Design and Implementation of a Digital Capacitance Meter

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***Abstract*— Capacitance measurement has been exercised with various method among researchers and manufacturers to improve the precision. At the same time, simple circuits are also being tested compromising the accuracy to considerable level for faster and easier implementation. ATmega328P at the heart of this architecture determines the capacitance from time constant and it has yielded around 10% error for the span where the values have been quite accurate for the low capacitance.**

Keywords—ATmega328P, Capacitance meter, Time constant, AVR Board.

I. Introduction

"Digital Capacitance Meter" is a device that can determine the capacitance of an unknown capacitor to a certain extent of precision. Here, capacitance is a term that describes the inherent property of a capacitor which is the electric charge stored with respect to a potential difference where two parallel plate conductors are used maintaining dielectric between them. Usually we get the measurement of capacitance via RLC meter which can determine the values of capacitance(C) along with the R and L which are resistance and inductance respectively. According to US Patents record, capacitance meter design had been patented in 1960 [1]. "Leyden Jar" which is the oldest and the most basic version on the today's capacitors, was invented in 1745-46 originally by Edward Jargen and later Pieter van Musschenbroek presented a working sample the following year [2]. Till then there have been numerous models and approaches were devised to determine the capacitance of a capacitor. In this work, an ATmega328P based capacitance measurement has been demonstrated along with its performance evaluation and usage analysis.

II. Literature Review

In the year 1998, using an RLC circuit, the capacitance meter had been built [3] in the device under test method. A recent paper demonstrated how we can very easily build an RLC meter by using the Arduino where a maximum of 9% error was recorded [4]. There has been other microprocessor-based capacitance meter with precision achieved at a linear level which also uses the RC discharge principle [5]. Even some projects could go on to achieve less than 0.7% error by using an RC circuit with the Arduino [6]. Another case of using op-amp along with MCU provided below 5% error [7]. All these related works implied the conclusion that the use of comparator or op-amp and other complex circuitry can increase the quality factor of the work. Selection of an IC with proper algorithmic analysis can lead to a quality work as well.

III. Apparatus

A. List

- ATmega328P
- Crystal Oscillator (16 MHz)
- Capacitor (22pf, 100µF, 10µF)
- Push Button
- Resistor (10KΩ, 220Ω)
- 16x2 LCD with I2C Header
- Voltage Regulator (LM 7805)
- Potentiometer (10KΩ)
- 9V Voltage Source

B. Details of the Materials

ATmega328P used here, is a 8-bit microcontroller built on the AVR architecture with 32 registers that are built for general purpose. It operates around 2 to 5 voltage with ±0.5V variation. It has 1kilobyte

EEPROM with an USART and have 2 kilobytes equivalent of SRAM [8].

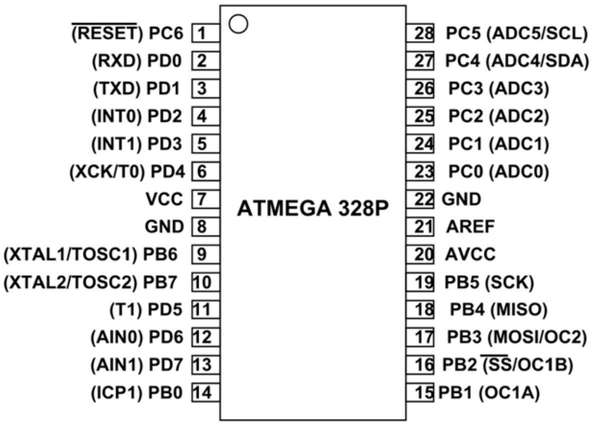

Fig.1. Pin diagram of ATmega328P [9]

A structure with quartz crystal basically responds to the electric field here which is an implementation of the inverse piezoelectricity [10]. It operates like frequency selective element which is an important element working with an MCU (Microcontroller Unit).

Fig.2. 16MHz Crystal Oscillator [11]

I2C header is used with the LCD to avoid the complication with regards to wiring setup. Built with PCF8574 [12], this piece collects the data from the microcontroller and convert them as usable to the LCD. I2C wired with LCD, we just require 4 pins to operate the display setup which are Vcc, Ground, SDA and SCL. Here, SDA is the Serial Data port and SCL is the Serial Clock port.

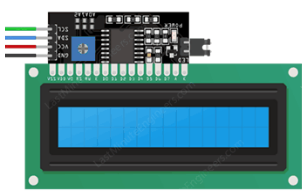

Fig.3. I2C wired with 16x2 LCD [13]

IV. METHODOLOGY

In this work, we have uploaded the code into ATmega328P and the functions have followed accordingly.

A. *Working Principle*

The capacitance meter here works on the principle of "Time Constant". We know that time constant, $\tau = R*C$ where the capacitance is getting charge with 63.2% of the supply voltage. The test capacitor whose value is to be measured will be charged. At first, the charging will be started, and the reference time will be taken. When the capacitor gets 63.2% charged which is around 3.1V (as the input was 5V), the time will be recorded.

