RLC Meter

Project Report

INTRODUCTION

The RLC meter is a versatile electronic device meticulously designed for precise and independent measurements of resistance (R), inductance (L), and capacitance (C). Powered by the Atmega328p microcontroller operating at 16MHz, the system ensures accuracy in timing. Signal precision is further augmented by the inclusion of a crystal oscillator, complemented by the smoothing effect of two 22pF capacitors. To enhance user interaction and facilitate clear presentation of measured parameters, the RLC meter incorporates a 16*2 LCD display with an I2C module. A user-friendly interface is achieved through a 10k potentiometer connected to the A2 pin of the microcontroller, cleverly divided into three sections. As the potentiometer is rotated within each section, the device seamlessly transitions between the corresponding meter sections—R, L, or C. This ergonomic design choice prioritizes user experience, making the RLC meter accessible and intuitive for both novice and experienced users, and solidifies its standing as an indispensable tool for electronic component analysis and measurement.

Measurement Calculation

The resistance measurement utilizes a voltage divider circuit, allows for adjustment to measure unknown resistance accurately. The microcontroller, through analog readings, calculates the resistance based on the voltage division principle.

The inductance measurement involves an LM339 operational amplifier configured as a comparator. This setup, including a diode, a 330-ohm pull-up resistor, 150ohm resistors, 1N4007 diode and two 104pF non-polar capacitors, facilitates the charging and discharging of the inductor. The LM339 compares voltages at specific intervals, enabling precise inductance calculations.

For capacitance measurement, a resistor-capacitor (RC) charging circuit is implemented. The algorithm sets the discharge pin to input, records the start time using millis(), and charges the capacitor. The voltage is monitored until it reaches 63.2% of the total voltage, and the time taken is used to calculate capacitance.

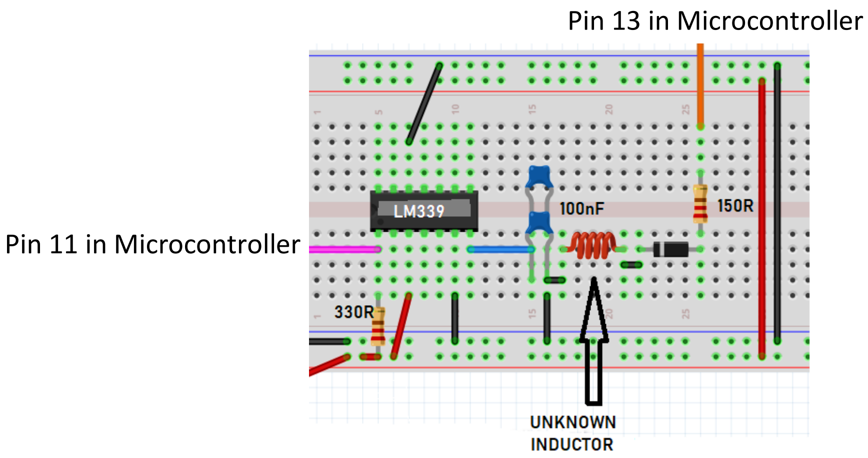
Components

Atmega328p
16MHz Crystal Oscillator
22 pF Ceramic Capacitors
104pF Ceramic Capacitors
10kohm, 220ohm, 330ohm, 1kohm and 150ohm Resistors
LM339N OP Amp
1N4007 diode
16X2 LCD with I2C to reduce connections
Dot board
Connecting wires

ELECTRONIC CIRCUIT OPERATION

Inductor Meter Circuit

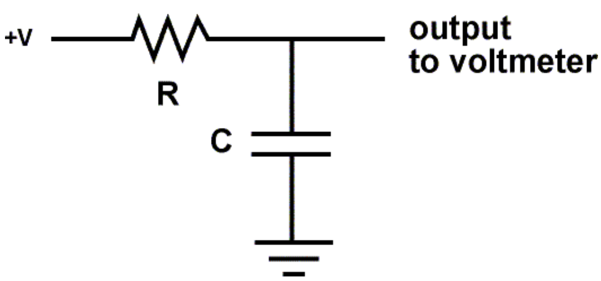
LM339 Comparator: Configured for voltage comparison during inductor charging and discharging.
Resistors: 330-ohm pull-up resistor and 150-ohm resistor in series with a diode.
Capacitors: Two 104pF non-polar capacitors used for charging and discharging.



