ELECTRONIC WORKSHOP-2

RC METER

https://iiitaphyd-my.sharepoint.com/:v:/g/personal/ajay_ray_students_iiit_ac_in/EZbLyZKzJndNljz_GBgg0ewBd_EK3U5qFYrpw24SCFmujA?e=uUiNcH

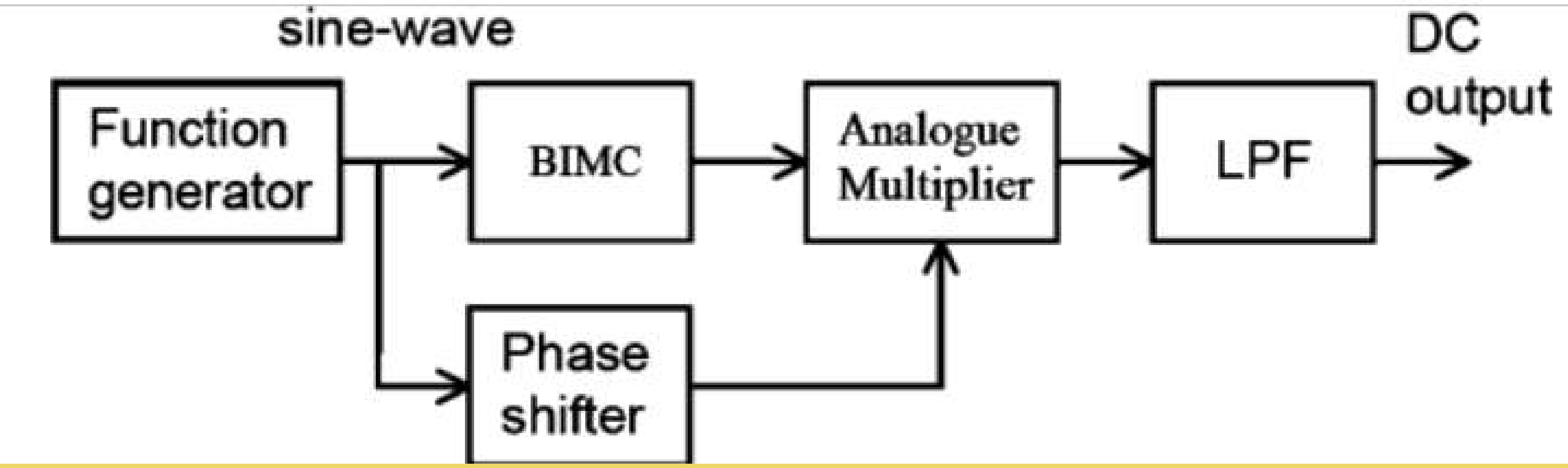
Slide Contents

WHY BUILD AN RC METER?

- To build a device that could measure capacitance since capacitance measurement devices are not common in the lab and its easier to measure it with a circuit without having to check for the diminished markings on the capacitors
- To build a more precise circuit to measure resistance

MOTIVATION

BLOCK DIAGRAM



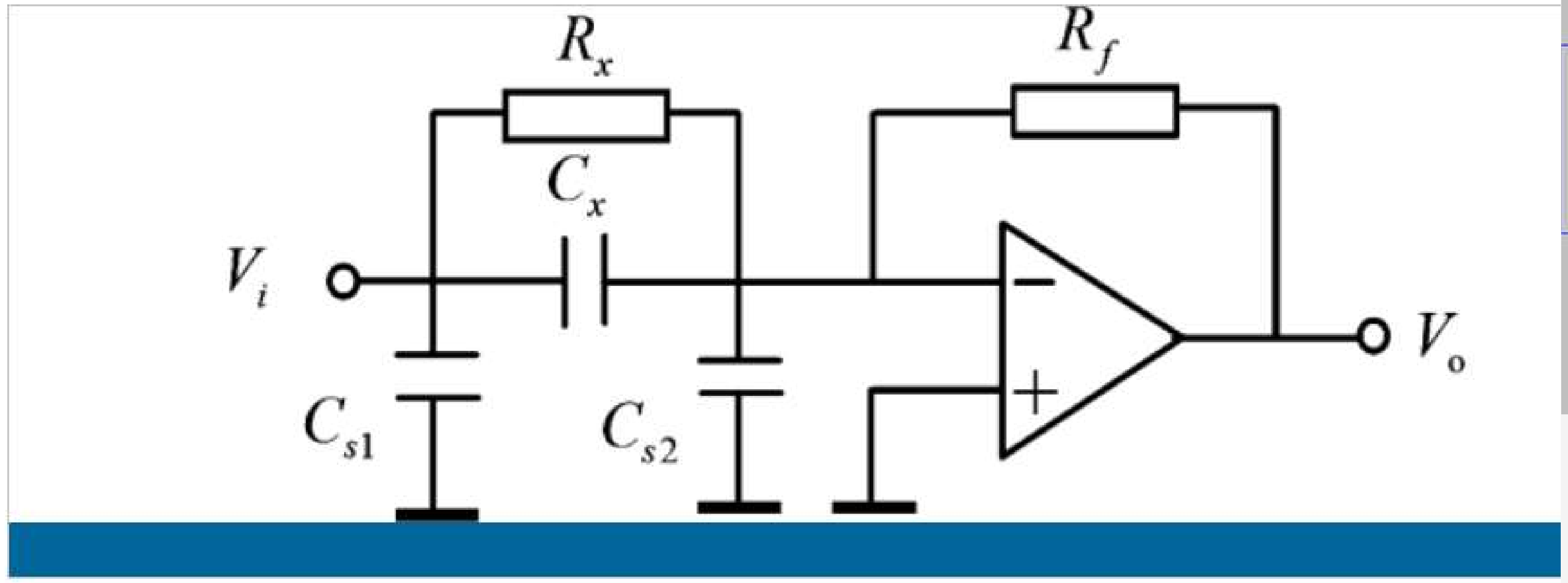
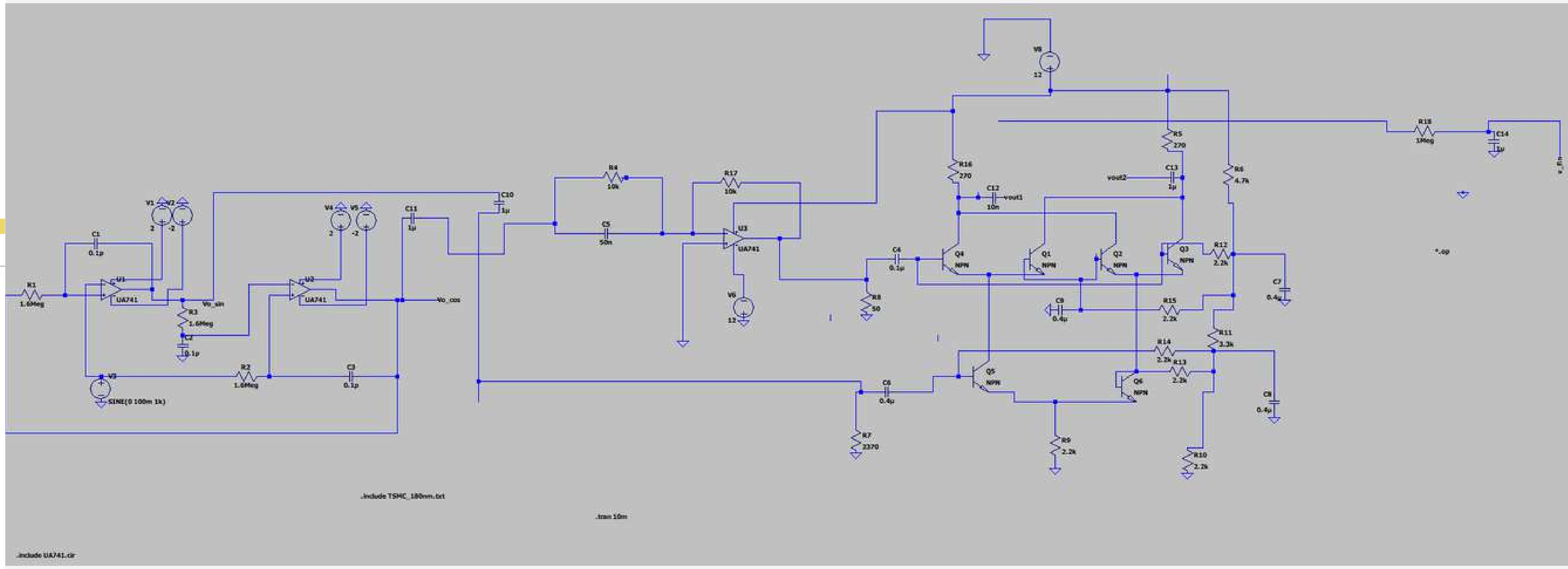


Fig. 1.
Basic impedance measuring circuit.