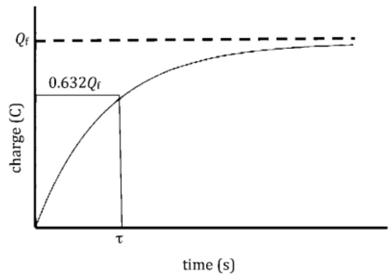

Fig.4. Charging time of a Capacitor

By the formula for time constant we will be able to determine the capacitance. For representing the output, we primarily chose micro Farad unit since the resistance through which the capacitor gets charged is 10KΩ. If the output is considerably low, we would change it to the nano Farad unit for better representation of the data. After the calculation, the voltage supply to the pin will be revoked and a discharge pin will be deployed to act as a sink for the capacitor and the discharge completes prohibiting all kinds of flow from the capacitor.

B. *Flow Chart*

The entire working principle can be very briefly understood via a flow chart. The chart in Fig.5 demonstrates our project work. It is to be noted that the flowchart represents a single loop where with the end notation drawing the completion, but in reality after discharging, we can take as much reading as we need and do not require any manual reset at every instance.

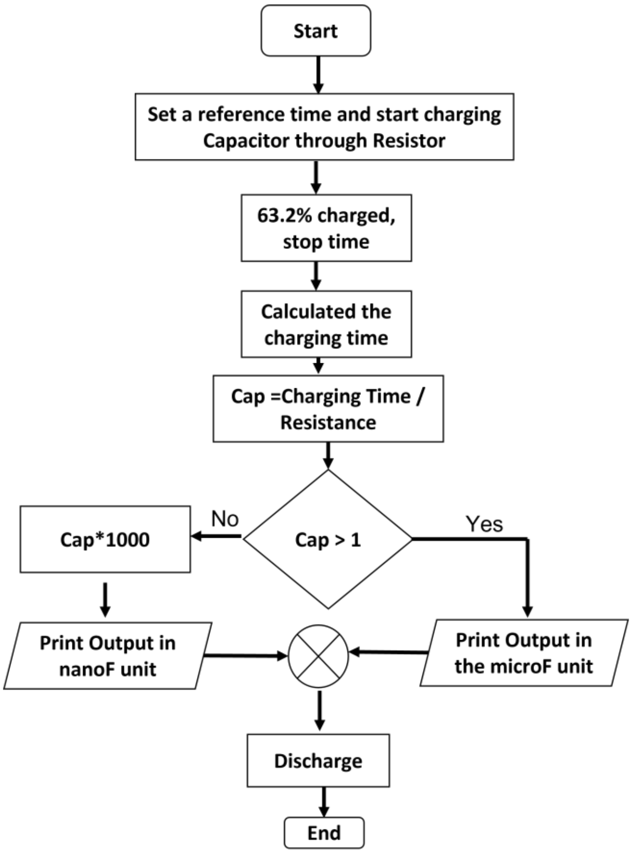

Fig.5. Flowchart of the project architecture

C. *Circuit Diagram*

A digital representation of our project is given below with the necessary circuit connections. The power supply has been regulated with LM7805 which acted as a voltage regulator.

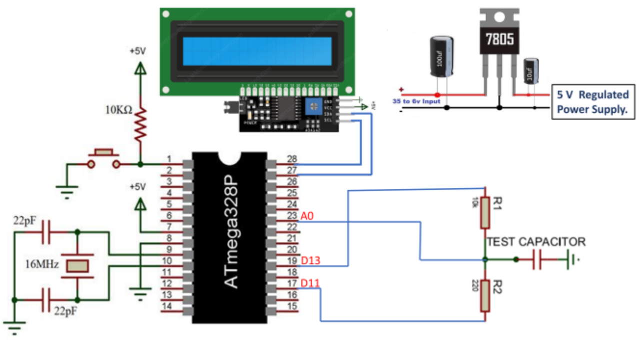

Fig.6. Circuit Diagram (Software Aided Design)

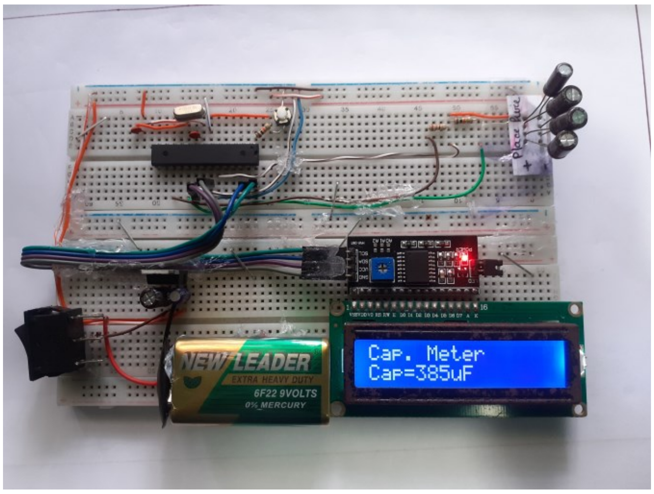

Fig.7. Circuit Diagram (Practical Project)

V. Performance Evaluation

A. *Collected Data*

We have measured different capacitors in the implemented project and a standard meter and recorded the values against the data embedded on the label of the capacitors.

