EPROM with USART and has 2 kilobytes equivalent of SRAM [8].

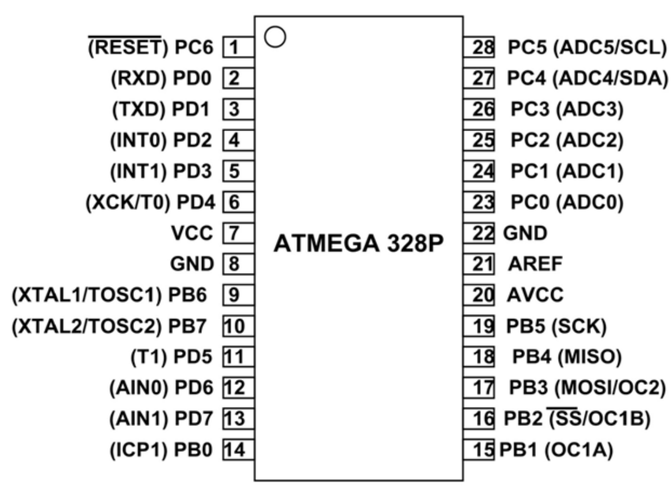

Fig. 1. Pinout of ATMega328p[9]

- Crystal Oscillator (16MHz): A structure with a quartz crystal basically responds to the electric field here, which is an implementation of the inverse piezoelectricity. It operates like a frequency-selective element, which is an important element when working with an MCU.

Fig. 2. Crystal Oscillator[10]

- 16 x 2 LCD display with I2C header: I2C header is used with the LCD to avoid complications with the wiring setup. Built with PCF8574, this piece collects the data from the microcontroller and converts them for use on the LCD. I2C with the LCD requires 4 pins to operate, which are VCC, Ground, SDA, and SCL.

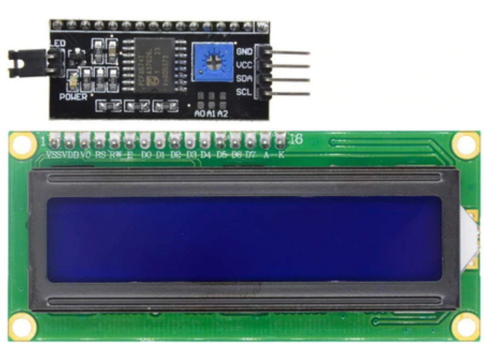

Fig. 3. 16 x 2 LCD display with I2C header[11]

- Voltage Regulator: A common linear voltage regulator, the LM7805 transforms input values between 7 and 25 volts to a steady +5 volt output. It has three pins: regulated output, ground, and input. It is frequently utilised for providing a constant +5V supply in a variety of electronic applications, notably microcontroller-based projects, with a maximum current capacity of 1A.

Fig. 4. Voltage Regulator[12]

IV. Methodology

In this project, the code has been uploaded into ATmega328P and the functions have followed accordingly.

A. Working Principle

One fundamental characteristic of the capacitor, the Time Constant, serves as the basis for the theory underlying this capacitance meter. The time it takes to charge a capacitor through a resistor to achieve 63.2% of the maximum supply voltage is known as the time constant (Tau). The time it takes for a fully charged capacitor C to discharge via a resistor R to 36.7% of its maximum voltage is another way to define the time constant of a capacitor. Smaller capacitors will have a lower time constant since charging them takes less time. The temporal constants of larger capacitors will also be higher. Mathematically it can be defined that, Time Constant TC or Tau = R x C Here, Tau or RC is the time constant of Capacitor in seconds (s), C is the Capacitance of the Capacitor in Farads (F) and R is the Resistance of the Resistor in Ohms. In this micro controller-based capacitance meter, the same idea is utilized. Using ATMega328p pins, an unknown capacitor has been charged through a known resistance and has been determined how long it takes to achieve 63.2% of the supply voltage (about 3.1 V). Using the formula C = Tau / R, we determined the capacitance based on the time.

