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Entitled

Design and implementation of an intelligent universal electronic components' tester

Evaluated on: …………………………...

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General Introduction

The field of electronics is continuously evolving, with an ever-expanding range of electronic components being introduced to meet the demands of advanced technologies. Ensuring the quality, performance, and compatibility of these components before integrating them into complex systems is of utmost importance. This necessitates the development of efficient and intelligent testing methodologies, utilizing modern platforms like micro-controllers, to assess the viability and functionality of electronic components.

In this thesis report, we present the design and implementation of an Intelligent Universal Electronic Components Tester (IUECT) using Arduino as its core platform. The IUECT represents a low-cost solution for testing a diverse range of electronic components, including resistors, capacitors, diodes and transistors.

The primary objective of the IUECT is to provide engineers, electronics students and enthusiasts with a reliable and versatile testing platform built upon the Arduino framework. By exploiting the power of Arduino, the IUECT offers enhanced accuracy, speed, and efficiency in the testing process. It leverages the flexibility of Arduino programming to enable users to assess the performance and quality of electronic components instantly and effectively.

This project report delves into various aspects of the IUECT according to the following structure:

In the first part, we will discuss the measurement methods of passive elements such as resistors, capacitors, inductors, and active elements such as transistors and diodes.

As for the second part, we will talk about the intelligent measuring device and the principle of its work.

Ultimately, we discuss the code and make a general conclusion about the topic.

Chapter I:Passive and active components: Theoretical background

I.1 Introduction:

A passive component is a module that does not require energy to operate, except for the available alternating current (AC) circuit that it is connected to. A passive module is not capable of power gain and is not a source of energy. A typical passive component would be a chassis, inductor, resistor, transformer, or capacitor.

Generally, passive components are not able to increase the power of a signal nor are they able to amplify it. However, they can increase current or voltage by an LC circuit that stores electrical energy from resonant frequencies or by a transformer that acts like an electrical isolator.

In the context of electronic technology, there are stricter guidelines for the term passive component. Electronic engineers view this term usually in correlation with circuit analysis, which involves methods of finding the currents through and the voltages across every component in the network. Passive components can influence the flow of electricity running through them. For example, they can resist its flow, store energy for later use, or produce inductance. However, they cannot control or amplify electricity themselves.

Active components require a source of energy, typically in the form of a direct current, in order to perform their specific function. They can manipulate the flow of electricity in some way. Most active components consist of semiconductor devices, such as transistors and integrated circuits.

I.2 Passive electronic components:

I.2.1 Resistors:

The resistor is a passive electrical component that creates resistance in the flow of electric current. In almost all electrical networks and electronic circuits they can be found. The resistance

is measured in ohms (Ω). An ohm is the resistance that occurs when a current of one ampere (A) passes through a resistor with a one volt (V) drop across its terminals. The current is proportional to the voltage across the terminal ends. This ratio is represented by ohm's law:

$$R = \frac{V}{I} \qquad (1)$$

I.2.1.1 Application of Resistors:

Resistors are the most used component in electronic devices; they find use in:

- **Use of Resistor in Circuit Functions:**

In most of the circuits, there is a resistor knob that is used to control the flow of current through resistance. Resistors are used in large machinery to reduce any damage to the appliance. The main uses of this knob-type resistor:

   - Controlling the loudness of amplifier signals.
   - Controlling the speed of motors and other machinery.
   - It helps us to find modulation at different resistances.

- **Use of Resistors as protection for LED and Transistors:**

LEDs are known for their low consumption of electricity as they can't conduct a high amount of current. Hence, resistors are used in between the semiconductors for better control of the desired current range that is ideal for them.

- **Use of Resistors for Heating:**

The collision between electrons and ions in resistors produces heat and hence resistors are used in heaters and toasters. Electric cookers, Microwaves, and Sterilizing units also use these resistors. The metal filament of a bulb glows white-hot because of the high temperature produced due to the resistance when electricity is passed through it.

- **Use of Resistors in Dividing Voltages:**

Dividing the voltage is required when some components need to work in a lesser voltage than the supplied input voltage. Each component requires different voltages hence dividing voltages can help the components to run smoothly. Connecting the resistors in series will help to lower the voltage equally across each resistor.

- **Use of Resistors in Amplifiers:**

The amplifier is used to increase its input signal. Resistors are mainly used in it to produce various signals and to set different gain and phase values through absolute values and ratios of resistances.

- **Uses of Resistors as Temperature Sensors:**

Some resistors can change their resistance according to the temperature. These can be used as temperature sensors and are linked to devices that can automatically decrease the Air Conditioner temperature according to the room temperature.[1]

I.2.1.2 How to test a resistor:

Figure I.1 shows the circuit diagram of a simple resistance measurement scheme. Rx is the resistance to be measured. R1 is the input resistance. i is the current passing through the loop and 5V is the supply voltage. To find the unknown resistance Rx, the voltage across Rx is measured first. let the voltage across R1 be VR1.

Since R1 and Rx are connected in series, the current through them will be equal. So the unknown resistance. [2]
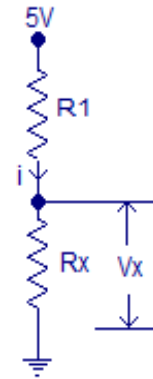

Figure I-1: A simple resistance measurement scheme.

$$Rx = R1\left(\frac{VX}{5-VX}\right) \qquad (2)$$

I.2.2 Capacitors:

Capacitors are analog electrical components that can collect and store electrical energy. As a direct current flows into a capacitor, the latter charges with energy and releases an alternating current flow back into the circuit.[3]

I.2.2.1 Applications of Capacitors:

- **Decoupling and Bypass Capacitors:**

    Capacitors play a critical role in the operation of digital electronics by protecting sensitive microchips from noise on the power signal. This noise can cause abnormal behaviors. Capacitors used in this application are called decoupling capacitors. These capacitors should be placed close to each microchip to be effective because circuit traces act as antennas and pick up noise from the surrounding environment. Decoupling and bypass capacitors are also used in any area of a circuit to reduce the overall impact of electrical noise.

- **Coupling or DC Blocking Capacitors:**

    Capacitors can pass AC signals while blocking DC and can be used to separate the AC and DC components of a signal. The value of the capacitor doesn't need to be precise or accurate for coupling. However, it should be a high value, as the reactance of the capacitor drives the performance in coupling applications.

- **Snubbed Capacitors :**

    In circuits where a high-inductance load is driven, such as a motor or transformer, large transient power spikes can occur as the energy stored in the inductive load is suddenly discharged. This discharge can damage components and contacts. Applying a capacitor can limit, or snub, the voltage spike across the circuit, making the operation safer and the circuit more reliable. Using a snubbing technique in lower-power circuits prevents spikes from creating undesirable radio frequency interference. This interference generates anomalous behavior in circuits and causes difficulty in gaining product certification and approval.

- **Pulsed Power Capacitors:**

    Capacitors are small batteries that offer unique energy storage capabilities beyond those of chemical-reaction batteries. When lots of power is required in a short period of time, large capacitors and banks of capacitors are a superior option for many applications. Capacitor banks store energy for applications such as pulsed lasers, radars, particle accelerators, and rail guns. A common application of the pulsed-power capacitor is in the flash on disposable cameras, which is charged then rapidly discharged through the flash, providing a large pulse of current.

- **Capacitor Safety :**

As energy storage components, capacitors can store dangerous amounts of energy. This high level of energy can cause fatal electrical shocks and damage equipment even when a capacitor is disconnected from power for a considerable amount of time. For this reason, it is always a good idea to discharge capacitors before working on electrical equipment.

Electrolytic capacitors are prone to fail violently under certain conditions, especially if the voltage on a polarized electrolytic capacitor is reversed. Capacitors used in high-power and high-voltage applications may also fail violently as the dielectric materials break down and vaporize.[4]

I.2.2.2 How to test Capacitors:

The capacitance meter relies on a property of resistor capacitor (RC) circuits- the time constant. The time constant of an RC circuit is defined as the time it takes for the voltage across the capacitor to reach 63.2% of its voltage when fully charged: Larger capacitors take longer to charge, and therefore will create larger time constants.

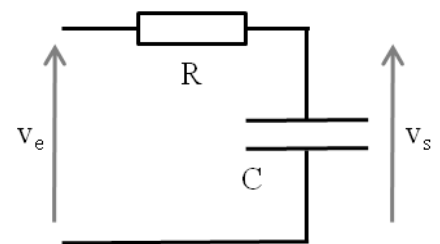**Figure I-02:** RC circuit.

The capacitance in an RC circuit is related to the time constant by the equation:

$$TC = R \times C \tag{3}$$

TC=Time constant of the capacitor (in seconds)

R=Resistance of the circuit (in Ohms)
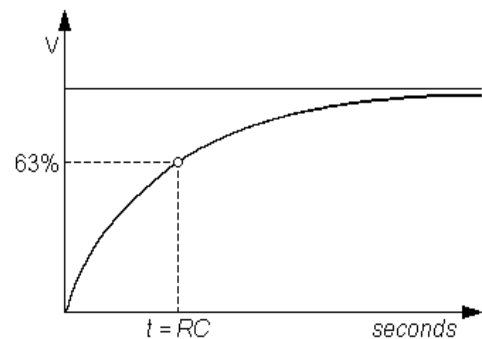
C=Capacitance of the capacitor (in Farads)

Figure I-3: the time constant.

Rearranging the equation to solve for capacitance gives: [5]

$$C = \frac{TC}{R} \tag{4}$$

I.2.3 Inductors:

An inductor is a coil of wire around a central core that can consist of a variety of materials. Therefore, inductors are also known as "coils" or "reactors". If an electric current flows through this coil of wire, it produces a magnetic field around it. The strength of the magnetic field induced by the electric current flowing around the central core depends on the type of core material, the number of coils on the wire, and the cross-sectional area and length of the coil. For example, if the central core were also magnetic, the magnetic field around the inductor would be much stronger .Inductors are a very important component in electronic circuits because they can resist or oppose current changes in the circuit. [6]

I.2.3.1 Applications of Inductors:

We use inductors for:

- Boost converters where they help increase the direct current (DC) output voltage while decreasing the current.
- To choke alternating current supplies and only allow direct current (DC) to pass through a circuit.
- Separation of different frequencies.
- RF circuits, analog circuits, and tuned circuits.
- Motors, transformers, relays, and a wide range of other electronics and converters.