PRELIMINARY DESIGN



LT SPICE DESIGN

Main Challenges Faced

01

QUADRATURE OSCILLATOR DESIGN:
ERROR IN OBTAINING PERFECT COSINE & SINE WAVES

There was a mismatch in the amplitudes of the cos and sin waves produced by the quadrature oscillator that will hamper with the calculations to finally calculate the resistance and capacitance.

02

ANALOG MULTIPLIER DESIGN:
ERROR IN OBTAINING PERFECT OUTPUT PRODUCT

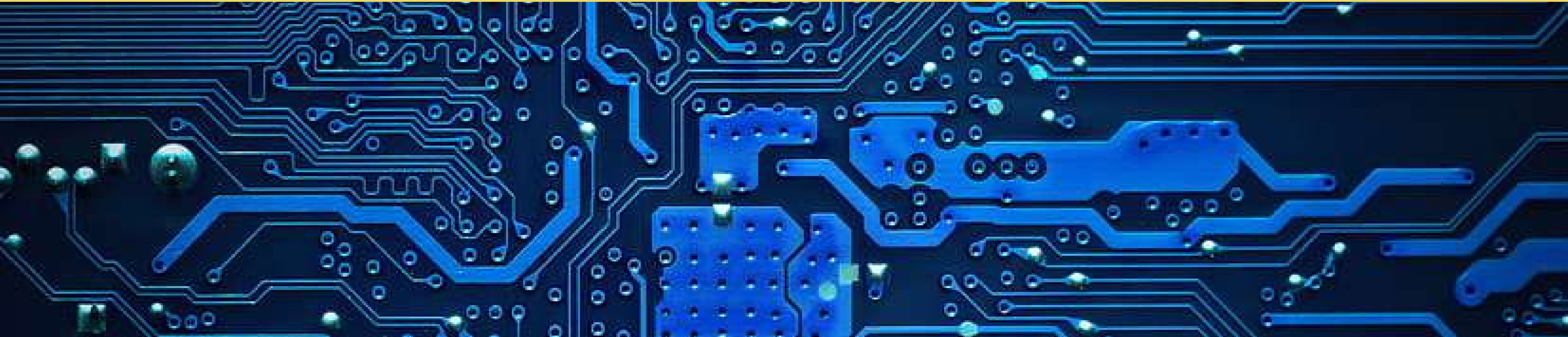
The analog multiplier didn't give the correct output for negative inputs in particular and a wide range of other inputs.

03

CIRCUIT COMPLEXITY:
TIME CONSTRAINTS & IMPERFECTIONS

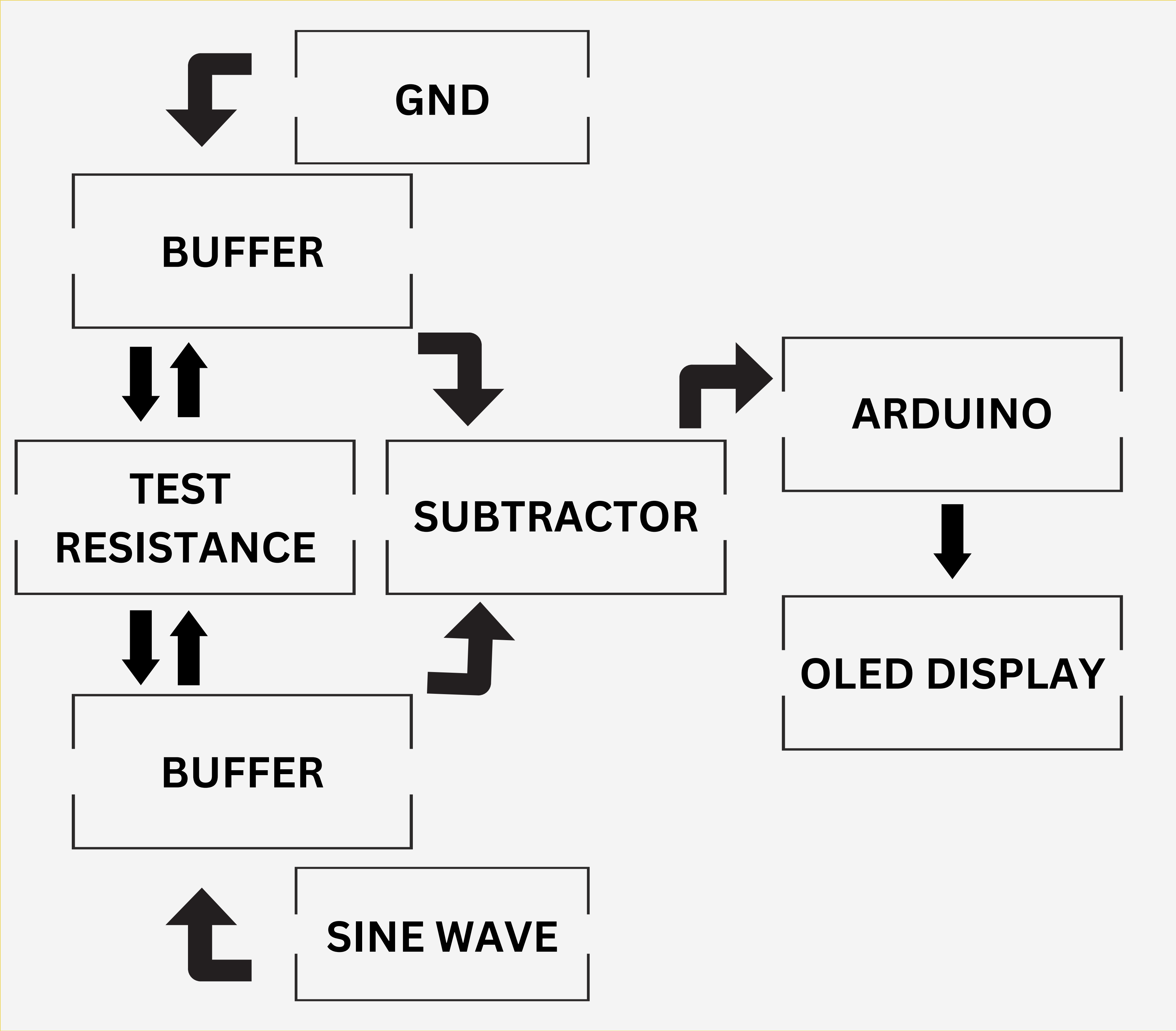
Due to time constraints and the complexity of the circuit and also the imperfections in the output for a wide range of inputs, the circuit was not a practical solution. It was extremely difficult to find an analog circuit design so we had to design the circuit from scratch by our own.