B. Flowchart of project

The following flowchart shows how the project is going to work:

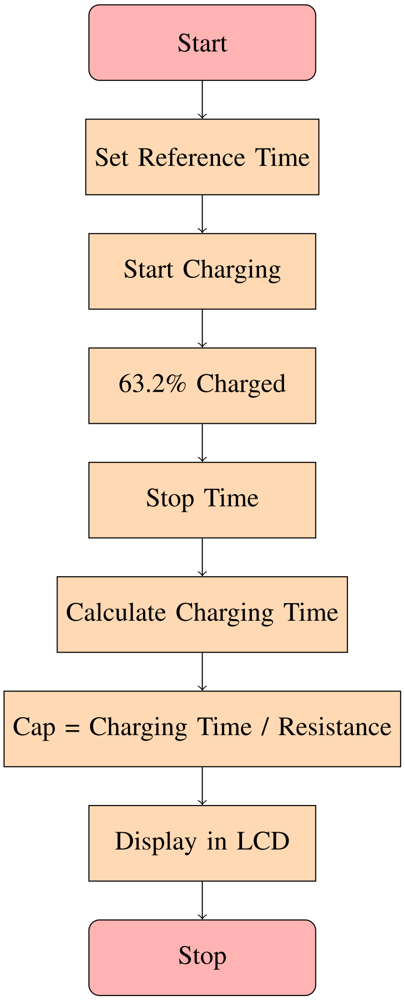

Fig. 5. Capacitance Measurement Flowchart

C. Circuit Diagram

Following is a digital representation of our project complete with all required circuit connections. The LM7805 power supply regulator has been in place since it acted as a regulator of voltage.

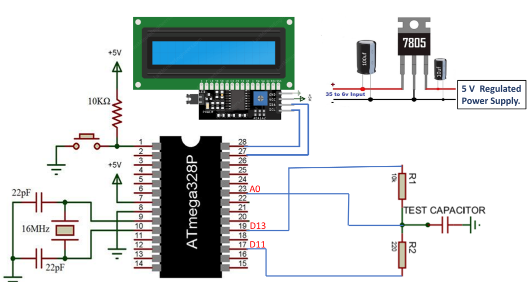

Fig. 6. Circuit diagram of project

V. Result and Analysis

The capacitance meter has shown the capacitance through the 16x2 LCD display as expected after providing an unknown capacitor in the circuit. For example, a 10 micro farad capacitor has been put in the circuit as input and the capacitance has been measured as 10 micro farad. The working project has been shown below in figure 7.

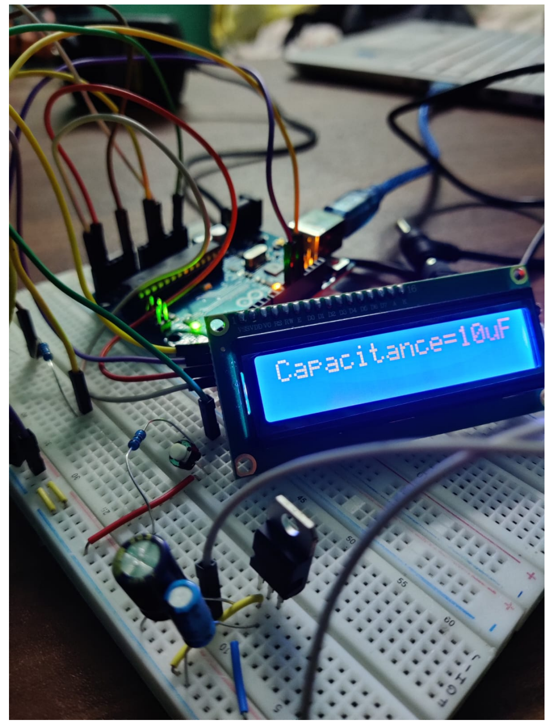

Fig. 7. Working of project

There would have been scope for multiple inputs but due to some technical circumstances the multiple capacitor input has not been included in the project. However, the project works for a single capacitor as input and shows the desired capacitance.

VI. Conclusion

In conclusion, this project suggests using the ATmega328P micro-controller to create a digital capacitance meter. In parallel plate conductors, energy is stored primarily through the use of capacitance, a fundamental electronic feature. This project intends to integrate key components and make use of the charging and discharging principles of a capacitor to build an accurate and effective capacitance meter, leveraging the historical foundation and technological breakthroughs in capacitance measuring. The proposed instrument offers the potential to boost capacitance measuring procedures, showcase the capabilities of micro-controllers in this domain, and enhance electronic instrumentation.

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