EE-465 Project 2
Project Proposal – Extending VOM to include Function Generator and Oscilloscope
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1. Problem Statement:

Perhaps the most fundamental equipment that every electrical engineer needs include a multimeter to measure current, voltage and resistance, a function generator and an oscilloscope. The cost of good oscilloscopes and function generators is extremely high and is often completely unaffordable for students and novice engineers. Furthermore, the arrival of COVID'19 imposed restricted access to universities and laboratories which rendered students unable to complete their projects that needed waveform analysis or signal response analysis. Keeping all the mentioned reasons in my mind, this project proposes to extend the VOM meter, designed and implemented in project 1 of EE-465 course, to include a basic function generator and oscilloscope. Moreover, to reduce the cost of the system, the display will be replaced with the user's android smartphone which will act as an interface between user and the measurement system.

2. Constraints:

As mentioned previously, the newly added features of function generation and waveform display are not the only features that are being added in this project. The integration of android smartphone for display purposes is also a major novelty that will prove to be beneficial for the user by providing a highly simplified, portable electrical engineer's workbench. Some of the important constraints imposed on this project include:

- Complete portability in terms of power supply and data presentation.
- Compact presentation and structure of the measurement system.
- Precise and accurate measured values.
- Usage of android smartphone for data and waveform display.

Keeping the above constraints in mind, a few project specifications were derived that are being proposed below:

3. Planned Specifications:

- DC Voltmeter should have a range of 0 to 1000V.
- DC Ammeter should have a range of 0 to 500mA.
- Ohmmeter should have a range of 1 to 1MΩ.
- Function Generator will produce three waveforms: sinusoidal, square, and triangular waves. The amplitude of the wave will be fixed at +5V peak to peak. The range of frequencies will be from 600Hz to 9kHz.
- Oscilloscope will be able to display voltage range from +10V to -10V. The maximum frequency of the oscilloscope will depend on the smartphone as well as the microcontroller board and is therefore yet to be decided.
- The display of all the measured values, including the waveforms will be performed on the android smartphone which will be in serial communication with the microcontroller using a USB OTG cable.

4. Design Details:

The design and operation the VOM meter was satisfactorily done in project 1 therefore it will be only briefly discussed here. The DC voltmeter uses a simple voltage divider circuit which scales the voltage level down to 5V so that it can be fed to the ADC on the microcontroller board. This voltage is then sampled and processed only to be displayed on the user's phone. Similarly, the DC ammeter works by the principle of a 10Ω shunt power resistor through which most of the current passes. The voltage across this resistor is measured and the value is processed to be displayed in the form of milliamperes on the phone screen. Finally, the implemented ohmmeter is auto-ranging which means that it can present reasonably accurate values of for a large range of 1 to 1MΩ. It is constructed using five PNP transistors which perform the task of switching to select the best possible range among the five possible ranges. The circuit design for the entire circuit is given in figure 1 below:

