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Part I

Introduction

Capacitance is the ability of a component or circuit to collect and store energy in the form of an electrical charge. Capacitors are energy-storing devices available in many sizes and shapes. They consist of two plates of conducting material (usually a thin metal) sandwiched between an insulator made of ceramic, film, glass or other materials, even air. A capacitor collects energy (voltage) as current flows through an electrical circuit. Both plates hold equal charges, and as the positive plate collects a charge, an equal charge flows off the negative plate. When the circuit is switched off, a capacitor retains the energy it has gathered, though slight leakage usually occurs. When a capacitance meter is connected with a capacitor it charges it with a preset value of current. When the capacitor is charged and discharged in this way by the capacitance meter, the capacitance meter measures the rate at which the voltage rises in that capacitor due to that current. The capacitance is then measured as a function of that voltage rise. The slower the voltage rises in the capacitor, the larger will be the value of its capacitance.[1]

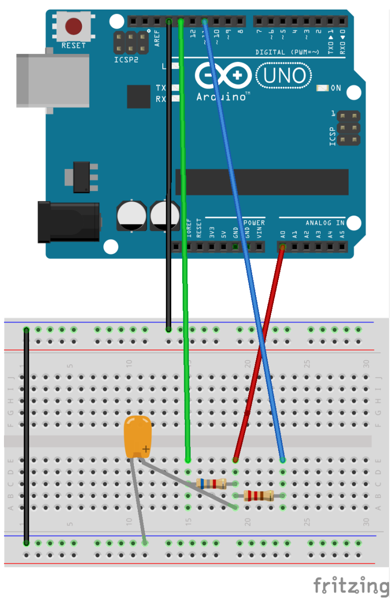
In this practice the capacitance value for different capacitors was found using a microcontroller by the method earlier mentioned.

Part II

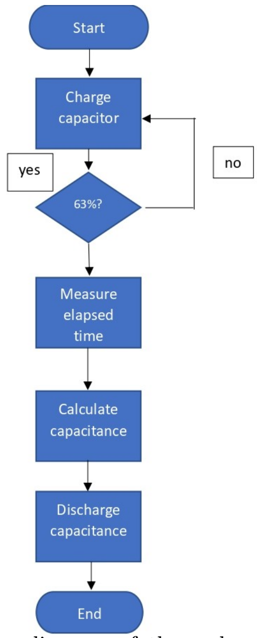
Method

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc.[2] The ATmega328 is a single-chip microcontroller created by Atmel in the megaAVR family (later Microchip Technology acquired Atmel in 2016). It has a modified Harvard architecture 8-bit RISC processor core. The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves throughput approaching 1 MIPS per MHz.[3]

First, the circuit shown in Figure 1 (a) was built, where also materials are specified. Then based on the algorithm shown in Figure 1 (b) a code was developed in Arduino.



(a) Diagram of a capacimeter built using Arduino



(b) Flux diagram of the code used to measure capacitance using Arduino

Figure 1: Connection and flux diagram for capacimeter using Arduino

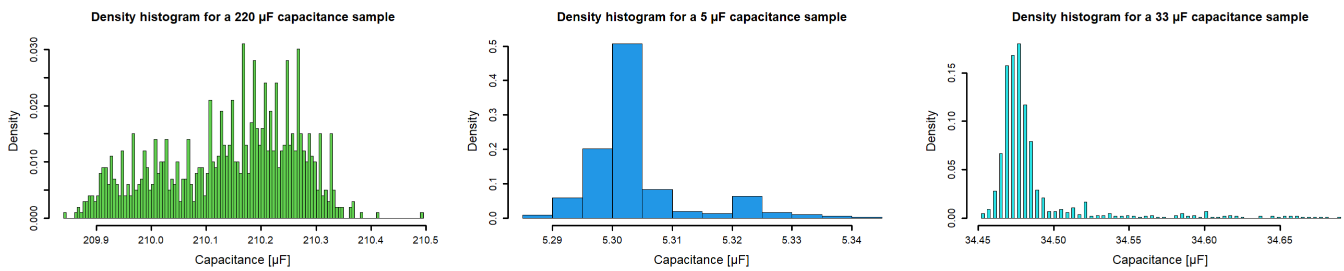
Part III
Results

Capacitance of 3 capacitors (220 µF, 33 µF, 4.7 µF) was measured with the device shown in Figure 1. A sample of 1000 measurements was taken for each capacitor. From each sample a density histogram was plotted (Figure 2) and the mean and the standard deviation were calculated using RStudio; said results are shown below:

```
# Mean and standard deviation of capacitances measured
# 220µF
> mean(220)
[1] 210.1408
> sd(220)
[1] 0.1226096

# 33µF
> mean(33)
[1] 34.48661
> sd(33)
[1] 0.03504483

# 4.7µF
> mean(4.7)
[1] 5.303425
> sd(4.7)
[1] 0.008996333
```



(a) 220 µF (b) 4.7 µF (c) 33 µF

Figure 2: Density histograms for a sample of 1000 measurement of capacitance of 3 different capacitors

To know the accuracy of the capacimeter[4], it is necessary to test the following hypotheses:
For 220 µF capacitor, the null hypothesis is $H_0 : \mu = 220$ and since the mean measured capacitance was 210.14 then the alternative hypothesis is $H_1 : \mu < 220$. A significance level of 0.05 was selected for this test. Since the size of the sample is 1000 (bigger than 30) and standard deviation of the population is known, the statistical test that fits better is

$$z_c = \frac{\overline{x} - \mu}{\sigma/\sqrt{n}} \tag{1}$$

Substituting $\sigma = 44$, $n = 1000$, $\mu = 220$ and $\overline{x} = 210.1408$, $z_c = -7.085$. Immediately, from the z-score value, $|z_c| - |z_t| >> 0.05$.

Following the same procedure for the other 2 capacitors, the P value turns to be bigger than the significance value. For the 33 µF it is 6.7 and for the 4.7 µF the z scores is 20.18.

Part IV
Conclusions

In all of the three capacitors measured, the results obtained show that the capacimeter is highly precise since all of the 3 standard deviations were less than 1, but not exact because all z-scores indicated that alternative hypothesis were to be selected.

Such results could be due to the values of resistors. A bigger resistor could absorb more energy from the capacitor, so that the capacitor would have more time to discharge, so that would allow Arduno voltage read to be more exact, which is what is needed for the accuracy of the device.

References

[1] Harrington, Roger F. (2003). Introduction to Electromagnetic Engineering (1st ed.). Dover Publications. p. 43. ISBN 0-486-43241-6.

[2] "Arduino UNO for beginners - Projects, Programming and Parts". makerspaces.com. Retrieved 4 February 2018.

[3] "ATmega328P". Retrieved 2016-07-14.

[4] Probability and Statistics for Engineering and the Sciences, Ninth Edition. Jay L. Devore