These are the most common inductor applications, and we can use higher frequency inductors in radio applications. [7]

I.2.3.2 How to test Inductors:

If you would like to calculate the inductance, you need to calculate the resonant frequency of an LC circuit.

An LC circuit (also called a resonant circuit, tank circuit, or tuned circuit) is an idealized RLC circuit of zero resistance. An LC circuit contains only an inductor and a capacitor, in a parallel or series configuration:
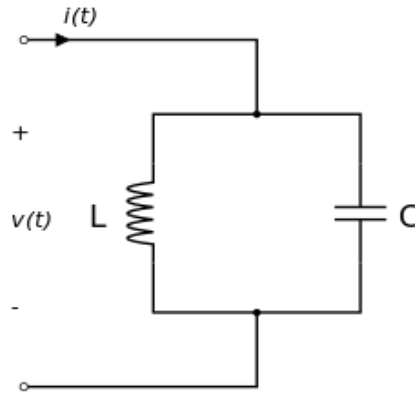
Figure I-4: Configuration for inductance measurement

Tank circuits are commonly used as signal generators and band pass filters - meaning that they are selecting a signal at a particular frequency from a more complex signal.

The resonant frequency is a natural, undamped frequency of a system. If we apply a resonant frequency, the oscillations become the maximum amplitude, and even relatively small forces can produce large amplitudes. However, if any other frequency is chosen, that signal is dampened. There are many different types of resonances, e.g.:

- Mechanical and acoustic
- Electrical
- Optical
- Orbital
- Molecular.

For LC circuits, the capacitance C and the impedance L. by the formula below determine the resonant frequency:

$$F_r = \frac{1}{2\pi\sqrt{LC}} \qquad\qquad (5)$$

So using the equation (3) we get :

$$L = \frac{1}{4\,\pi^2 F_r^2\, C} \hspace{3cm} (6)$$

I.3 Active Electronic Components:

I.3.1 Transistors:

I.3.1.1 Definition:

A transistor is a miniature semiconductor that regulates or controls current or voltage flow in addition to amplifying and generating these electrical signals and acting as a switch/gate for them. Typically, transistors consist of three layers, or terminals, of semiconductor material, each of which can carry a current.

Transistors are one of the key components in most of the electronic devices that are present today. Developed in the year 1947 by three American physicists John Bardeen, Walter Brattain, and William Shockley, the transistor is considered one of the most important inventions in the history of science.

A typical transistor is composed of three layers of semiconductor materials or more specifically terminals that help to make a connection to an external circuit and carry the current. A voltage or current that is applied to any one pair of the terminals of a transistor controls the current through the other pair of terminals. There are three terminals for a transistor. Depending of their type, the terminals are named:

- Base/Gate: This is used to activate the transistor.
- Collector/Drain: It is the positive lead of the transistor.
- Emitter/Source: It is the negative lead of the transistor. [9]

I.3.1.2 Application:

Transistors have extensive uses in our day-to-day life. They are used in nearly every kind of circuit to perform a function. A few applications of transistors are switches, amplifiers, oscillators, modulators, detectors, BJT, FET, HBT, avalanche transistors, etc.[10]

I.3.1.3 Types:

Transistors are classified into two major types:

a) Bipolar junction transistor (BJT):

A BJT is one of the most common types of transistors and can be either NPN or PNP. This means a BJT consists of three terminals: the emitter, the base and the collector. By joining these three layers, a BJT can amplify an electrical signal or switch the current on or off.

Two kinds of electrical charge -- electrons and holes -- are involved in creating a current flow.
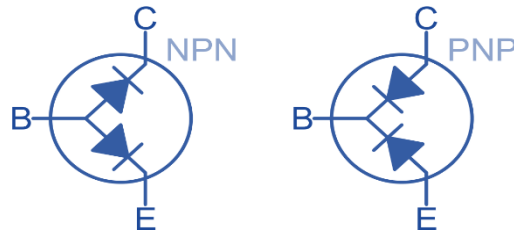

Figure I-5: BJT transistors ''NPN - PNP''

In its normal operation, the BJT's base-emitter junction is forward-biased with a very small emitter resistance, while the base-collector junction is reverse-biased with a large resistance.

In a PNP-type BJT, conduction happens through holes or the absence of electrons. The collector current is slightly less than the emitter current. Changes in the latter affect the former. The base controls the current flow from the emitter to the collector. In this case, the emitter emits holes, which are then collected by the collector.

In an NPN-type BJT, electrons pass from the emitter to the base and are collected by the collector. When this happens, conventional current flows from the collector to the emitter. The base controls the number of electrons emitted by the emitter.

b) Field-effect transistor (FET):

A field-effect transistor (FET) also has three terminals, source, drain and gate , which are analogous to BJT's emitter, collector and base, respectively. In the FET, the n-type and p-type silicon layers are arranged differently from those of the BJT. They are also coated with layers of metal and oxide to create the metal-oxide-semiconductor field effect transistor (MOSFET).
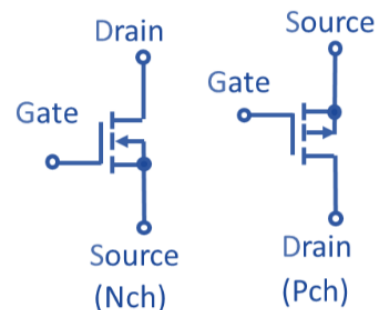

Figure I-6: FET Transistors (mosfets)

In the FET, the field effect refers to an effect that enables the flow of current and switches the transistor on. Electrons can't flow from the n-type source to the drain because the p-type gate between them contains holes.

But attaching a positive voltage to the gate creates an electric field that enables electrons to flow from the source to the drain. This creates the field effect, which facilitates the flow of current in the FET.

FETs are commonly used in low-noise amplifiers, buffer amplifiers and analog switches. The metal-semiconductor field-effect transistor (MESFET) is commonly used for high-frequency applications, such as microwave circuits. [11]

I.3.1.4 Characteristics:

1-Bipolar Junction transistors characteristics:

   a) Type:

BJTs are of two types namely NPN and PNP based on the doping types of the three main terminals. An NPN transistor consists of two semiconductor junctions that have a thin p-doped anode region and a PNP transistor also consists of two semiconductor junctions that have a thin n-doped cathode region.

   b) Current gain:

It is defined as the ratio of the output current to the input current of the transistor.

There are two types of current gain in BJT i.e. α and β.

$$\alpha = \frac{IC}{IE} \hspace{5cm} (7)$$

$$\beta = \frac{IC}{IB} \hspace{5cm} (8)$$

Where I_E is the emitter current, I_C is the collector current and I_B is the base current.

   c) Emitter current:

The emitter current of a transistor, Ie, is the amplified output current of a bipolar junction transistor. As the emitter current for a common emitter configuration is defined as

$$Ie = Ic + Ib. \hspace{4cm} (9)$$

   d) Base to Emitter voltage:

The voltage between the Base and Emitter (VBE), should be positive for an NPN transistor: the Base terminal is always positive with respect to the Emitter to ensure a direct biasing for the base-emitter diode. The Collector supply voltage must also be more positive with respect to the Emitter (VCE) to allow electrons flow from the emitter to the collector.

e) Leakage current:

The current flowing through the collector when the emitter terminal is open is called collector to base leakage current with emitter open ICBO. This leakage current doubles for every 10°C rise in temperature. This leakage current also increases when the reverse bias voltage is increased.

2-Field effect transistors (MOSFET) characteristics

a) Threshold voltage

One of the most important physical parameters of a MOSFET is its threshold voltage *Vth*, defined as the gate voltage at which the device starts to turn on. The accurate modeling of threshold voltage is important to predict correct circuit behavior from a circuit simulator.

b) Gate-source capacitance

CGS is the capacitance due to the overlap of the source and the channel regions by the polysilicon gate and is independent of applied voltage. It is an important parameter for a MOSFET transistor as it largely shapes its dynamic behavior, beside other parasitic capacitances.

c) Drain-source on resistance

RDS(on) stands for "drain-source on resistance," or the total resistance between the drain and source in a MOSFET when it is turned on. RDS(on) is the basis for a maximum current rating of the MOSFET and is also associated with current loss.[12]

I.3.2 Diode:

I.3.2.1 Definition:

A diode is a two-terminal electronic component that conducts electricity primarily in one direction. It has high resistance on one end and low resistance on the other end.

I.3.2.2 Application:

There are various types of diodes and these diodes are used in numerous ways.

- The most basic function would be changing AC current to DC current by removing some part of the signal. This functionality would make them rectifiers. They are used in electrical switches and are used in surge protectors because they can prevent a spike in the voltage.

- Diodes help in performing digital logic. Millions of diodes are used like logic gates and used in modern processors.

- They are used for isolating signals from a supply. For example, one of the major uses of diodes is to remove negative signals from AC current. This is known as signal demodulation. This function is basically used in radios as a filtering system to extract radio signals from a carrier wave.

- They are also used in creating power supplies and voltage-doublers. Using a full wave rectifier will help to deliver a more stable voltage. A combination of a diode with a capacitor will help to make small AC voltage multiply to create a very high voltage.

- The light emitting diodes or LEDs are used in sensors and in laser devices any many other light illumination devices.

- Zener diodes are used as voltage regulators and varactors are used in electronic tuning and varistors are used in suppressing AC lines.

- Diodes are the basis of op-amps and transistors.

These were some of the uses of diodes that can be seen in the practical world. For more such physics articles and important notes, keep visiting BYJU'S.