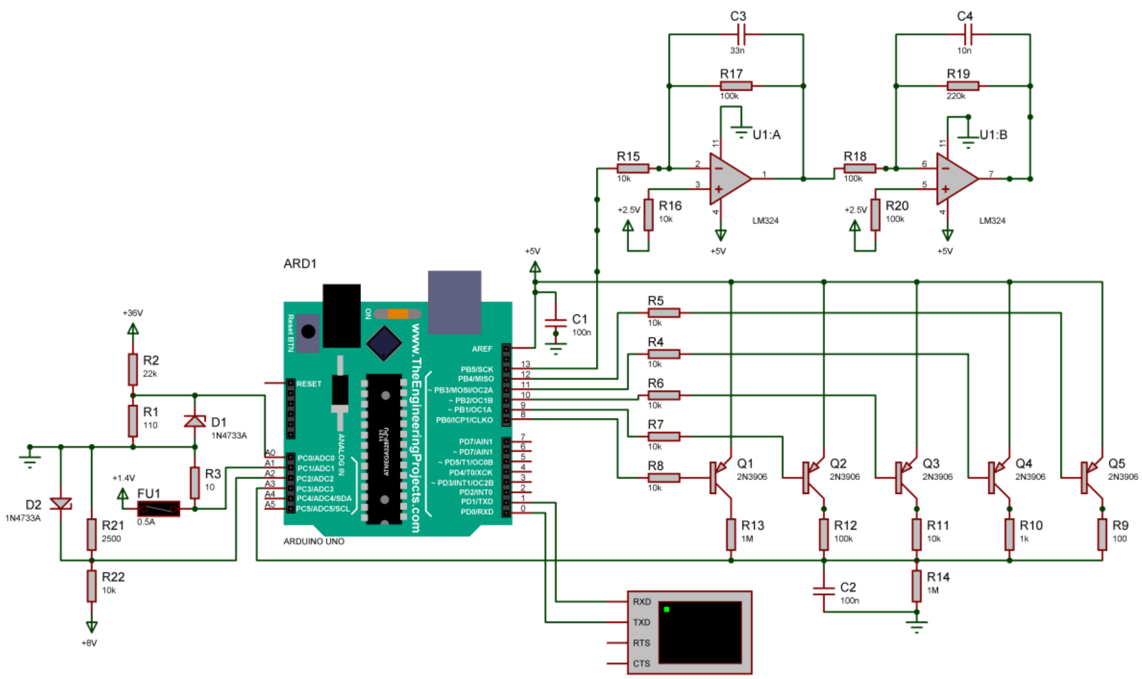

Figure 1: Project Schematic on Proteus

For this iteration of the project, function generator and a very basic oscilloscope are being added along with android integration. The function generator has a complicated signal conditioning circuitry and it works as follows: Arduino produces a variable frequency square wave from its digital pin 13 which is then conditioned using two op-amp based integrating amplifier circuits. The first op-amp converts the square to a triangular wave while simultaneously amplifying it to counter the voltage drop across 10kΩ resistor. This triangular wave is then passed through another integrating amplifier which converts it a sinusoidal wave. There is no way to vary the amplitude of the produced waveforms in this design, however it can certainly be incorporated in later iterations. The frequency of the waveforms are controlled by the frequency of the square wave produced by the tone() function of the Arduino microcontroller. This function takes frequency as an argument, which will be sent through the android phone using USB serial communication.

Unlike the function generator, the oscilloscope circuit is as simple as it possibly can be. However, the main working of the oscilloscope takes place in the android application. The circuit consists of a simple voltage divider which scales the voltage to a reading which is suitable to be read by Arduino ADC. Then the values are scaled up in Arduino IDE and sent to the smartphone using USB communication where they are instantly plotted on a real-time graph.

5. Simulation and Testing:

5.1. VOM Simulation:

In the following figure, the results of the VOM are represented using the virtual terminal through simulation in Proteus. The values being displayed are set arbitrarily to show the working of the circuit. These values will be presented in the smartphone in the actual implementation of the project.