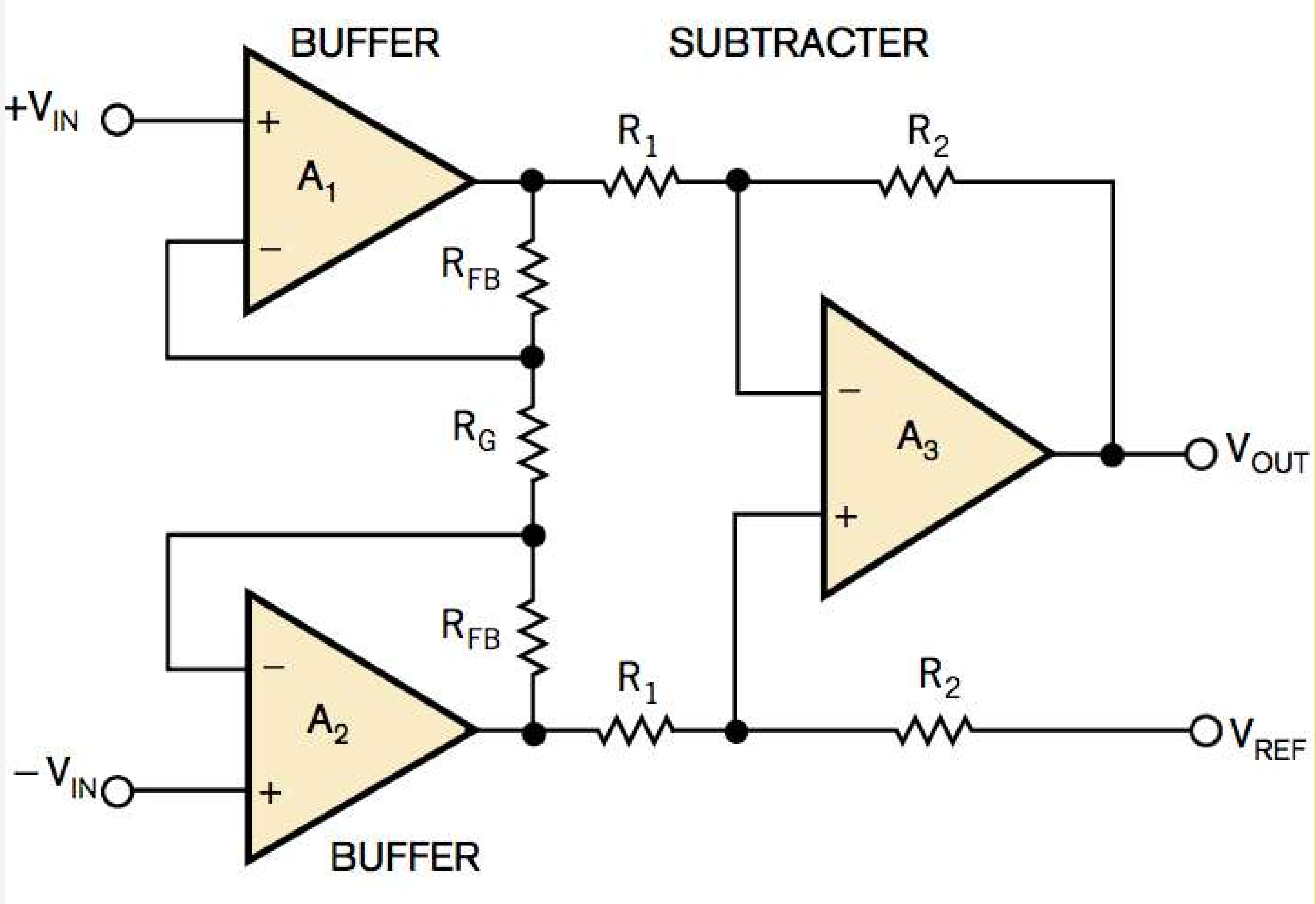
IMPROVISED CIRCUIT APPROACH



BLOCK DIAGRAM

RESISTANCE MEASUREMENT CIRCUIT – INSTRUMENTAL AMPLIFIER



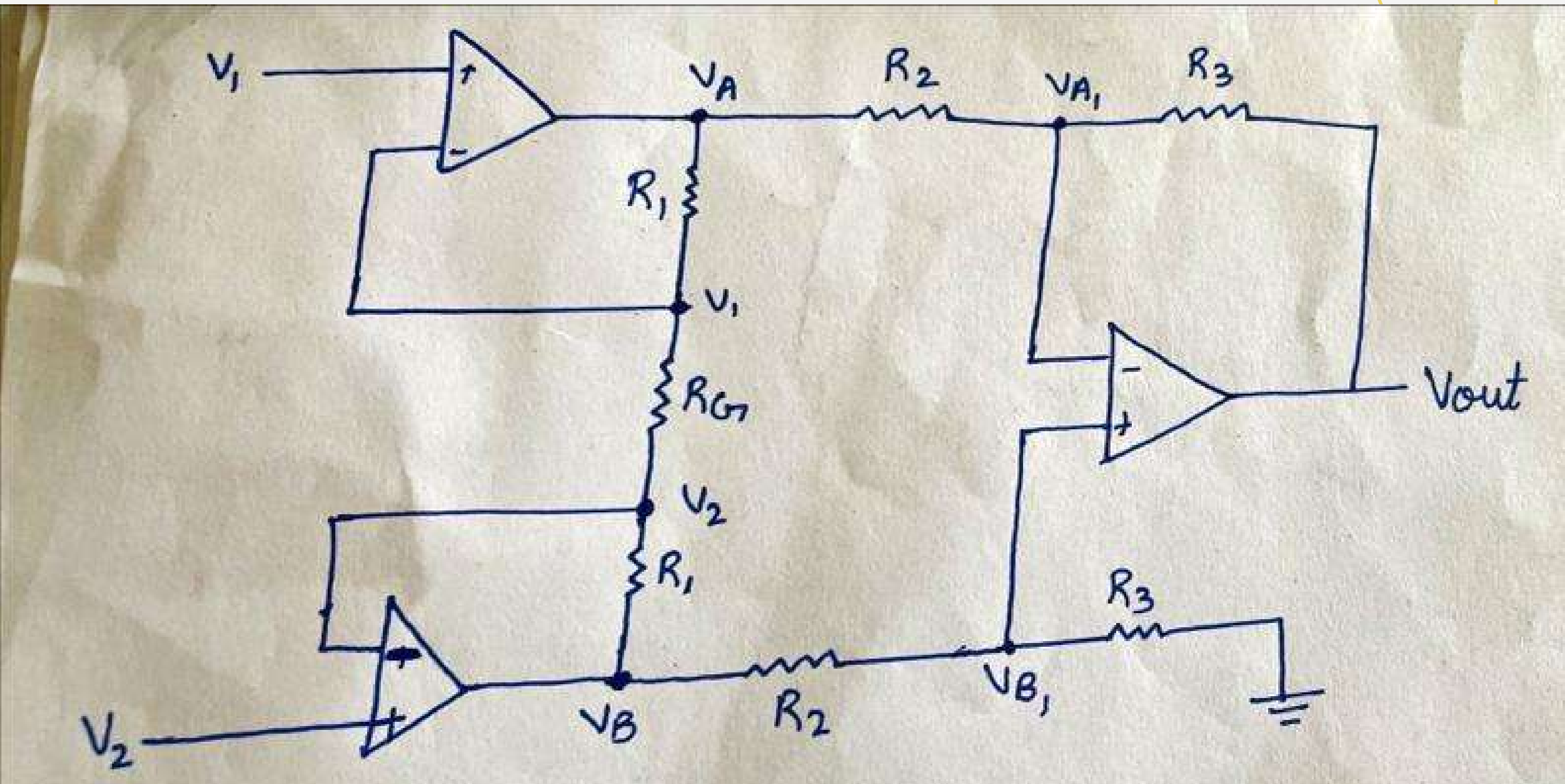


NOTES:

$GAIN = ((1 + (2R_{FB})/R_G))(R_2/R_1))$.

$V_{OUT} = +V_{IN} - (-V_{IN})(GAIN) + V_{REF}$.

WORKING OF THE CIRCUIT



R_G = test resistance

R_1 value changes with range.

$V_1 = 0$

$V_2 = \sin(2\pi f t)$

$f = 1KHz$

$V_2 = \sin(2000\pi t)$

In our circuit, given $R_3 = R_2$ & $V_1 = 0$, we have

$$V_{out} = (-V_2)\left(1+\frac{2R_1}{R_G}\right) \Rightarrow \cancel{R_G} \; V_{out} = -\sin(2000\pi t)\left(1+\frac{2R_1}{R_G}\right)$$

Now we pass only the amplitude (max value) of Vout to arduino to calculate R_G, so let amplitude received be A then,

$$A = 1+\frac{2R_1}{R_G} \Rightarrow \cancel{R_G = (A-1)} \quad \boxed{R_G = R_{test} = (2R_1)/(A-1)}$$

$$V_{out} = \frac{R_3}{R_2}(V_A - V_B) \quad - (4)$$

Now, I_G : current through R_G

$$= \frac{V_1 - V_2}{R_G} \quad - (1)$$

= current through the R_1's

$$= \frac{V_A - V_B}{R_G + 2R_1} \quad - (2)$$

from (1) & (2), $$V_A - V_B = \frac{(V_1 - V_2)(R_G + 2R_1)}{R_G} \quad - (3)$$

from (3) & (4), $$V_{out} = \frac{R_3}{R_2}(V_1 - V_2)\left(1 + \frac{2R_1}{R_G}\right)$$

Rtest = (2 . R1) / (Avout – 1)