I.3.1.3 Types:

a) Light Emitting Diode

When an electric current between the electrodes passes through this diode, light is produced. In other words, light is generated when enough forwarding current passes through it. In many diodes, this light generated is not visible as there are frequency levels that do not allow visibility. LEDs are available in different colors. There are tricolor LEDs that can emit three colors at a time. Light color depends on the energy gap of the semiconductor used.

b) Laser diode

It is a different type of diode as it produces coherent light. It is highly used in CD drives, DVDs and laser devices. These are costly when compared to LEDs and are cheaper when compared to other laser generators. Limited life is the only drawback of these diodes.

c) Avalanche diode

This diode belongs to a reverse bias type and operates using the avalanche effect. When voltage drop is constant and is independent of current, the breakdown of avalanche takes place. They exhibit high levels of sensitivity and hence are used for photo detection.

d) Zener diode

It is the most useful type of diode as it can provide a stable reference voltage. These are operated in reverse bias and break down on the arrival of a certain voltage. If current passing through the resistor is limited, a stable voltage is generated. Zener diodes are widely used in power supplies to provide a reference voltage.

e) Schottky diode

It has a lower forward voltage than other silicon PN junction diodes. The drop will be seen where there is low current and at that stage, voltage ranges between 0.15 and 0.4 volts. These are constructed differently to obtain that performance. Schottky diodes are highly used in rectifier applications.

f)   Photodiode

A photodiode can identify even a small amount of current flow resulting from the light. These are very helpful in the detection of light. This is a reverse bias diode and used in solar cells and photometers. They are even used to generate electricity.

g) PN junction diode

The P-N junction diode is also known as rectifier diodes. These diodes are used for the rectification process and are made up of semiconductor material. The P-N junction diode includes two layers of semiconductors. One layer of the semiconductor material is doped with P-type material and the other layer with N-type material. The combination of these both P and N-type layers form a junction known as the P-N junction. Hence, the name P-N junction diode.

I.3.2.4 Characteristics:

a) Forward-biased Diode

There is a small drop of voltage across the diode when the diode is forward-biased and the current is conducting. For silicon diodes, the forward voltage is 690mV and for germanium, 300mV is the forward voltage. The potential energy across the p-type material is positive and across the n-type material, the potential energy is negative.

b) Reverse-biased Diode

A diode is said to be reverse-biased when the battery's voltage is dropped completely. For silicon diodes, the reverse current is -20μA and for germanium, -50μA is the reverse current. The potential energy across the p-type material is negative and across the n-type material, the potential energy is positive.

c) Zero-biased Diode

When the diode is zero-biased, the voltage potential across the diode is zero.

I.4 Conclusion:

In conclusion, the theoretical background on passive and active electronic components has provided a comprehensive understanding of these essential building blocks of electronic systems. Throughout this chapter, we explored the definitions, characteristics, types, and areas of use for both passive and active components.

Passive components, such as resistors, capacitors, and inductors, were examined. Their primary function is to store, control, or dissipate energy without amplification. We discussed their various properties and applications: Passive components find wide usage in signal conditioning, filtering, energy storage, and timing circuits, among others.

On the other hand, active components, including transistors and diodes, were explored for their ability to amplify, control, or generate electrical signals. We delved into the basic types of active components, such as bipolar junction transistors and metal-oxide-semiconductors field-effect transistors. We examined their unique properties and functions. Active components play a pivotal

role in signal amplification, switching, modulation, and signal processing across various electronic systems and applications.

Armed with this knowledge about the passive and active components, we can now move forward to the subsequent stages of our project, building upon the understanding of these components to develop the universal intelligent electronic components tester.

Chapter II:

The design and implementation of the universal intelligent components' tester

II.1 Introduction:

In the preceding chapter, we explored the diverse types and values of electronic components, ranging from simple values associated with passive components to the varying types and distinctive characteristics of active components. In this chapter, our focus shifts towards a practical examination of each component individually. To simplify our study, we will approach each component by addressing the following key aspects:

- The idea: We will delve into the concepts and methodologies underlying the calculations involved in our system, emphasizing practical applications.
- Hardware: This section will provide a comprehensive list of the components required to realize the tester, accompanied by a schematic representation of the setup.
- Software: We will uncover the algorithm powering the functionality of the tester, shedding light on its inner workings and operational principles.

Ultimately, we will present the final outcomes of our project, including key takeaways and any challenges encountered throughout the development process. By adopting this structured approach, we aim to provide a clear and practical understanding of each component, facilitating a seamless progression in our exploration of this project.

II.2 Resistance:

II.2.1 The idea:

We will use a basic voltage divider to calculate the resistance. As we know, a voltage divider is made of two resistances (R_1 and R_2) in series. The output voltage in the middle point is:

$$V_{out} = (\frac{R_1}{R_1+R_2})\ V_{in} \qquad\qquad (10)$$

$$R_2 = 1\ (\frac{V_{in}}{V_{out}} - 1) \qquad\qquad (11)$$

Knowing Vin and R2, this voltage-divider based setup allows the measurement of an unknown resistance R1. However, using a voltage divider to measure resistance can introduce certain limitations and potential issues. Here are some problems associated with using a voltage divider for resistance measurement:

Loading Effect: When a voltage divider is used for resistance measurement, the act of connecting the measuring device or load to the midpoint of the divider can alter the voltage across the resistor being measured. This change in voltage affects the accuracy of the measurement, as it creates an unintended loading effect on the resistor under test.

Voltage Drop: A voltage divider operates by dividing the input voltage across multiple resistors. This division of voltage results in a reduced voltage across the resistor being measured. If the voltage drop across the resistor is too low, it can affect the accuracy of the measurement and make it more susceptible to noise and errors.

Sensitivity to Load Impedance: The accuracy of a voltage divider measurement is influenced by the load impedance connected to the midpoint. If the load impedance is not sufficiently high compared to the resistor being measured, it can alter the voltage division and introduce errors in the resistance measurement.

Limited Measurement Range: The use of a voltage divider restricts the measurement range based on the resistors used in the divider circuit. If the resistance being measured falls outside the range of the voltage divider, the accuracy and reliability of the measurement can be compromised.

Using an Arduino analog input to measure the midpoint voltage can help address some of the issues associated with using a voltage divider for resistance measurement:

Loading Effect: The Arduino analog input has a high input impedance, which means it draws very little current from the voltage divider circuit. As a result, it minimizes the loading effect on the resistor being measured, ensuring that the voltage across the resistor remains relatively unaffected.

Sensitivity to Load Impedance: The high input impedance of the Arduino analog input minimizes the impact of the load impedance connected to the midpoint. It ensures that the voltage division remains consistent and unaffected by the load impedance, thereby improving the accuracy of the resistance measurement.

Voltage Drop: The Arduino analog input has a known and stable reference voltage. By measuring the voltage at the midpoint of the voltage divider directly with the Arduino, you can accurately determine the voltage drop across the resistor being measured, even if it's a small value. This helps maintain measurement accuracy and reduces errors caused by voltage division.

Extended Measurement Range:

Using an Arduino, we have the flexibility to choose different resistors for the voltage divider circuit based on the resistance range we want to measure. This allows to extend the measurement range beyond the limitations of a fixed voltage divider, providing more versatility in resistance measurement.

For example, with a reference resistor $R_2=1k\Omega$, we can measure resistance values from 0 to $1k\Omega$ with quite good precision. However, to measure a higher resistance we must use larger values of R_2, typically in the same range up to ten times as the measured resistor .

In our design we opted for the following choices for the reference resistor:

Reference resistor R2	Range of measured values
2кΩ	0 to 2kΩ
20кΩ	2kΩ to 20kΩ
200кΩ	20kΩ to 200kΩ
1M Ω	200kΩ to 2MΩ

The changing of the reference resistor could be done using a manual switch, be the use of Arduino offer the possibility to automate this process, thus implementing and " auto-range" function.

The schematic diagram shown in Figure II.1 illustrates the implementation of our resistance meter, which incorporates an auto-ranging capability for resistance measurement.
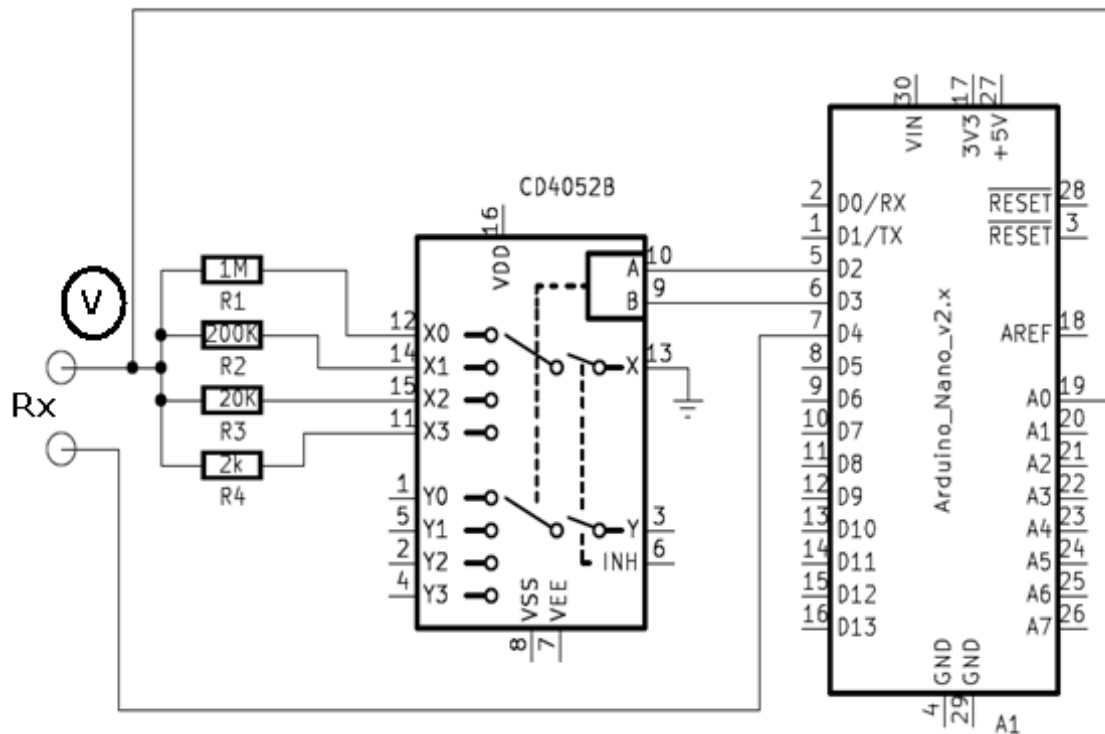

Figure II-1: The schematic diagram of the Resistance meter

The circuit includes an Arduino, a few resistors, and the CD4052 integrated circuit. The CD4052 is an analog multiplexer that allows the selection and routing of analog signals from multiple inputs to a single output. It contains two independent 4-channel multiplexers in a single IC package, with individual control capabilities for each multiplexer. This versatile IC exhibits low on-resistance and leakage characteristics, ensuring minimal signal degradation during switching. It also provides a wide bandwidth, enabling the transmission of high-frequency signals without significant signal loss. Its compatibility with a broad range of voltage levels (3V to 18V) makes it suitable for both digital and analog circuits, making it an excellent choice for our design.