Circuit also has an OP-AMP; we are using LM339 due to its simplicity. Here, the Operation amplifier is used as a comparator, which measures the voltage at two instants and compares them. 330ohm resistor is used as a pull-up resistor and connected to PIN 1 of the Lm339 to ATmega328p digital pin 11. 150ohm resistor is used after diode and further connected to digital pin 13 of the ATmega328p. We are using here capacitor 208pF (one of 104pFf). The value 2.E-8 can be changed if you are using a different value capacitor. We can change the op-amp to lm358, 741, or any other having the same configuration. But low noise operational amplifier is preferred more in this case.

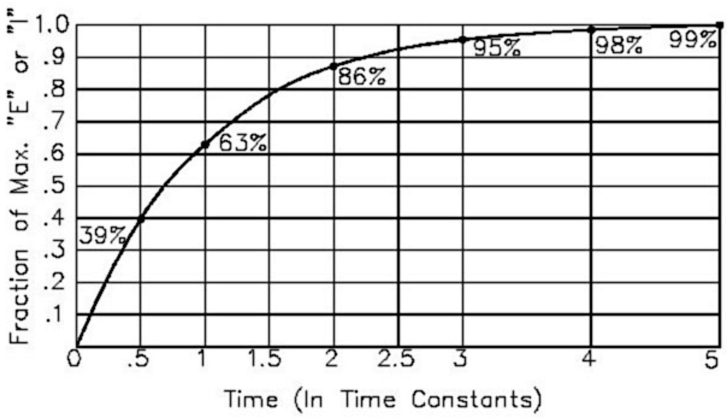
Capacitance Meter Circuit

Resistors: 220-ohm and 10K ohm resistors used in the charging circuit.
Capacitor Charging: Time constant measured to calculate capacitance.
Algorithm: The algorithm employs pins set as input and output to charge and discharge the capacitor, measuring time and calculating capacitance



RC schematic

A resistor will charge a capacitor in TC seconds, where:
TC = R * C
TC = time constant in seconds
R = resistance in ohms
C = capacitance in farads (1 microfarad [ufd] = .000001 farad = 10^-6 farads)
The voltage at 1 Time Constant equals 63.2% of the charging voltage.
Example: 1 megohm * 1 microfarad = 1 second
Example: 10k ohms * 100 microfarad = 1 second

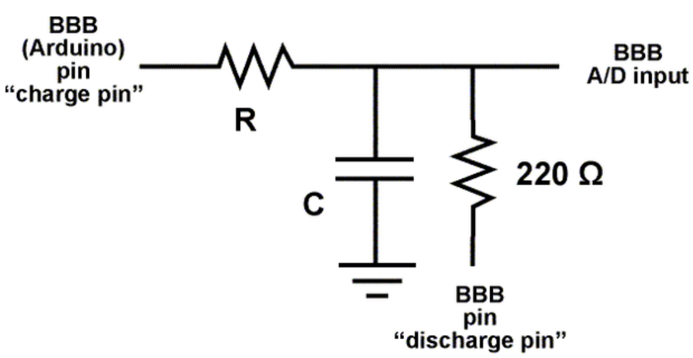


This sketch works because the ATmega328p pins can be in one of two states, which are electrically very different.

- Input State (set with pinMode(pin, INPUT);)
- High Impedance (resistance) - Makes very little demand on the circuit that it is sampling
- Output State (set with pinMode(pin, OUTPUT);)
- Low Impedance - Can provide 40 mA source (positive voltage), or sink (negative voltage)

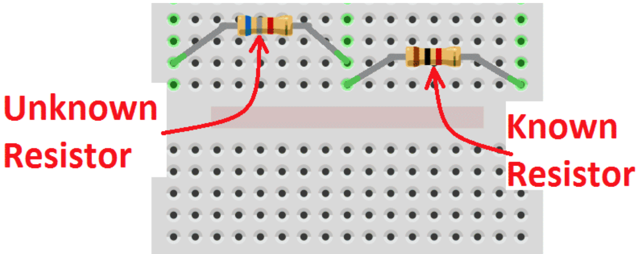
Additionally, the pins can be HIGH (+5 volts), to charge the capacitor; or LOW (ground) to discharge the capacitor