3-OPAMP INSTRUMENTAL AMPLIFIER

INPUT RESISTANCE RANGES & REQUIRED R1 VALUES

01

4K – 10K:
R1 VALUE REQUIRED: 1K

02

10K – 100K
R1 VALUE REQUIRED: 10K

03

100K – 1000K:
R1 VALUE REQUIRED: 100K

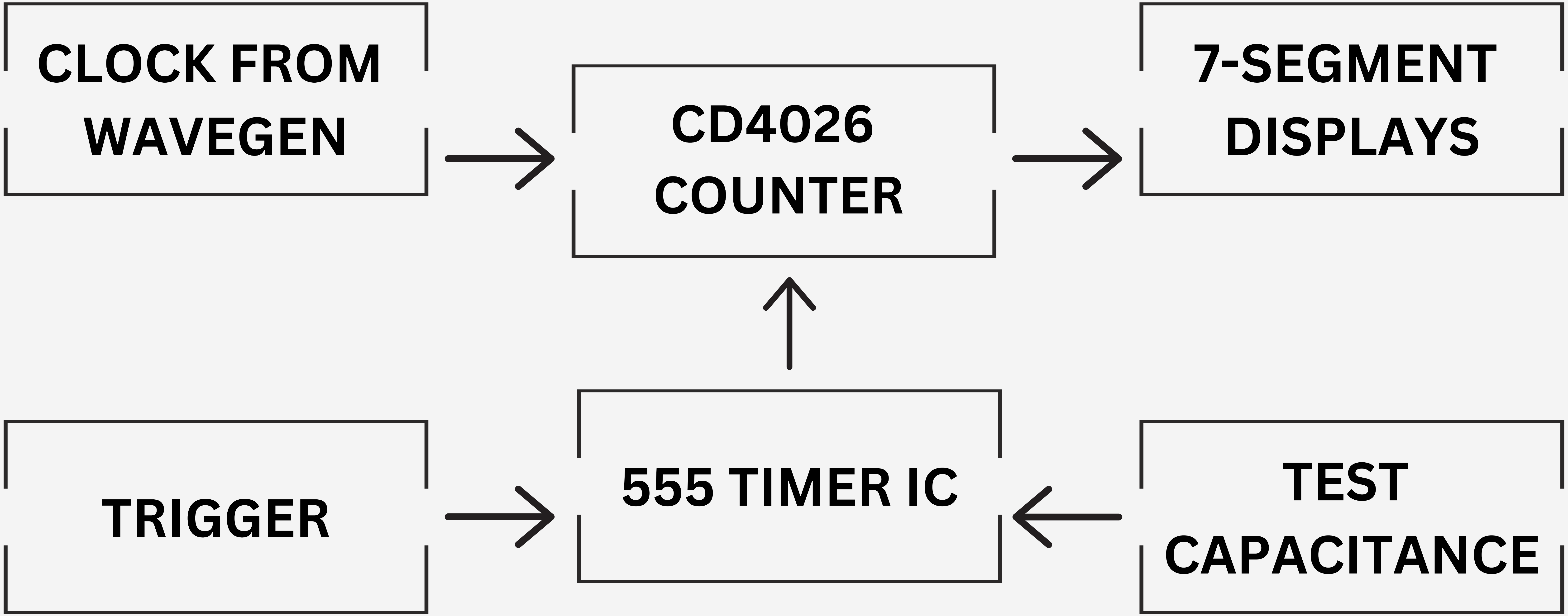
For all the above cases, we want the output voltage amplitude to be in the range of [1.2V, 3V] so that the Arduino can catch that signal (Arduino cannot take >5V as analog input).So, for a given test resistance range and output voltage range, we can calculate the R1 values from the given equation:

$$v_{out} = -\frac{R_3}{R_2}\left(1 + \frac{2R_1}{R_{gain}}\right)$$

where R3 = R2 and Rgain = Test resistance value and R1 is what we have to find out.

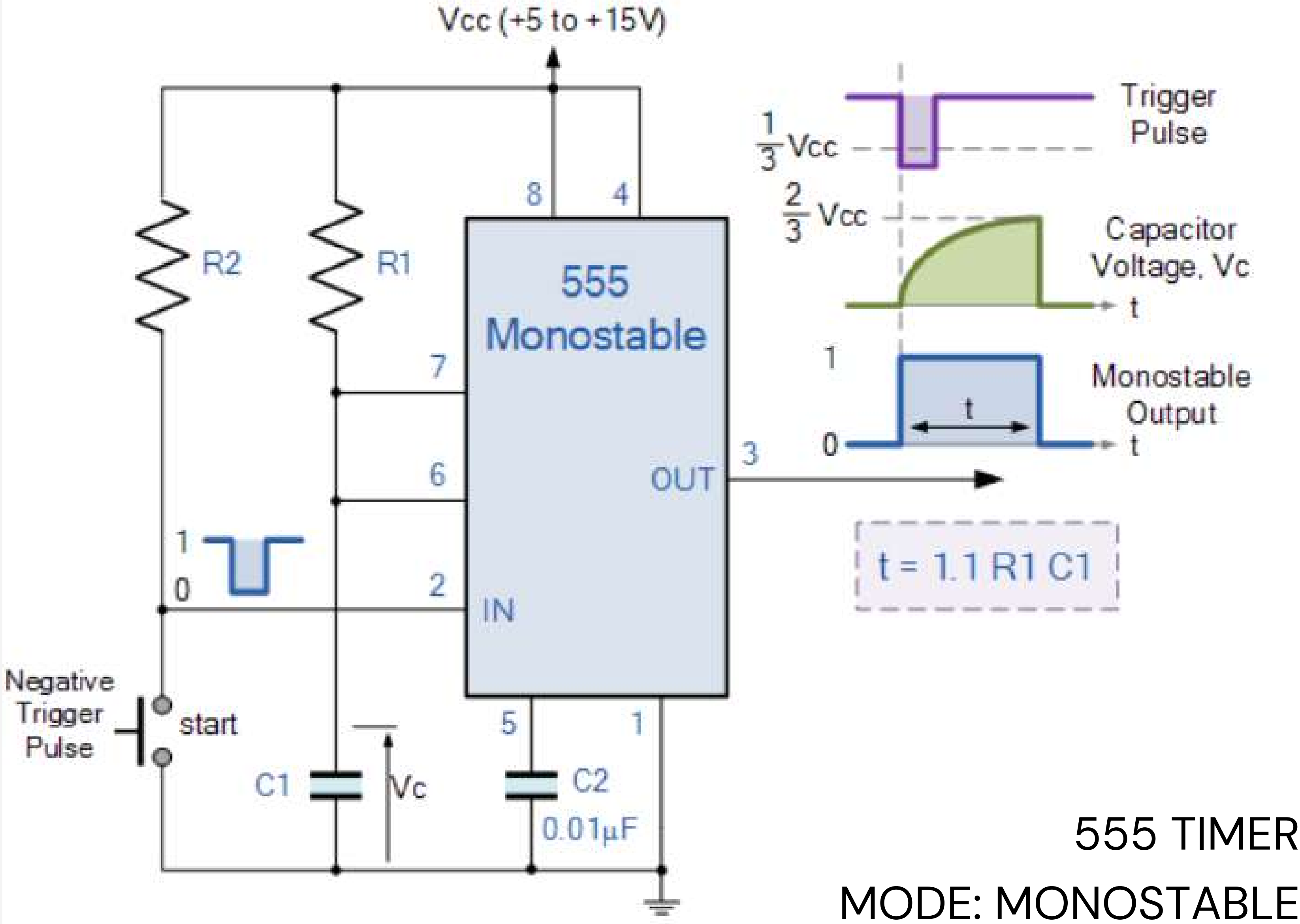
BLOCK DIAGRAM

CAPACITANCE MEASUREMENT CIRCUIT



WORKING OF THE CIRCUIT

The Monostable 555 Timer circuit triggers on a negative-going pulse applied to pin 2. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the R1 x C1 network has elapsed. The amount of time that the output voltage remains "HIGH" or at a logic "1" level, is given by the following time constant equation.



555 TIMER
MODE: MONOSTABLE

$$\tau = 1.1\, R_1 C_1$$

MONOSTABLE 555 TIMER

WORKING OF THE CIRCUIT

The output of the 555 timer is given as enable to the counter having a clock time period smaller than the time constant for the specified range of capacitance values. So, the counter will count as long as the enable is ON and once the enable goes OFF, it stops counting and displays a value and based on the frequency of the counter clock (lets say fs), we can calculate the capacitance value as follows:

Time constant = R1 . C1 . 1.1

Let x be the number displayed on the 7-segment displays

So, time calculated by the counter = x . fs
= Time constant = 1.1 * R1 * C1

So, we get the equation to calculate C as:

C = (x * fs)/(1.1 * R1)

INPUT CAPACITANCE RANGES & REQUIRED COUNTER CLOCK FREQUENCIES

01

1PICO – 999PICO:
FREQUENCY REQUIRED: 1MHZ

For each count of the clock to count 1pico farad and for the clock time period to be lower than the time constant which is in the range of 10^-6 to10^-3, we need to have the frequency as 1MHz;
1/fs = 1.1 . 1M . 1pico
fs = 1MHz approx

02

1NANO – 999NANO
FREQUENCY REQUIRED: 1KHZ

For each count of the clock to count 1nano farad and for the clock time period to be lower than the time constant which is in the range of 10^-3 to1, we need to have the frequency as 1KHZ;
1/fs = 1.1 . 1M . 1nano
fs = 1KHz approx