In our design, the analog multiplexer is utilized to switch between various reference resistors. The Arduino controls the selection inputs of the multiplexer using two digital outputs (D2 and D3). The voltage divider configuration consists of the resistor under test (Rx) connected in series with one of the four reference resistors, determined by the control word sent to the multiplexer. The voltage divider's supply is provided by the digital output D4, while the common ground is established at pin 13 of the multiplexer. The critical mid-point voltage, necessary for resistance measurement, is captured through the Arduino's analog input (A0), which acts as a voltmeter (indicated by the symbol V within a circle in the schematic).

The software plays a vital role in calculating the unknown resistor value (using equation 9) and implementing the auto-ranging functionality, which will be discussed in the subsequent section. Another possible approach could have involved utilizing separate analog inputs for each reference value and performing the switching operation through software. However, due to limitations in our setup and the need to allocate the remaining analog inputs for other component measurements, this alternative was not feasible.

II.2.2 Hardware:

Here is the list of the used hardware components:

- Arduino NANO (1 part)
- I2C serial interface board (1 part)
- LCD display (1 part)
- 2 KΩ resistor (1 part)
- 20 KΩ resistor (1 part)

- 200 KΩ resistor (1 part)
- 1 MΩ resistor (1 part)
- push button (1 piece)
- Multiplexer CD4052 (1 part)

II.2.3 Software:

We have developed a C program to automate and control the circuit shown in Figure II.1. This program ensures the proper operation of the circuit based on the following chart, which we summarize as follows:

Initially, the power supply is applied to one end of Rx through the Arduino digital pin D4 using the function:

digitalWrite(pinX, HIGH);

Here, pinX is configured in the **setup()** part of the code as:

pinMode(pinX, OUTPUT);

The **HIGH** state corresponds to a 5V voltage.

Next, a control word is issued through pins D2 and D3 to establish a connection between Rx and one of the reference resistors, while also closing the circuit at the ground (pin 3 of the multiplexer). All possible combinations of D2D3 are sequentially generated to sweep through the four reference resistors, starting from the lowest to the highest. The code snippet describing this operation is as follows:

```
 if(Mod == 1)
 {  //…….
  digitalWrite(MUXA1,LOW);
  digitalWrite(MUXB1,LOW); //D2D3=00
//…
  Start2K:
  digitalWrite(MUXA2,LOW);
  digitalWrite(MUXB2,LOW);
//…define 2k reference resistor, read mid-point and calculate Rx
// check if Rx is  in range
  Start20K://….
  digitalWrite(MUXA2,HIGH);
  digitalWrite(MUXB2,LOW); // word D2D3=01
//… define 20k reference resistor, read mid-point and calculate Rx
// check if Rx is in range
```

```
Start200K:
 digitalWrite(MUXA2,LOW);
 digitalWrite(MUXB2,HIGH); // D2D3= 10
 // define 200k reference resistor, read mid-point and calculate Rx
// check if Rx is in range
 //*********1M*********
 Start1M:   //….
 digitalWrite(MUXA2,HIGH);
 digitalWrite(MUXB2,HIGH); // digital word D2D3= 11
// define 2M reference resistor, read mid-point and calculate Rx
 // check if Rx is in range
```

After applying the first D2D3 word (lowest reference resistor), we need to read the voltage at the mid-point of the voltage divider formed by Rx and Rref. This is achieved by connecting this mid-point to the Arduino analog input A0. The voltage at this point is then read using the function:

```
analogRead(A0);
```

The program checks if the voltage reading is valid. If it is not, it indicates that the measured value is out of range and proceeds to increase the scale by issuing the next D2D3 word until an acceptable voltage reading is obtained. This process is known as "auto-ranging."
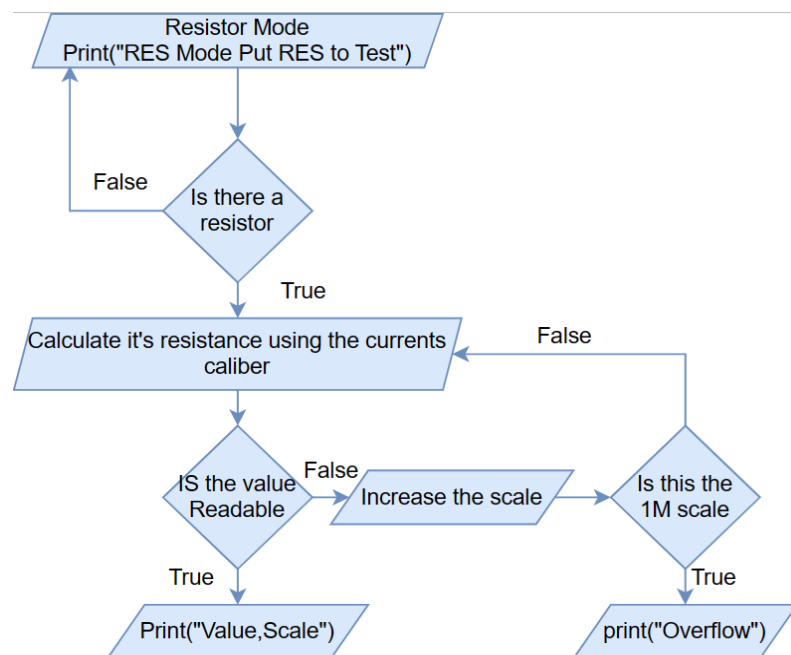

Figure II-2: Algorithm chart of the Resistance meter

If the voltage is still unreadable, the program concludes that the resistance being measured falls outside the designed measurable range and generates an "overflow" message. Figure II.2 provides a summary of this operation in the form of an algorithm chart.

II.3 Capacitance:

II.3.1 The idea:

Arduino capacitance meter relies on the basic property of capacitors: the time constant. An Arduino can measure capacitance because the time a capacitor takes to charge is directly related to its capacitance by the next equation:

$$\mathbf{T_C = R \times C} \text{.. (12)}$$

Usually, T_C is measured between 0 and 63.2% of the voltage charging dynamic.

In our design, we are going to charge the capacitor through a resistor using one of the Arduino digital pins, according to schematic diagram Figure II.3.

Using the ADC of the Arduino (one analog input), we can measure the voltage across the capacitor to be measured Cx. The measured voltage is monitored: as soon as it reaches 63.2% of the full charge, we stop the charge and calculate the capacitance as :

$$\mathbf{C = T_C / R} \hspace{4cm} (13)$$

When using this RC time constant method to measure capacitance, several issues can be encountered. Here are some common challenges associated with this measurement technique:

Accuracy: The RC time constant method relies on measuring the time it takes for the voltage across the capacitor to reach a certain threshold level. However, factors such as leakage currents, parasitic resistances, and variations in the capacitor's characteristics can introduce errors and affect the accuracy of the measurement.

Limited Measurement Range: The RC time constant method is typically suitable for measuring small to moderate capacitance values. Larger capacitors or those with higher capacitance values

may require longer charging or discharging times, making it challenging to achieve accurate measurements within a reasonable time frame.

Calibration and Calibration Components: To achieve accurate capacitance measurements, the RC time constant method often requires calibration using known reference capacitors. Calibration components may introduce additional complexities and uncertainties, especially if their characteristics are not well-matched with the capacitor under test.

Time Constraints: The RC time constant method typically requires a certain duration for charging or discharging the capacitor to accurately measure its capacitance. This can be time-consuming, especially when dealing with larger capacitance values, limiting the speed of the measurement process.

To mitigate these challenges, alternative measurement methods like bridge circuits, LCR meters, or dedicated capacitance measurement ICs can be employed. These techniques provide more precise and reliable measurements by compensating for environmental factors, handling a wider range of capacitance values, and minimizing the impact of parasitic components.
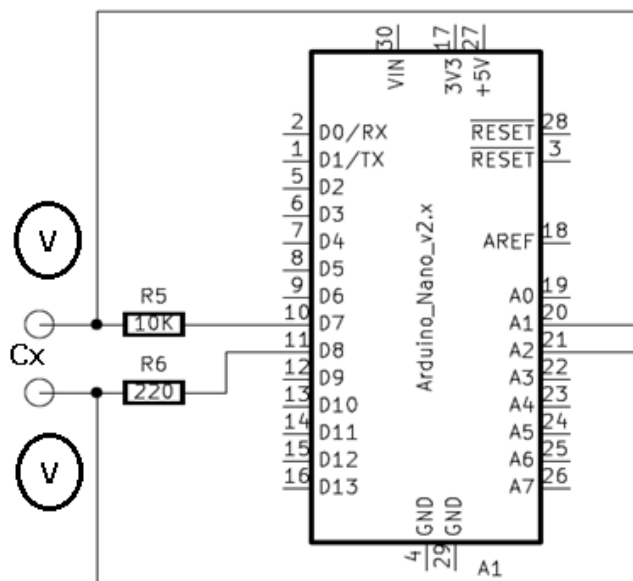

Figure II-3: The schematic of the Capacitor meter

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We opted for the RC method despite its limits as it is more cost-effective and more suitable for a smaller portable solution, which are requirements of our design. The first issue here is that it was almost impossible to measure capacitors from 1pF to 100F using one simple circuit. to fix this problem we chose to use two alternative circuits using two different reference resistors. This offers two ranges: one ranges from 0.1uF to 3.9F and the other from 10pF to 4.7nF. With these two setups, we could measure capacitors from 10pF to almost 4F.