Table.1. Comparison found for the Capacitance value among the Measured (meter built in this project), LC Meter Data and Label.

SL.	Label	Measured	Std LC Meter	Error wrt Label
1	1	1	1	0.0%
2	5	5.1	5	2.0%
3	10	10.2	9.8	2.0%
4	15	16	16	6.7%
5	47	43	48	8.5%
6	100	114	103	14.0%
7	110	122	114	10.9%
8	147	157	149	6.8%
9	200	223	209	11.5%
10	247	269	255	8.9%
11	300	331	317	10.3%
12	347	377	359	8.6%
13	400	441	423	10.3%

*All the capacitance data are recorded and written in microfarad unit.

B. Graphical Representation

The recorded samples have been visualized with respect to one another for comparison below.

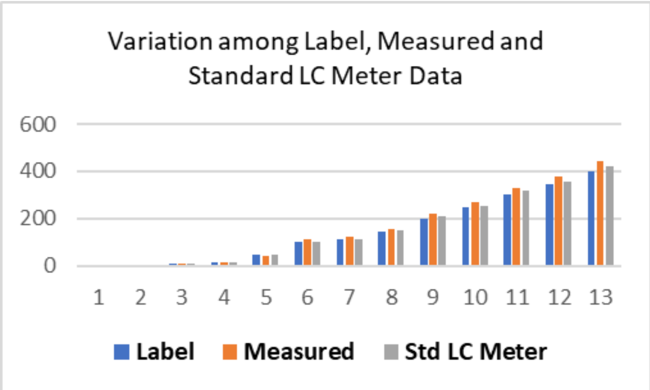

Fig.8. Label , Measured and LC Meter data comparison.

Data from a standard LC meter and the capacitance meter built in the project are put into comparison below.

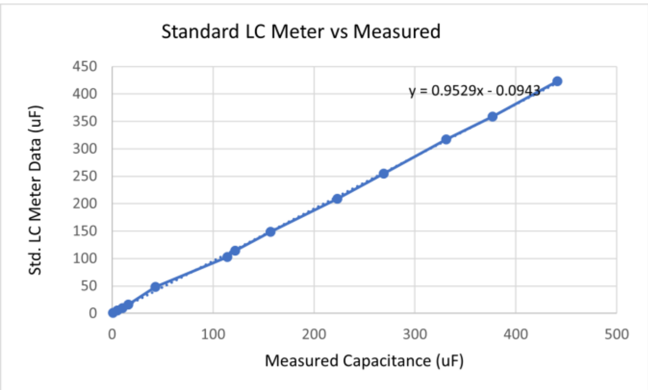

Fig.9. Comparison between standard LC meter and measured data in this project

Capacitance data written on label is compared with the data measured by the meter built in this project is given below :

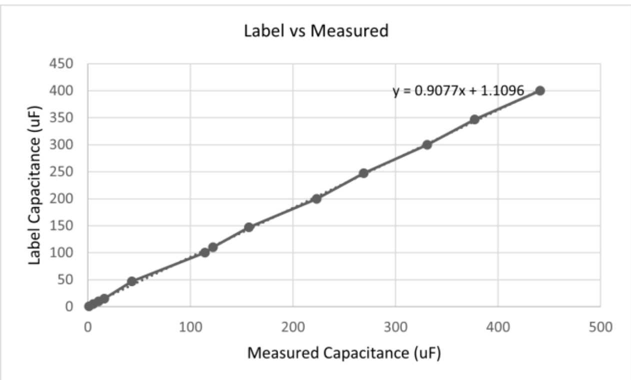

Fig.10. Comparison between label data on capacitor and measured data in this project

C. Data Insights

The values collected portray that the error or variation is slightly less for the low capacitance values. But the error margin increases quite rapidly when dealing with larger capacitance values. This fact can be related with the increasing time constant creating more variation from the accurate data.

The regression line generated yield that :

Case-1 : $y = 0.9077x + 1.1096$
where y = Label data and x= Measured Data with the implemented capacitance meter.

Case-2 : $y = 0.9529x - 0.0943$
where y = Standard LC Meter data and x= Measured Data with the implemented capacitance meter.

VI. LIMITATIONS

The values tested mostly range in between 1μF to 400 μF. The values beyond the range could not be tested. From the literature analysis, this capacitance meter is expected to work in the nano farad to micro farad range. The values while being measured also tend to fluctuate at the time of recording.

VII. CONCLUSION

This work has been an attempt to build a capacitance meter with a mere IC and some primary components. The error rate has been in considerable limit and following the regression line can essentially provide a value with nearly zero error. This project may not provide high precision owing the amount and quality of equipment employed, but this is a simpler approach towards measuring the capacitance.

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