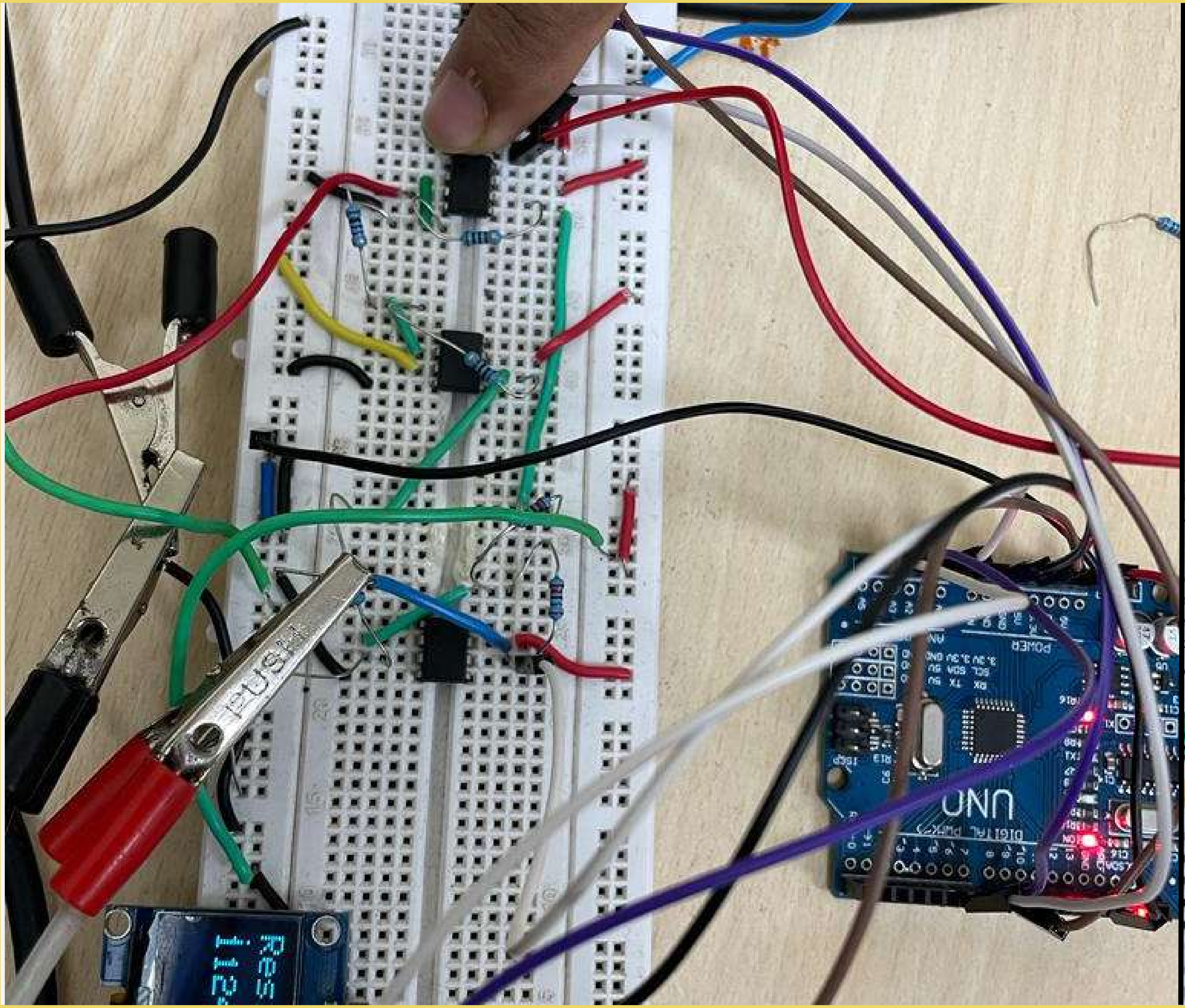
03

1MICRO – 999MICRO:
FREQUENCY REQUIRED: 1HZ

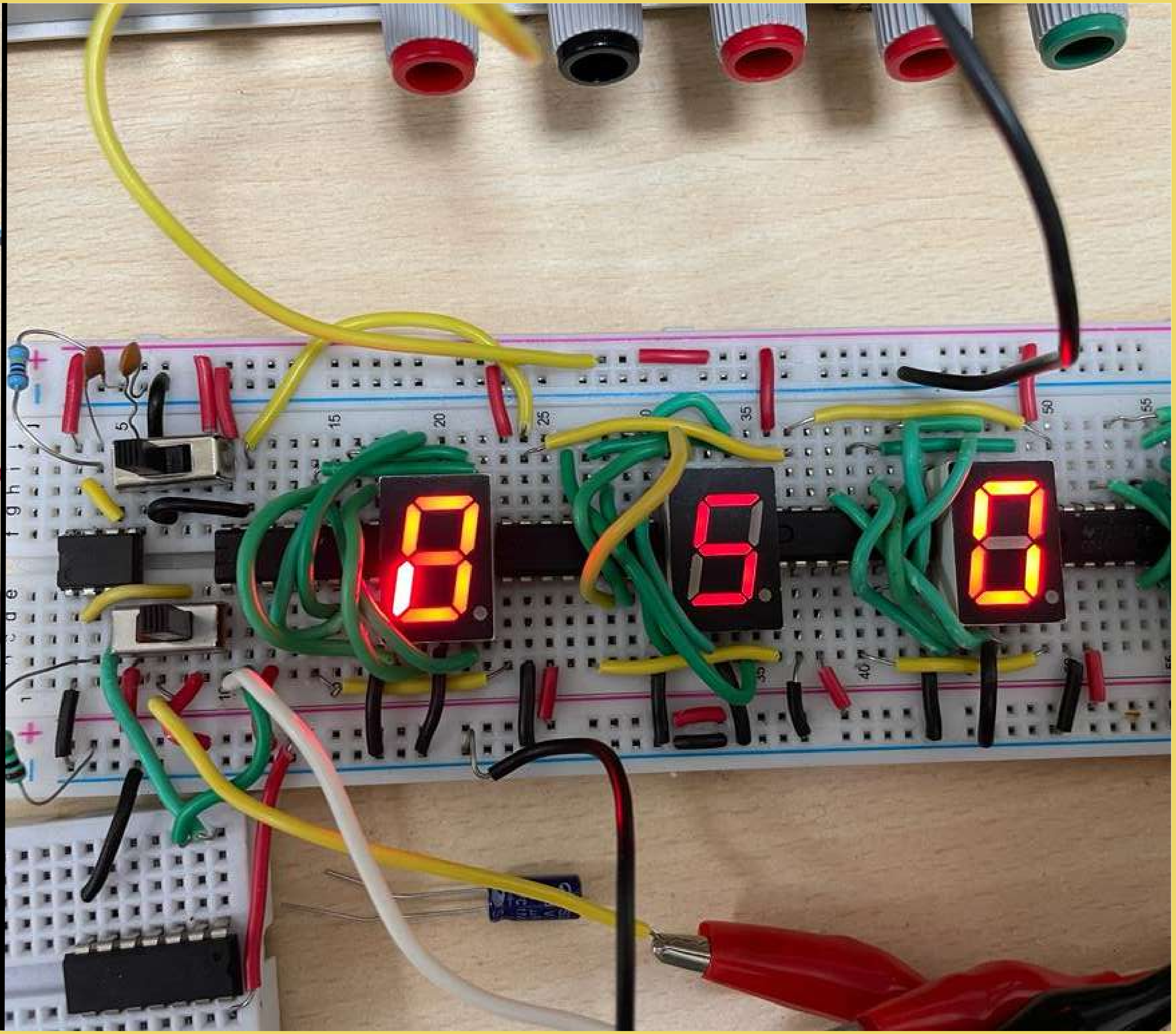
For each count of the clock to count 1micro farad and for the clock time period to be lower than the time constant which is in the range of 1 to 10^3, we need to have the frequency as 1Hz;
1/fs = 1.1 . 1M . 1micro
fs = 1Hz approx