II.3.2 Hardware:

Here is the part list for the schematic in figure II.3.

- Arduino NANO (1 part)
- I2C serial interface board (1 part)
- LCD display (1 part)
- 10 KΩ resistor (1 part)
- 220 Ω resistor (1 part)

II.3.3 Software:

The RC circuit needs a DC voltage as input. This will be provided through the digital output D7. The R could be either 10kΩ or 220Ω.

With one reference resistor set, we measure the charging voltage (the V in circle in the schematic) through on analog input (A1). A timer is started at the same time, and the the measured is continuously compared to the 63.2% value. As soon as this value is reached, the corresponding time is saved and used to calculate the capacitance using formula (eq 11). This part of the code is the following:

```
val = analogRead(IN_PIN);
//…
if (val < 976) // this is the 63.9 % of full scale charging
  { //..
    capacitance = val * IN_CAP_TO_GND / (MAX_ADC_VALUE - val);
   // if not readable go back to start
   // else print Cx
  }
```

The previous setup has a lot of errors for small capacitors with a range between 1pF and 1nF. Therefore, we will use A2 to charge the capacitor and A1 to discharge it. With this second choice, no extra resistor is needed because we configured the use of the internal pull-up and pull-down resistors. The change in scale, that is the use of the 10k or the 220 resistors, is automatic by the Arduino .Figure II.4 shows the algorithmic chart for the capacitance meter of the tester.
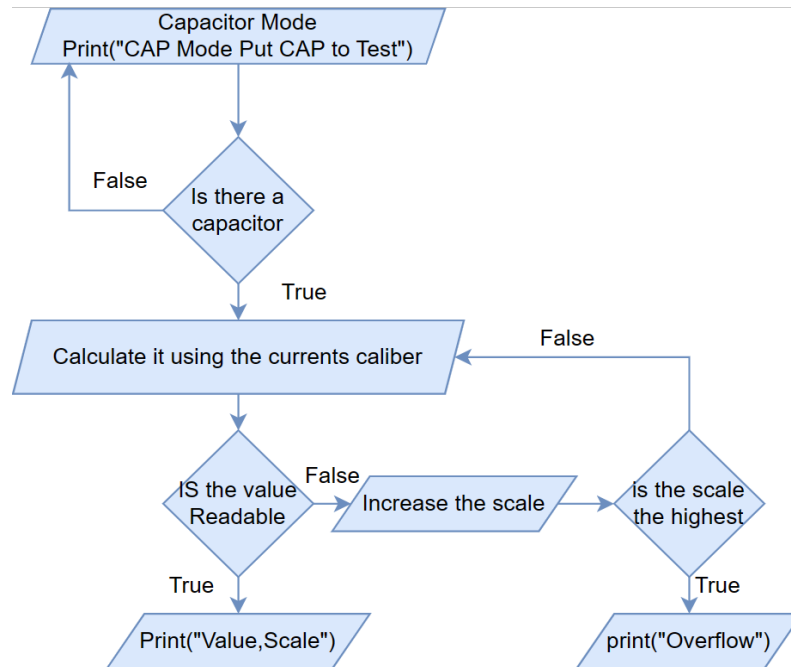

Figure II-4: algorithmic chart of the Capacitor meter

II.4 Inductor:

II.4.1 The idea:

The ATMEGA328 ADC is capable of sampling analog signals at 9600 Hz or .1ms, which is fast but nowhere near what this project requires. By using the LM339 we can turn real-world signals into basic digital signals.

As soon as the voltage on the LC circuit becomes positive, the LM339 will be floating, which can be pulled high with a pull-up resistor. When the voltage on the LC circuit becomes negative, the LM339 will pull its output to the ground.

What we will do is apply a pulse signal to the LC circuit through one digital output (D9). In this case, it will be 5 volts from the Arduino. Then we change the voltage from 5 volts directly to 0. That pulse will make the circuit resonate creating a cushioned sinusoidal signal oscillating at the resonant frequency. What we need to do is to measure that frequency and later use the formulas to obtain the inductance value.

$$F_r = \frac{1}{2\pi\sqrt{LC}} \tag{14}$$

$$L = \frac{1}{F_r^2 4\pi^2 C} \tag{15}$$

Since our wave is a true sinusoidal wave, the comparator will turn it into a square wave with a duty of 50%, and it will measure the time, in microseconds, elapsed from the rising edge to the falling edge. This measurement (through digital input D10) can then be doubled to get the period and the inverse of the period of the frequency. Since the circuit is resonating, this frequency is the resonating frequency.
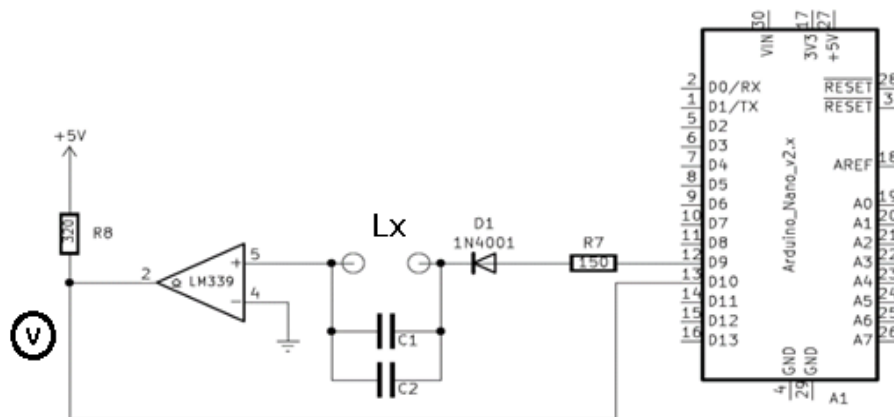

Figure II-5: The schematic of the Inductance meter

II.4.2 Hardware:

This is the list of parts for figure II.5:

- Arduino NANO (1 part)

- I2C serial interface board (1 part)

- LCD display (1 part)

- LM339 Comparator (1 part)

- non-polarized capacitors (2 parts)

- 150Ω resistor (1 part)

- 330Ω resistor (1 part)

- diode (1N4001) (1 part)

II.4.3 Software:

We apply a pulse of 5 volts to the LC circuit with the Arduino digital pin D9. The part of code implementing this is :

```
digitalWrite(DichargeI, HIGH);
```

The LC circuit will resonate and yield a sine signal. The comparator (LM339) will transform the sine wave into square wave. Arduino will measure using this signal through digital input D10 using the PulseIn function:
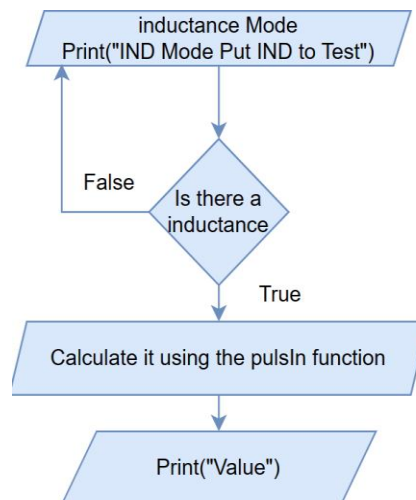
```
pulseIn(ChargeI,HIGH,5000);
```


Figure II-6: algorithmic chart of the

The chart summarizing this operation is shown in figure II.6.

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II.5 Diode:

II.5.1 The idea:

The Diode meter is the simplest circuit to design since we only have to calculate the voltage drop across the diode. By using the Arduino analog pins, we can calculate with precision the value of the voltage-drop of any type of diode.
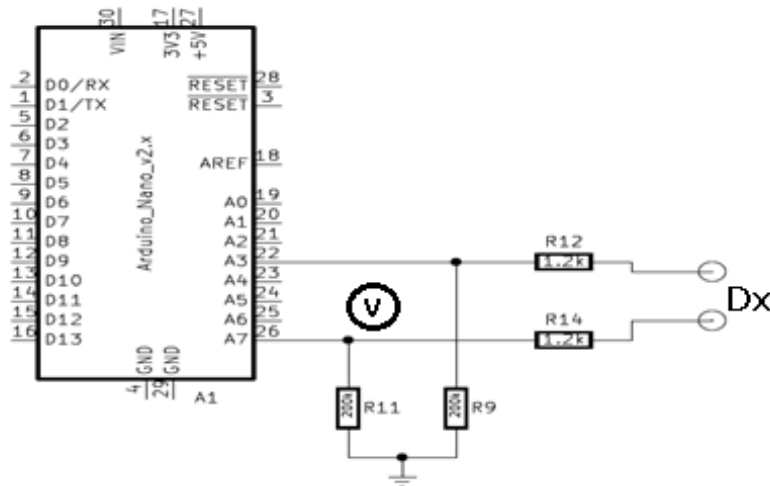

Figure II-7: the Diode meter

We can also take this even further and make a basic function of testing the continuity of a cable indicated by a buzzer and a red LED.

The basic idea to test a diode is as follows: Connect the diode in series with the current-limiting resistor. Connect one end of the diode to a digital pin of the Arduino and the other end to the ground (GND) pin. Connect the junction between the diode and resistor to an analog input pin of the Arduino (e.g., A0). With the circuit powered, the Arduino will read the analog value from the junction between the diode and resistor. It will convert the analog value to voltage using the appropriate scaling. The measured voltage drop across the diode will be displayed in the LCD (or other type of display).