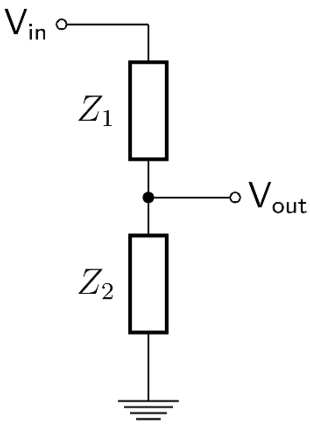
Sketch



Resistance Meter Circuit:

Voltage Divider Circuit: Comprising a rotary potentiometer and resistors to determine unknown resistance
Microcontroller Integration: Analog readings are used to calculate the unknown resistance based on voltage division.





With voltage divider we can take a portion of input voltage as output. This is achieved by connecting two resistances in series connection. Because they are connected in series, the same current I runs through them:

$$\left.\begin{aligned} V_{in} &= I(Z_1+Z_2) \\ V_{out} &= IZ_2 \end{aligned}\right\} \Rightarrow \left.\begin{aligned} I &= \frac{V_{in}}{Z_1+Z_2} \\ I &= \frac{V_{out}}{Z_2} \end{aligned}\right\} \Rightarrow \frac{V_{out}}{Z_2} = \frac{V_{in}}{Z_1+Z_2} \Rightarrow V_{out} = \frac{Z_2}{Z_1+Z_2}V_{in}$$

If we solve this equation for Z2 we have

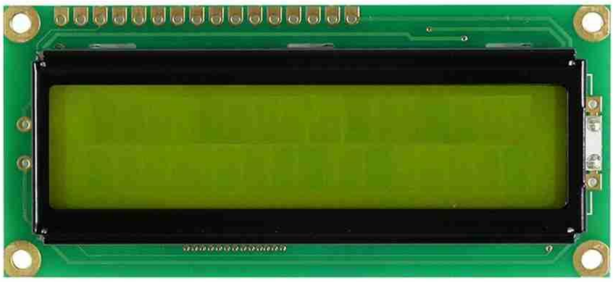
$$Z_2 = Z_1\left(\frac{1}{\frac{V_{in}}{V_{out}}-1}\right)$$

If all values apart from Z2 are known, we can compute the unknown resistance using Vout.

DISPLAY SYSTEM OPERATION

The display system in the RLC meter plays a crucial role in presenting accurate and user-friendly information to the operator. The components involved in this system are the 16*2 LCD display with an I2C module and a potentiometer integrated to facilitate navigation between R, L, and C measurements.

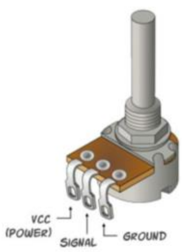
LCD 16*2 Display with I2C Module

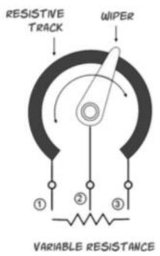


The heart of the display system is the 16*2 LCD screen, featuring an I2C module for enhanced communication efficiency. The I2C module simplifies the connection between the LCD and the Atmega328p microcontroller, reducing the number of required pins and enabling faster data transfer. This module enhances the overall responsiveness and performance of the display system.

The microcontroller sends formatted data to the LCD, which interprets and presents the information in a clear and easily readable format. The LCD serves as the primary interface for the user to interact with the RLC meter, providing real-time feedback on the measured values of resistance, inductance, and capacitance.

Potentiometer Integration





To enhance user experience and ease of navigation, a potentiometer is integrated into the system. The potentiometer is a 10k variable resistor divided into three distinct sections, each assigned to one of the meters (R, L, C). This design allows the operator to smoothly rotate the potentiometer, sequentially selecting the desired meter section without the need for additional buttons or controls.

The integration of the potentiometer simplifies the user interface and makes it intuitive for operators to switch between different measurement modes. Each section of the potentiometer corresponds to one of the meters, providing a seamless and responsive control mechanism for navigating through the RLC meter's functionalities.

DESIGN AND TESTING