FINAL CIRCUIT HARDWARE

RESISTANCE MEASUREMENT CIRCUIT

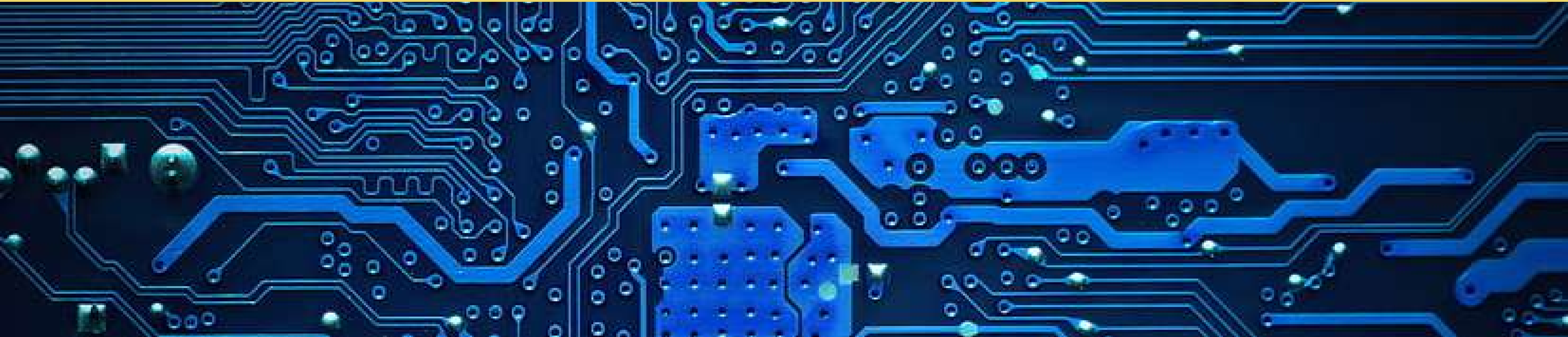


CAPACITANCE MEASUREMENT CIRCUIT



TEST RESULTS

RESISTANCE METER

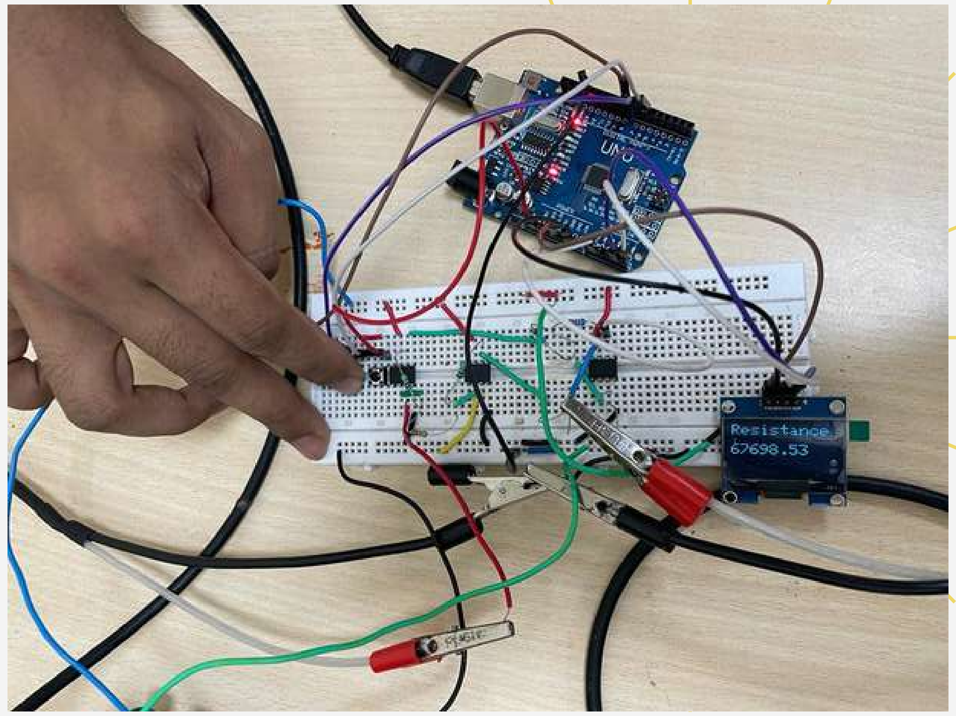


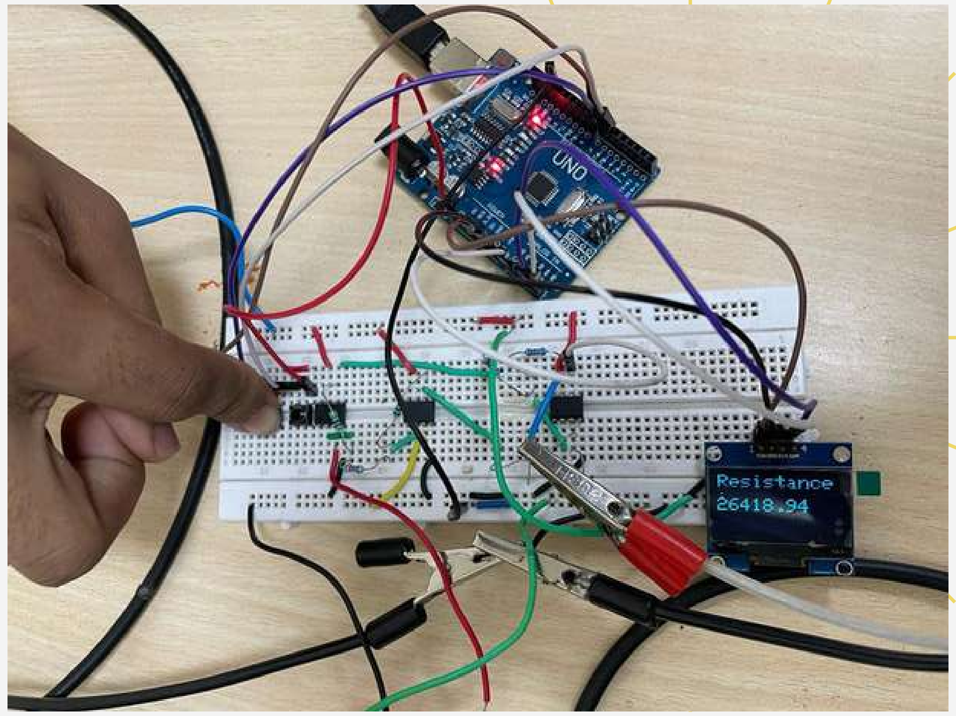
ACTUAL VALUES

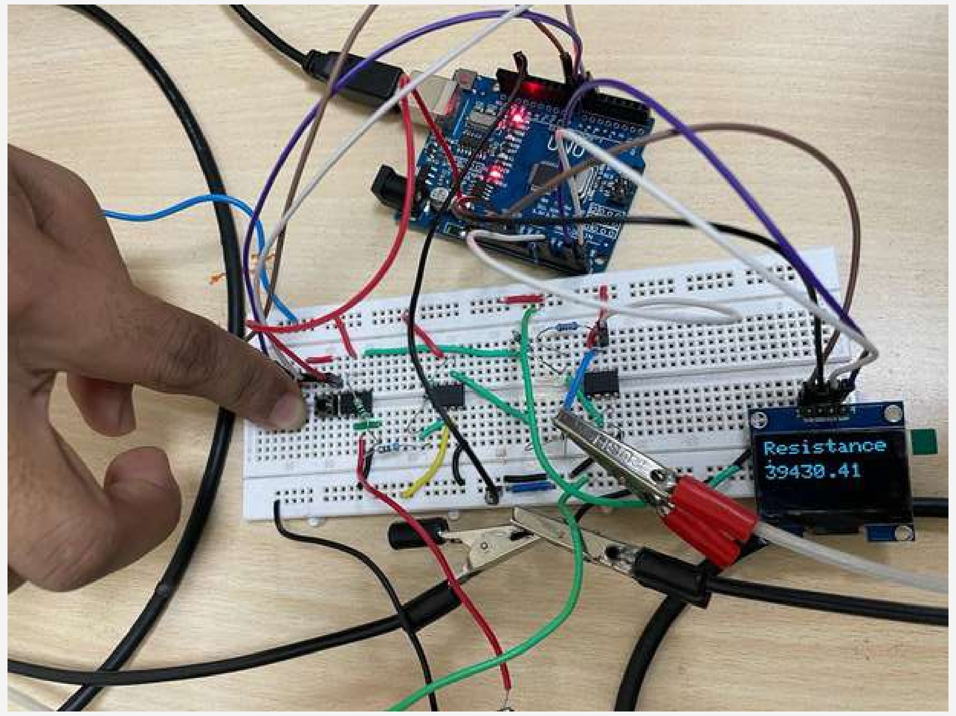
EXPERIMENTAL RESULTS

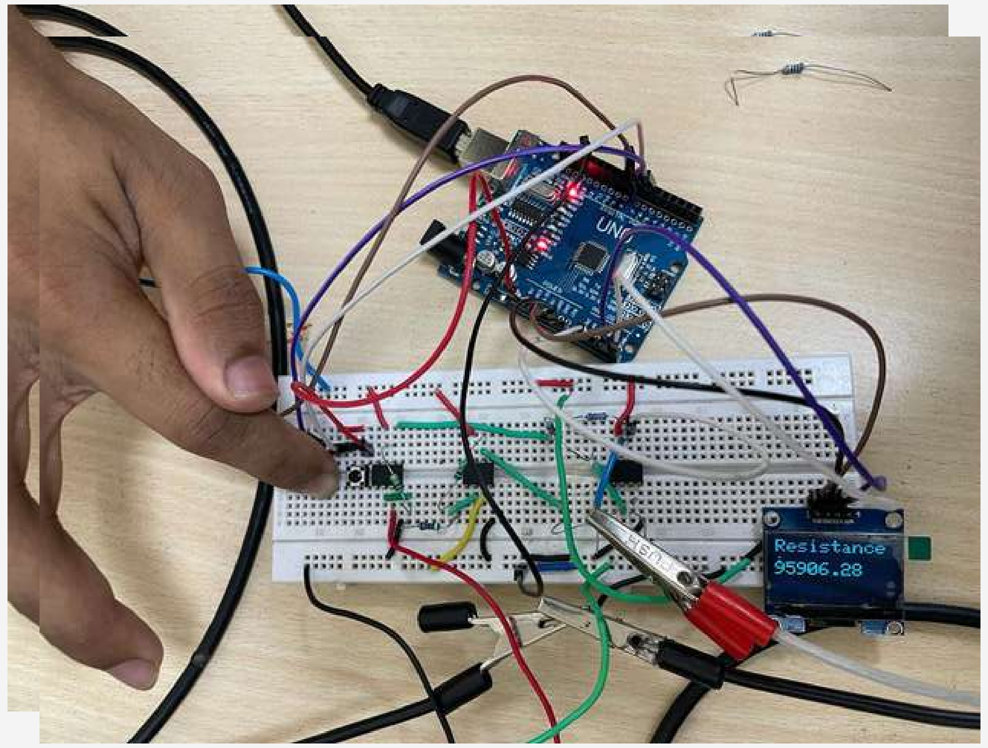
ACTUAL VALUES

EXPERIMENTAL RESULTS

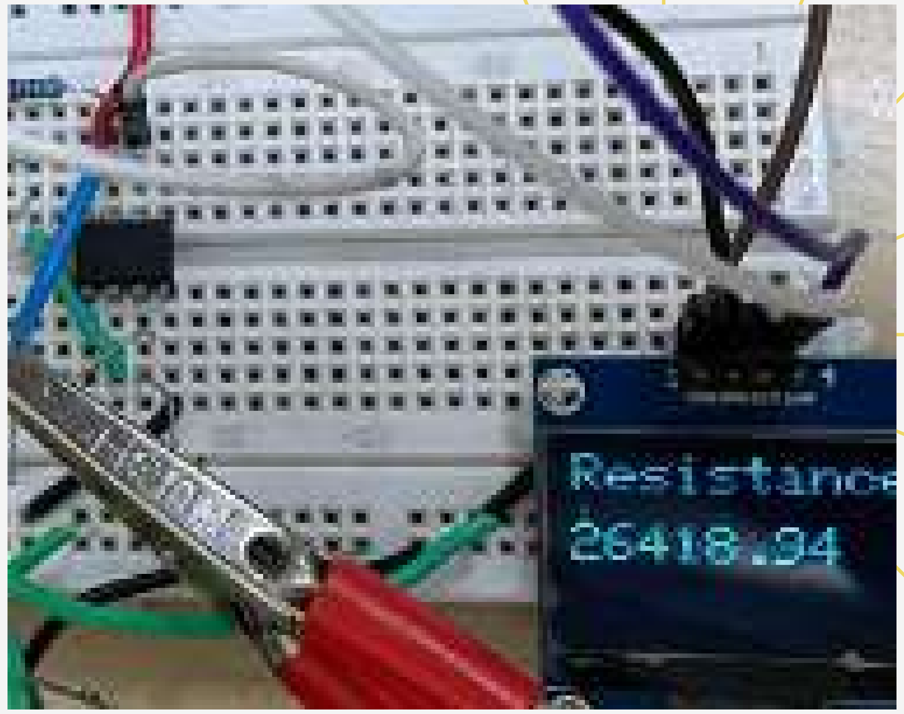


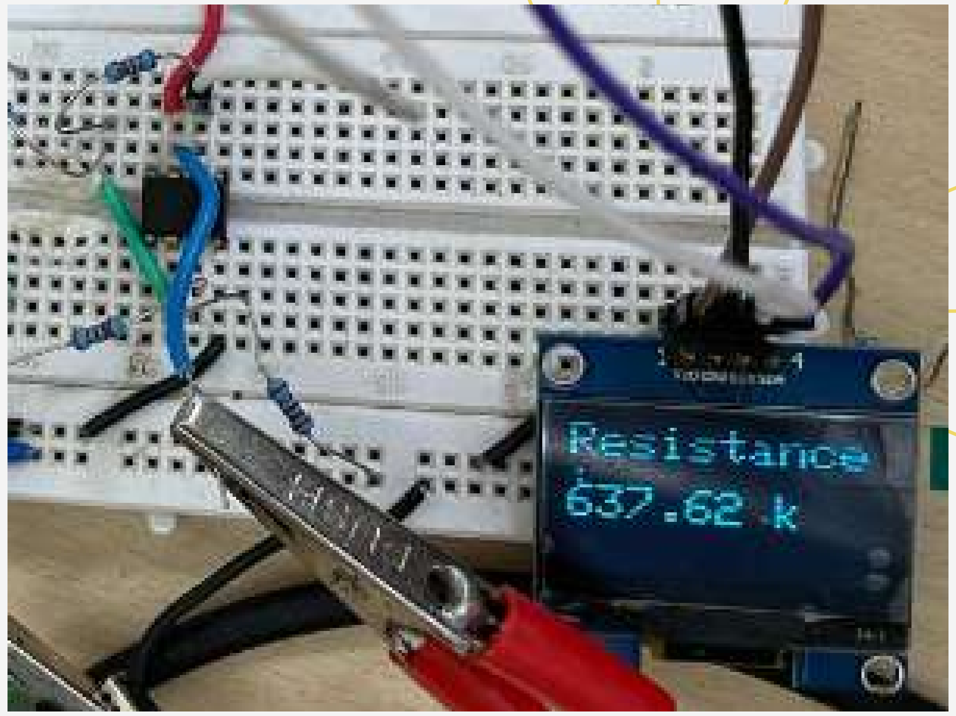


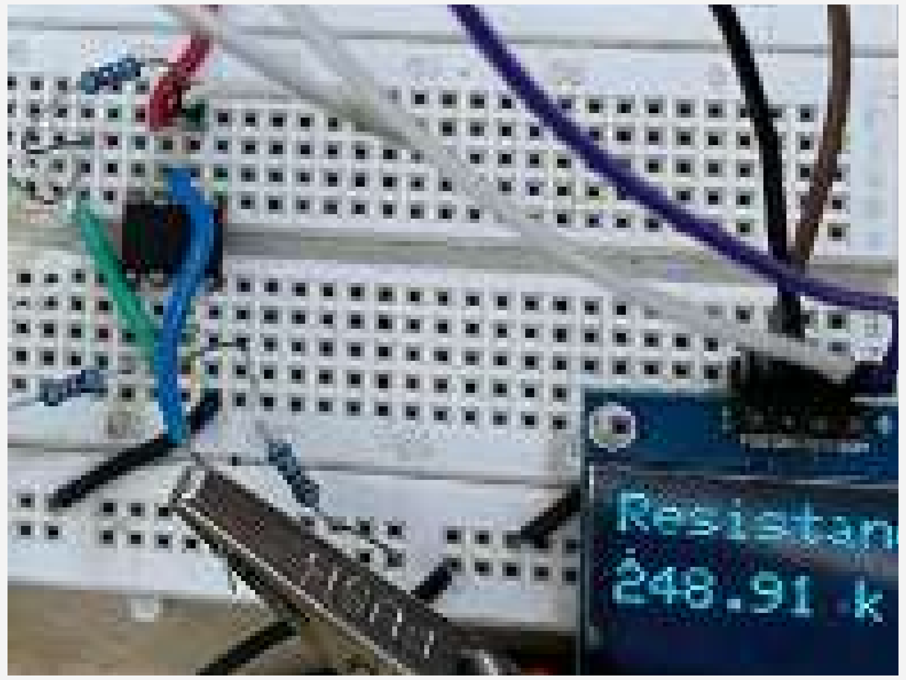




ACTUAL VALUES | EXPERIMENTAL RESULTS | ACTUAL VALUES | EXPERIMENTAL RESULTS

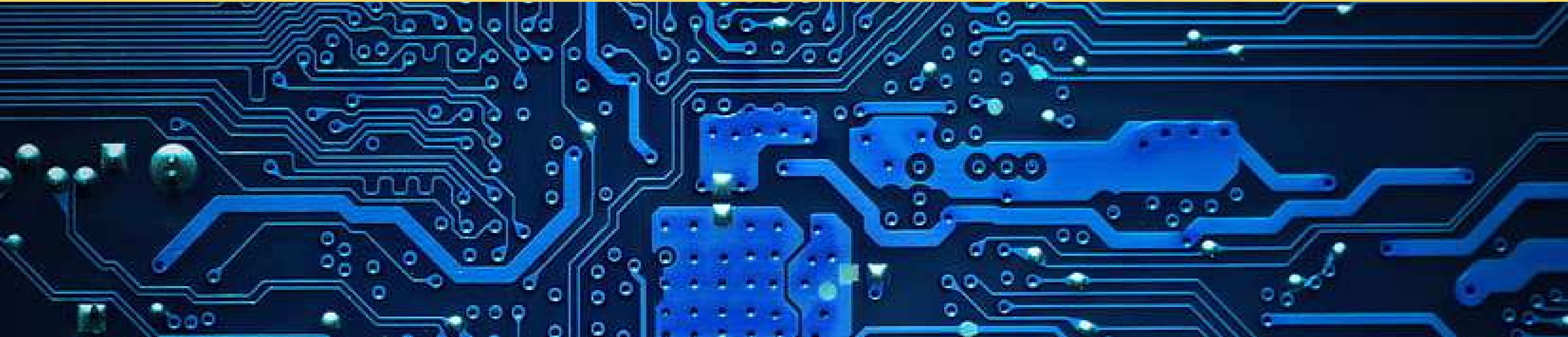






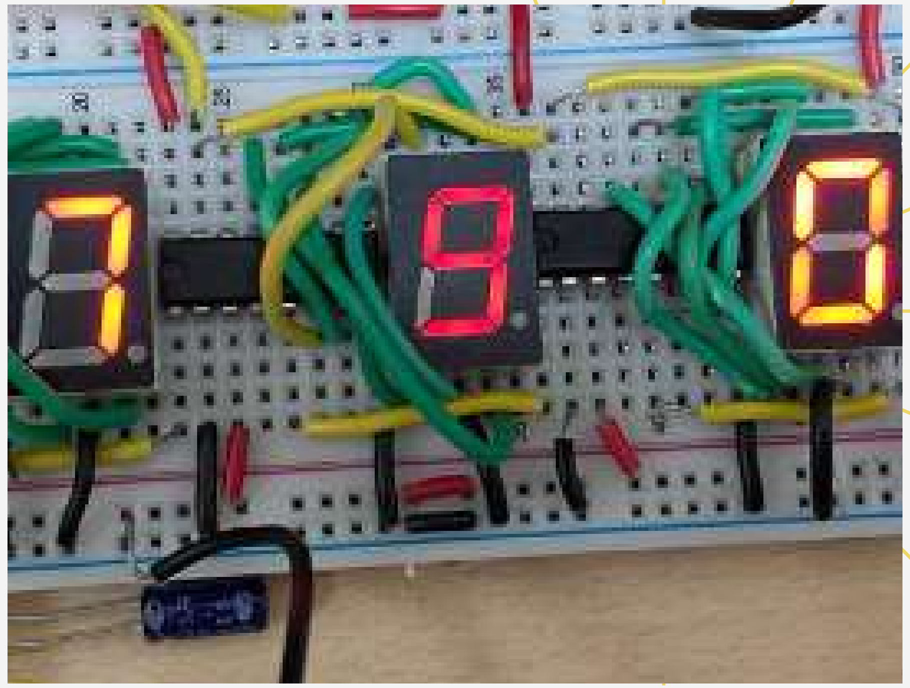
TEST RESULTS

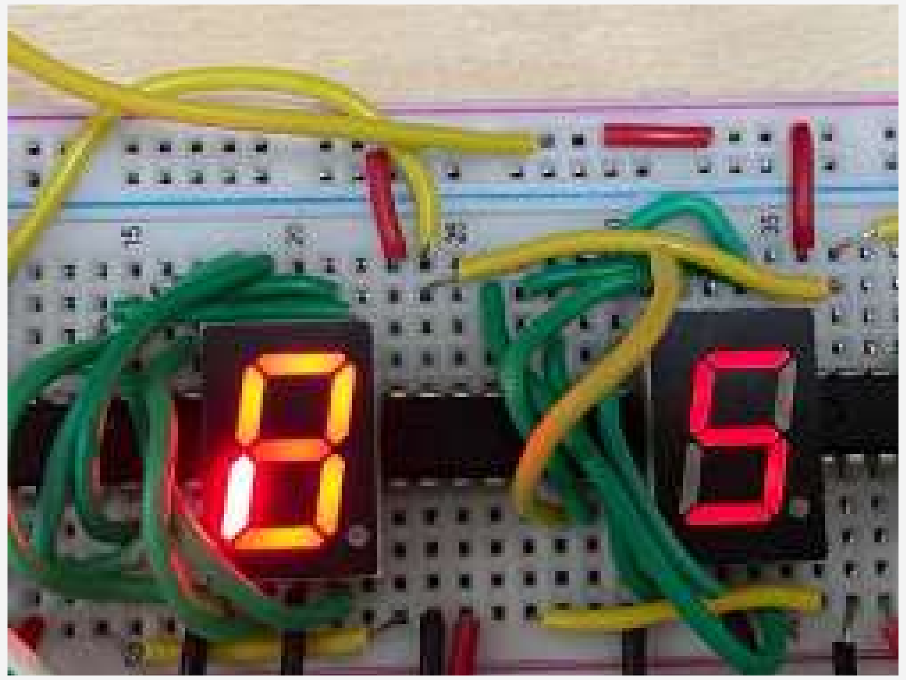
CAPACITANCE METER

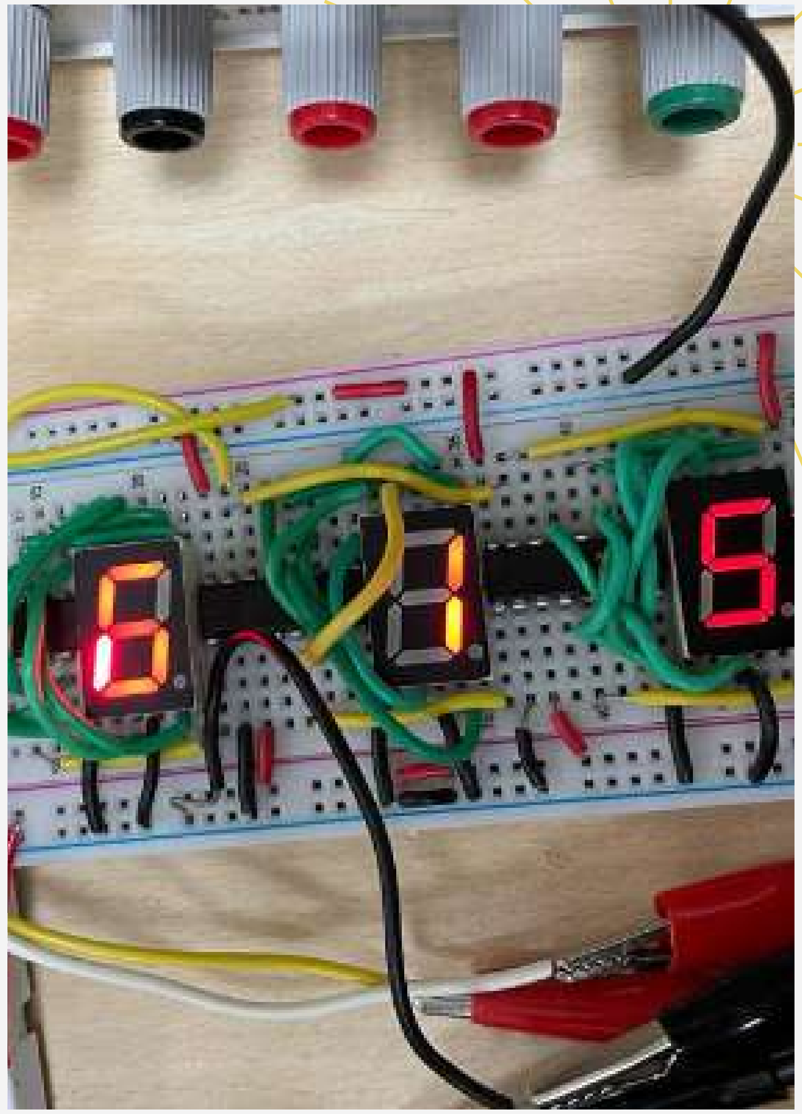


ACTUAL VALUES(nF) EXPERIMENTAL RESULTS

ACTUAL VALUES(pF) EXPERIMENTAL RESULTS







READ THE VALUES FROM THE RIGHT

Proposed Improvements & Constraints

01

PRECISION
CAPACITANCE AND RESISTANCE