In our design we chose to use the setup for transistors testing and use the first and third pins which are both connected to digital pins through resistors. Here, we should consider the different resistors making up the circuit. The measured voltage at the pin A7 would be if the diode is working:

$$Vout = (5-Vd)*R11/(R11+R12+R14) \qquad (16)$$

Practical values of the voltage drop Vd are in the range 0.2V up to 3V for Schottky diodes. So, for a reliable diode Vout would be in the range: 0.16v to 0.4 v. If the diode is shorted its direct voltage would be null; and the measured voltage would be Vout =0.42V. this case can also be used as a test of continuity.

If the diode is reversed or is broken, Vout would be 0.

II.5.2 Hardware:

- The list of parts used in the diode test is:
- Arduino NANO (1 part)
- I2C serial interface board (1 part)
- LCD display (1 part)
- 1.2KΩ Resistors (2 parts)
- 200KΩ Resistors (2 parts)

II.5.3 Software:

The digital pins D5 and D6 are used to power up the diode between 5v and GND through the lines:

```
digitalWrite(LEG1,HIGH);
digitalWrite(LEG3,LOW);
```

A7 is configured as analog inputs to read the voltage at both ends of the diode (using analogread() function).

The written program tests the measured voltage which represents the voltage drop across the diode: if the voltage drop is 0 the Arduino will indicate the detection of a short circuit. This option can be used as a continuity tester . if not, it displays the measured value and can give a basic value of the direct resistance. Figure II.7 represent the chart corresponding to diode testing.
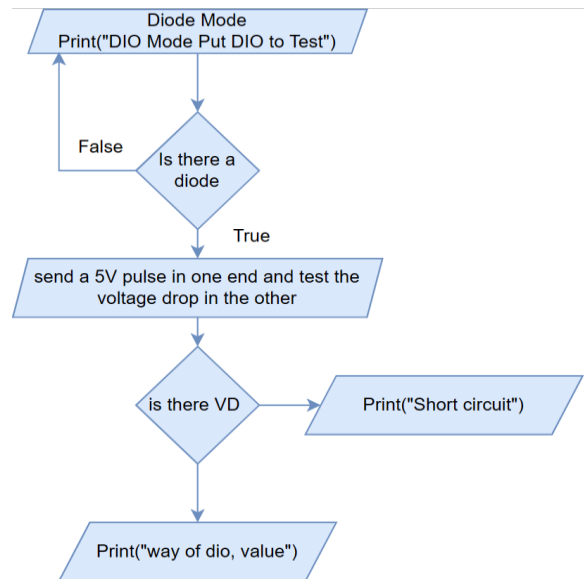
Figure II-8: algorithmic chart of the Diode meter

II.6 Transistor:

II.6.1 The idea:

The transistor meter function is divided into two steps: Type detection, parameters calculation.

Type detection: the Arduino will detect the type of the transistor, that is bipolar (BJT) or metal-oxide-semiconductor FET (MOS), its channel (Positive / Negative) and identify each of its pins' placements (EBC / GDS).

Parameters calculation: After identifying each pin the tester now can proceed to the parameters' calculation, which will give the transistor its most important values (Iceo, β, Vth).

Figure II.9 depicts the schematic of the proposed design. In the schematic, D5 and D6 digital outputs will be used to provide the +5/0v supply voltage for the transistor under test. The analog outputs A3, A7 will be used as voltmeters while A6 will be used to apply the base/gate voltage.
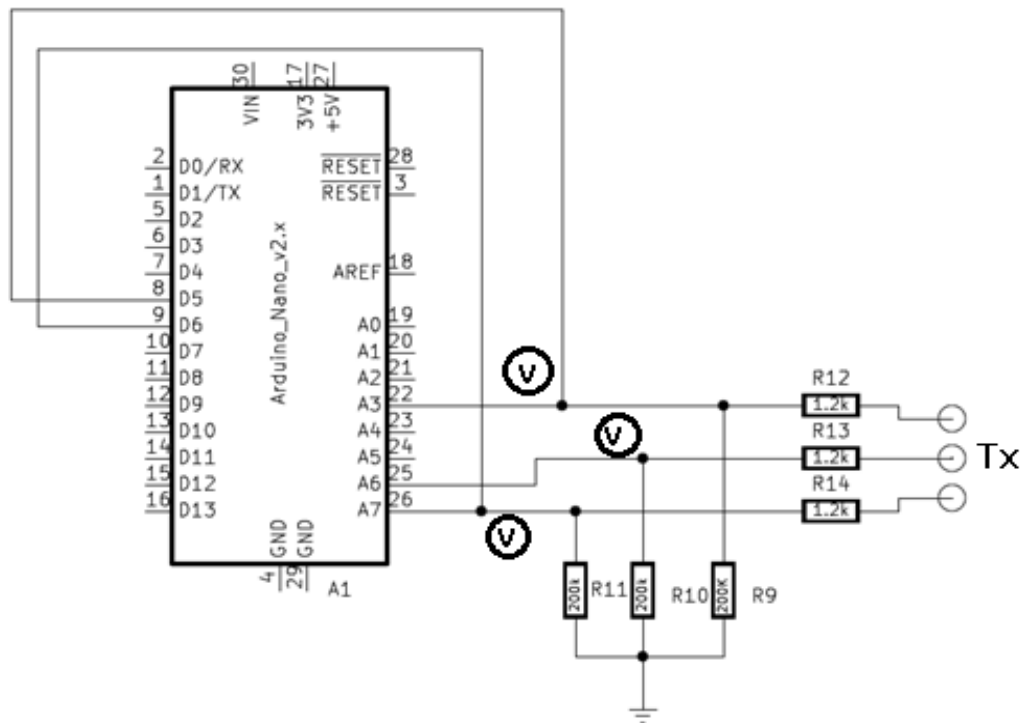
Figure II-9: the Transistor meter

Device type detection and pinout identification.

The principle underlying type detection is as follows: when a positive voltage is applied to the base/gate of a N type transistor, whether it is a BJT or MOSFET, it will conduct. Therefore, by applying a positive voltage to the base/gate and observing current flow between the other two pins, we can determine that the component is an N-type device. Conversely, if we detect current flow between the collector/drain and emitter/source pins while applying a negative voltage to the base/gate, we can conclude that it is a P-type device. To detect the current flow, circuit analysis is required. If a transistor conducts, it forms a path from its collector/drain to its emitter/source with minimal voltage drop. For example, in the case of a conducting N-type device, the voltage at the collector/drain resistance end should be low because this point is pulled down to ground through the emitter/source. Conversely, it should be high if the device is blocked. The same principle can be applied to a P-type device, considering the circuit configuration (common collector/drain or

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common emitter/source). The table below summarizes the various testing possibilities, with an upward-pointing arrow representing 5V and a downward-pointing arrow representing GND.

	Negative	Positive
BJT		
MOS		

After detecting the type of the transistor as N or P type device, we can proceed on identifying the base/gate, collector/drain and emitter/source pins' locations. This can be done using two algorithms for each type (BJT or MOSFET):

For BJTs:

The concept is to test the voltage drop across the base/emitter and base/collector diodes in BJT transistors. In NPN transistors, the emitter is typically more heavily doped than the collector. This is because the emitter is the source of electrons that may flow to the collector, which is lightly doped. Due to the difference in doping levels, the voltage drop from the base to the collector (VBC) is smaller than the voltage-drop from the base to the emitter (VBE) for an NPN transistor. Conversely, for a PNP transistor, VBE is lower than VBC.

To determine the collector pin in an NPN transistor, we can follow these steps: Apply a 5V input through the base (A6) and measure the voltage drop across the other pins. The pin with the lowest

voltage-drop corresponds to the collector. Another approach is to calculate the current gain in both directions and compare them. The direction with the highest gain corresponds to the collector.

For MOSFETs: The concept here is to test for a diode.

For power MOSFET, we test the presence of a built-in flyback diode. Typically, this diode is implemented in an anti-parallel configuration, meaning it is connected in the reverse direction from drain to source.

For regular MOSFET (non-power grade), we test the junction diode at the drain. In those devices the substrate is usually internally connected to the source, so a 5v at the source would forward bias the drain-substrate junction if we put the drain at 0v.

So, in both type of MOSFET, power and regular, there is a diode in anti-parallel connection between the drain and the source, so the procedure is the same.

The test procedure is as follows: Exclude the gate from the testing (A3 is at HZ). Apply a 5V signal through one of the pins and check for continuity in the other pin. If the signal passes through, it indicates the pin at 5v is the source. If there is no continuity, reverse the polarity of the signal and test again.

Important Remarque: the base of the BJT transistor is not always the middle pin, and the gate in MOS is not always the left one since there is the possibility of changing the face and the back of the transistor while testing.

Device parameters calculation:

After we got all the data we need about the transistor, we can now proceed into the parameters' calculation, where we calculate:

For a BJT:

we obtain Ib the same way as by applying 5V from the B to the E , measuring the voltage across the base resistor and dividing it by this same resistor.

$$I_B = V_{RB}/R_B \tag{17}$$

"Ic" is calculated by activating the transistor and sending a signal from C to E. we can calculate I_C by dividing the voltage obtained across the collector resistor by the same resistor.

$$I_C = V_{RC}/R_C \qquad\qquad (18)$$

the current gain "β" is calculated by dividing I_C by I_B.

$$\beta = I_C/I_B \qquad\qquad (19)$$

For a MOSFET: to calculate the threshold voltage "Vth" we send a triangular signal that ranges from 0 to 5V from a PWM compatible digital pin (D5/D6) to the gate. We then test the state of the transistor; as soon as the transistor begins to conduct current, the corresponding VGS is the threshold voltage.

Important Remarque: not all the Arduino digital pins have the PWM capability. The only pins that have it are (D3, D5, D6, D9, D10, D11). Also, we should emphasize that we could not implement this functionality due to the limited pins count in the Arduino nano. Indeed, all the digital pins have been used for the resistance and capacitance meters.