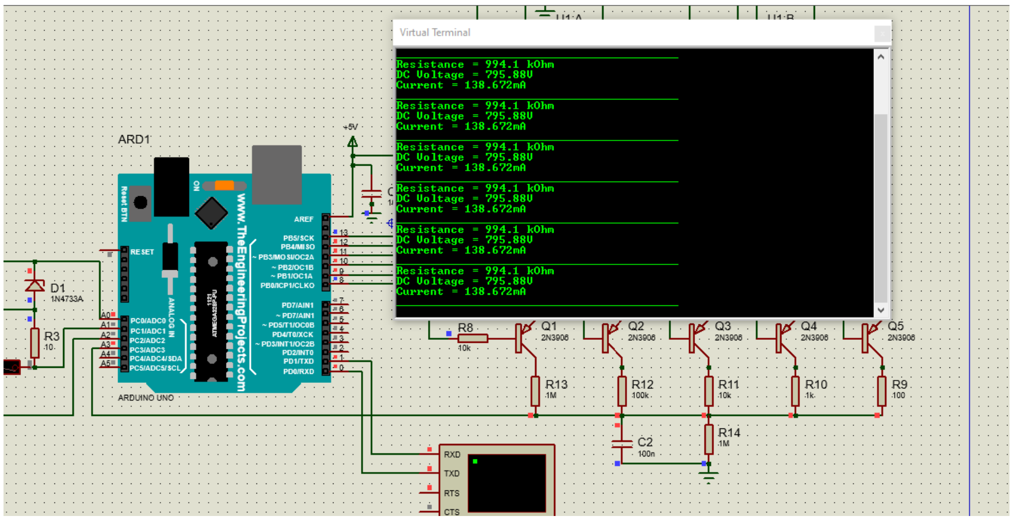

Figure 2: VOM Simulation on Proteus

5.2. Function Generator Simulation:

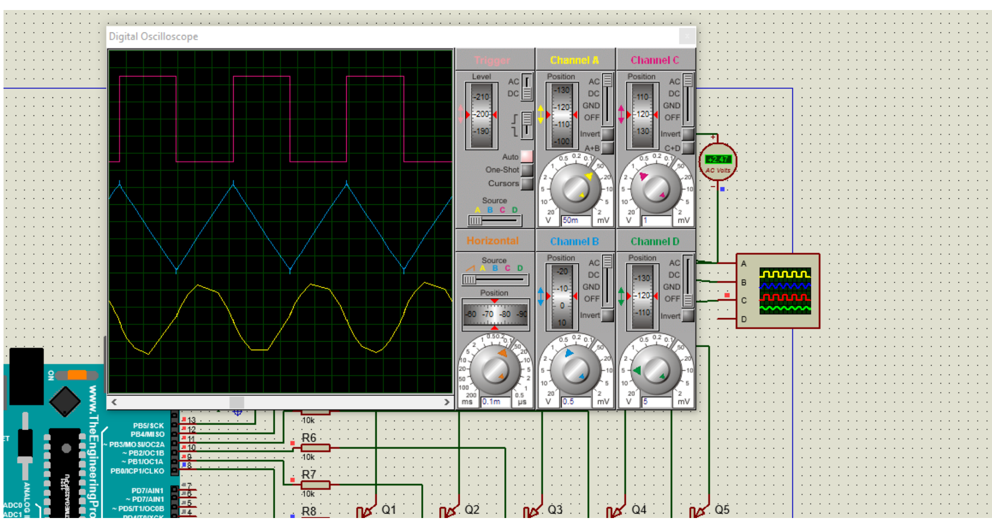

Figure 3: Function Generator Simulation on Proteus

In figure 3 above, the simulation of function generator has been shown. As visible in the oscilloscope in Proteus, three different waveforms have been derived from a single square waveform. Some problems are in the produced waves are visible clearly, the most important of them is the decreasing amplitude of the subsequent waveforms. To fix this problem, voltage follower circuits were placed after each layer of integration but the results were not desirable. Apart from that, the value of feedback resistor on the integrator circuits were also increased to amplify the amplitude of the waveforms but to no avail. More research and hardware testing needs to be done before these circuits can be implemented practically.

5.3. Oscilloscope:

Since there was no way in Proteus, or any other tool for that matter, to show the reception of signals in Android and the display of data in real-time, some minor hardware tests were conducted to verify the feasibility of the idea. Two different signals were generated using Arduino, one sinusoidal and one square wave. Both the signals were transmitted and received using the OTG channel, and the values were plotted in real-time on the phone. Following are the results of the tests:

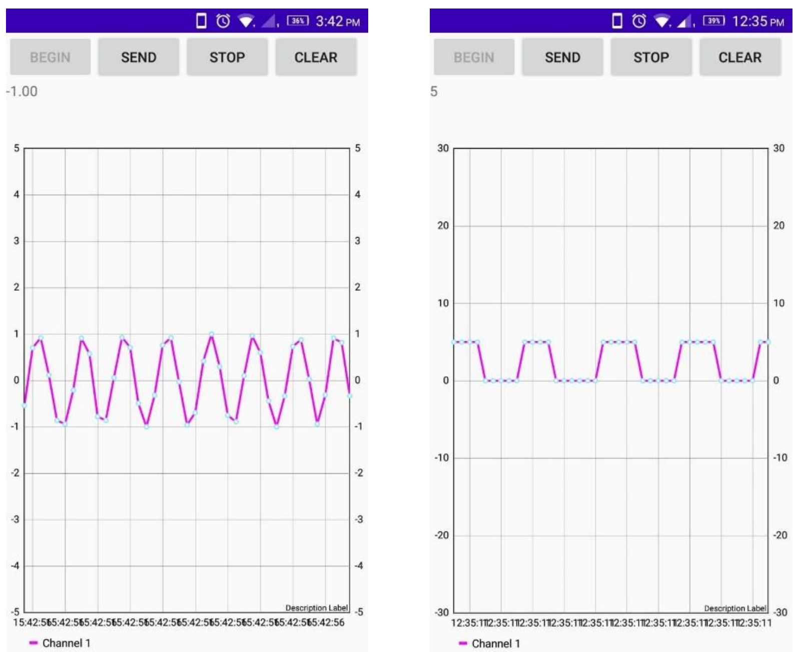

Figure 4: Oscilloscope Results

6. Hardware Implementation Plans:

The simulated VOM works very well for the specified range of values, and this was verified in the first project of the course. The current objectives, oscilloscope and function generator, are producing decent results as far as the simulation is concerned. There are two main problems that will need to be targeted during the hardware implementation of the project. The first problem is that the amplitude of the subsequent waveforms is decreasing in the function generator. This means that by the time the signal is converted to sinusoidal, the voltage amplitude is too small to be processed further. The second problem is that there has been some problem related to the plotting frequency of the android graph plotting library. It is unable to plot a lot of data so quickly which is putting a limitation on the frequency of the waveform that can be properly plotted.