There is an error of 3% - 5% in the measuring of resistance before attaching Arduino and directly performing calculations based on output voltage value, and an error of 10% after attaching Arduino and taking values from the display and an error of 7%-10% in capacitance measurement as a constraint which could be reduce.

02

RANGE AMBIGUITY
SET VALUES BASED ON RANGE

The measurement was range specific. In the resistor circuit, we had to change the stray resistances for different ranges specifically and we had to change the frequency of the input waveform from the wavegen respectively for different capacitance ranges. So, without knowing which range our device under tests falls, it is hard to measure

03

ARDUINO MEASUREMENT
PRECISION ERRORS

Due to the sampling of the Arduino, there have been precision errors in taking the input voltage and extracting the amplitude for which the maximum voltage had to be read precisely which was not perfect with an Arduino. This could be improved.

CONCLUSION

In conclusion, the projects of the resistor meter and capacitor meter have been valuable learning experiences. These meters are essential tools in testing and measuring the properties of resistors and capacitors, which are fundamental components of many electronic devices.

The resistor meter project involved designing and building a circuit that could accurately measure the resistance of a given resistor. Through this project, we gained knowledge about circuitry and how to build a circuit that can measure the resistance of a resistor accurately.

The capacitor meter project involved developing a circuit that could measure the capacitance of a given capacitor. Participants learned about the properties of capacitors, including their charging, and discharging, we learnt about counters and how to apply a 555 timer in practical usage and how to control its pulses.

Overall, these projects provided valuable hands-on experience in designing and building electronic circuits and testing electronic components. They also helped us develop problem-solving skills and a deeper understanding of the fundamental principles of electronics. The skills and knowledge gained through these projects will undoubtedly prove useful in future electronics projects and we thank the course instructors and teaching assistants for constant guidance and guidance.

Thank you!

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