II.6.2 Hardware:

- Arduino NANO (1 part)
- I2C serial interface board (1 part)
- LCD display (1 part)
- 150 Ω resistor (3 parts)
- 200 KΩ resistor (3 parts)

II.6.3 Software:

In the C code, the test procedure starts by defining and configuring the three test pins: the digital pins D5 and D6 serve as power supply (HIGH or LOW in the digitalwrite() function). The nalaog pins A3 and A7 are used to measure precise values of the voltages at the pin1 and pin 3 nodes. A6 is used to bias the gate. The measured voltage in every case is averaged upon 100 samples to enhance the precision of the reading. An example snippet of the code is :

```
for (x = 0; x < 100; x++){

    Vout1 = analogRead(LEG1);

    Samples = Samples + Vout1;

    delay (3);

    }
```

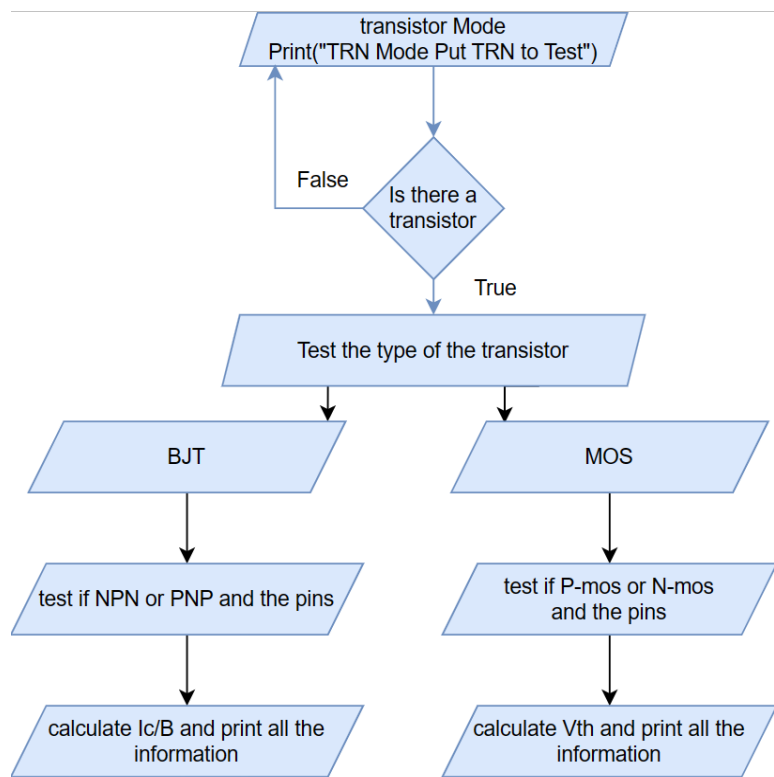The algorithmic chart below summarizes the operation of the transistor tester.

Figure II-10: algorithmic chart of the Diode meter

II.7 The complete universal tester:

II.7.1 The final schematic and software

After we discussed each mode of our tester, we can now proceed into assembling all of it in a single circuit. Figure II.11 illustrates the final schematic.
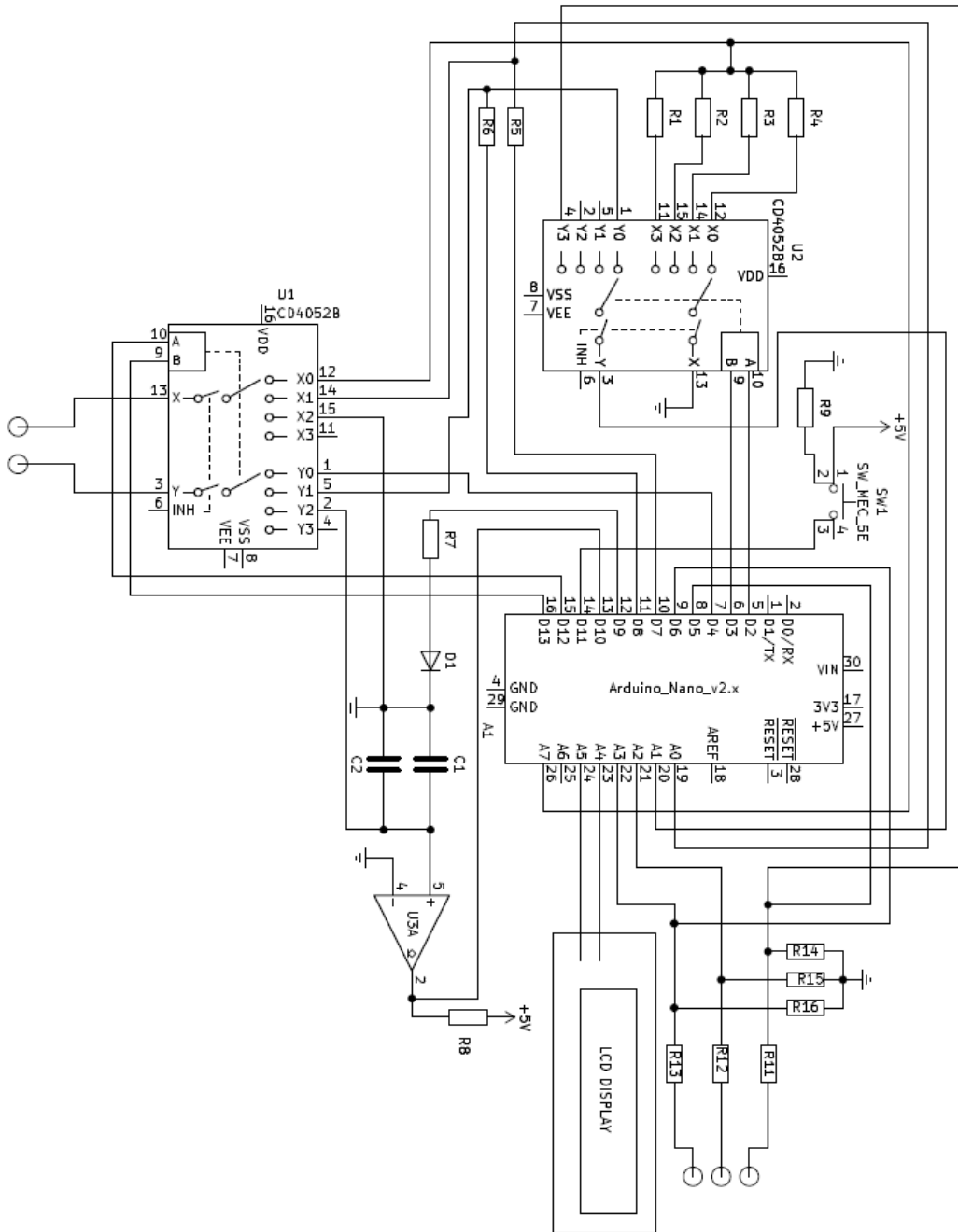
Figure II-11: schematic of the universal components' tester

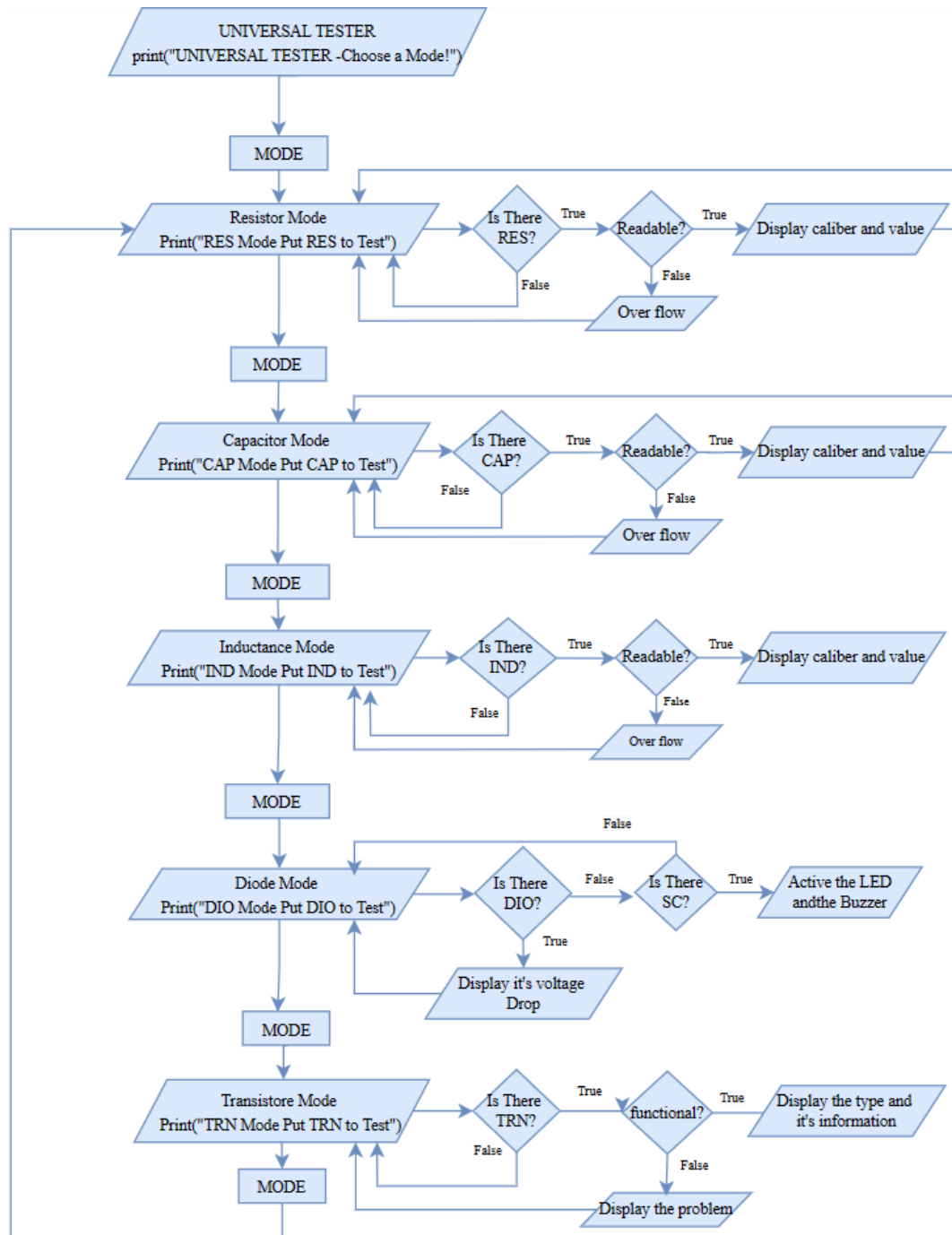The algorithmic chart describing the full operation is next:

Figure II-13: algorithm chart of the Universal intelligent components' tester

The final C code combines the previous procedure and runs the test sequentially starting by testing for the chosen MODE. MODE=1 for resistance, 2 for capacitance, 3 for inductance, 4 for diode and 5 for transistor.

II.7.2 The hardware implementation:

The hardware implementation is achieved using a matrix copper board. Figure II.13 shows its photograph.
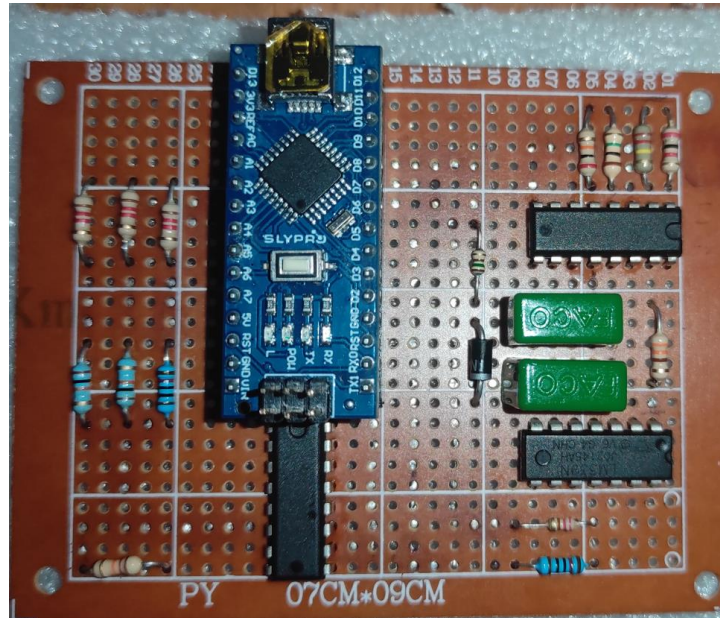

Figure II-13: Picture of the final project

During the making of this project, we also used the 3d technology of the Blender software to design and make the housing of our project and a 3D printer Anycubic I3 MEGA S/Pro to realize it (figure II.14).
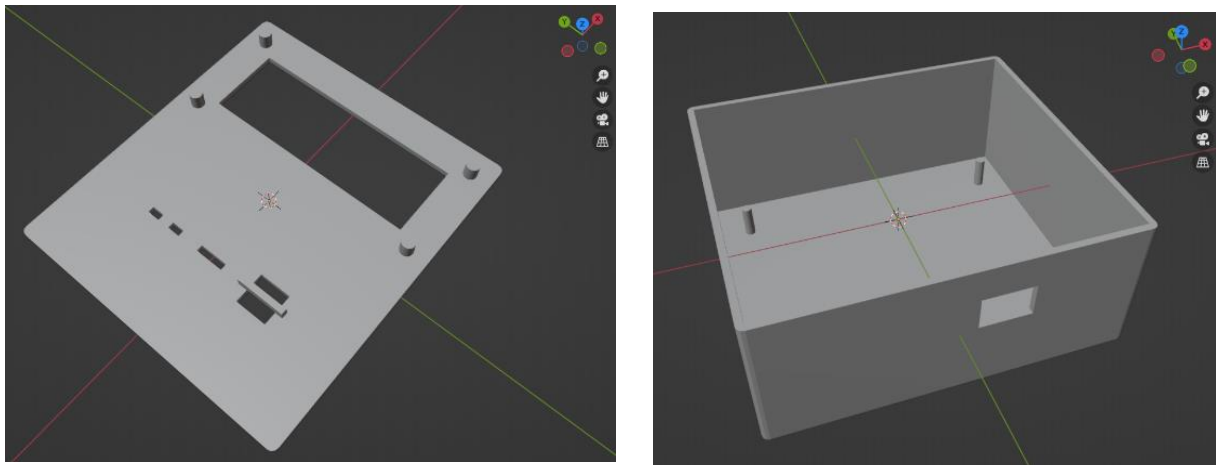

Figure II-14: 3D realization of the housing

Several tests, using different sets of components, were made to verify the operation of the tester. The tester proved to function properly every time.

However, many problems were encountered during the making of this project. Here we mention some of them:

- Due to the restricted availability of analog and digital pins in Arduino, we were compelled to make modifications in the design to accommodate all the necessary components. One of these adjustments involved utilizing a multiplexer for the resistor meter, while another was employed to consolidate all the passive outputs into just two pins. This adaptation was necessary to overcome the limitation of available pins and ensure the functionality of the system.
- The absence of necessary resources resulted in the utilization of alternative and less efficient methods, such as powering the project with the Arduino USB connected to a PC, instead of utilizing a lithium battery.
- The intricacy of certain aspects of this project, combined with the basic functionalities of the Arduino, resulted in certain points becoming unfeasible to implement. For instance, calculating the threshold voltage (Vth) of a P-MOS transistor requires a negative output, which the Arduino, without external components, is incapable of generating. Therefore, due to the limitations of the Arduino in this regard, the calculation of Vth for a P-MOS transistor was not achievable within the scope of this project.

II.8 Conclusion:

In this chapter we described the design and the implementation of the components' tester. The designed tester has proven to be a successful attempt, fulfilling the project's objectives to a large extent. Through meticulous hardware design and software implementation, a functional and versatile tester has been developed, capable of effectively testing a wide range of electronic components.

By utilizing an Arduino microcontroller as the core of the tester, we achieved a flexible and cost-effective solution for controlling and interfacing with various components. The integration of the

CD4052 analog multiplexer provided the necessary signal routing capabilities, enabling the selection of different reference resistors for accurate measurements.

The software implementation played a crucial role in automating the testing process and ensuring precise measurements. The programmed algorithms efficiently calculated unknown resistor values and implemented the vital auto-ranging functionality, expanding the tester's usability and enhancing measurement accuracy.

Though challenges arose, such as the limited number of available pins, careful pin allocation and the utilization of multiplexing techniques addressed these obstacles effectively.

Through testing and validation, the universal component tester demonstrated its consistency in delivering accurate results. The tester's robust design and functionality enabled us to perform component testing with ease and obtain precise measurements.

The successful realization of this project paves the way for future enhancements and potential applications in the field of electronics, driving advancements in electronic testing methodologies.

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Conclusion

This thesis has explored and developed a universal intelligent components' tester, aiming to provide a comprehensive solution for testing and analyzing various passive and active electronic components. In the thesis we covered the theoretical foundations of electronic components, including their definitions, characteristics, types, and areas of use.

The design and implementation chapter presented a detailed overview of the tester's architecture, hardware components, and software algorithms. The integration of an Arduino microcontroller as the central control unit proved to be a practical and efficient choice, enabling flexible control and accurate measurements.

Through careful consideration of circuit design and component selection, the tester demonstrated reliable performance in accurately measuring resistance, capacitance, and transistor type detection. The utilization of the CD4052 analog multiplexer facilitated efficient switching between different reference resistors, expanding the tester's measurement range and enhancing its versatility.

The developed software algorithms implemented auto-ranging functionality and ensured precise calculations for unknown component values.

The thesis also addressed challenges such as pin limitations and the need for additional power sources. Effective strategies were employed to overcome these challenges, including multiplexing techniques and utilizing the Arduino's USB interface for power supply.

Overall, the universal intelligent components' tester presented in this thesis showcases the successful integration of theoretical knowledge and practical implementation. It offers a valuable tool for students, hobbyists, and electronics enthusiasts in efficiently testing and analyzing a wide range of electronic components.

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Abstract

We designed and implemented a universal intelligent components' tester. The hardware and software solutions enable accurate testing and analysis of various electronic components. The tester demonstrates reliable and fast performance in measuring resistance, capacitance, and transistor types. The integration of an Arduino microcontroller and CD4052 analog multiplexer allows for flexible control and expanded measurement range. Challenges such as pin limitations and power source requirements are effectively addressed. The universal intelligent components' tester provides a valuable tool for engineers and electronics enthusiasts, offering efficient testing capabilities and contributing to the advancement of electronic component analysis.

Résumé

Nous avons concun et réalisé un testeur universel de composants intelligent. Les solutions matérielles et logicielles permettent une analyse et une mesure précises de divers composants électroniques. Le testeur démontre des performances fiables et rapides dans la mesure de la résistance, de la capacité et des types de transistors. L'intégration d'un microcontrôleur Arduino et d'un multiplexeur analogique CD4052 permet un contrôle flexible et une plage de mesure étendue. Les défis liés aux limitations de broches et aux besoins en alimentation sont efficacement résolus. Le testeur universel intelligent de composants offre un outil précieux aux étudiants et aux passionnés d'électronique, offrant des capacités de test efficaces et contribuant à l'avancement de l'analyse des composants électroniques.

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ملخص

تقدم هذه الأطروحة تصميمًا وتنفيذًا لجهاز اختبار العناصر الالكترونية عالمي وذكي. توفر الحلول المادية والبرمجية امكانية التحليل والقياس الدقيق لمكونات الإلكترونيات المتنوعة. يُظهر الجهاز الاختبار أداءً موثوقًا في قياس المقاومة والسعة وأنواع المتحولات. تتيح دارة Arduino ومضاعف متعدد القنوات CD4052 تحكمًا مرنًا ونطاق قياس واسع. تم حل التحديات المتعلقة بقيود التوصيلات واحتياجات الطاقة بشكل فعال. يوفر جهاز الاختبار العالمي الذكي للمكونات أداة قيمة للطلبة وهواة الإلكترونيات، ويوفر قدرات اختبار فعالة ويسهم في تقدم تحليل المكونات الإلكترونية.