A Laboratory Kit for Multimeter Design

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Abstract
The multimeter is an important electrical tool and is a combination of many individual instruments. In practice, common multimeter designs are digital and measure voltage, current, resistance, capacitance, etc., using a single set of probes. Before the digital age, the world relied on analog displays. Some argue that analog displays are outdated technology. However, this overlooks one of the most important characteristics provided by the analog display, which is its ability to provide an instantaneous visual perception. Analog displays are currently used for many applications in aviation and automobiles, demonstrating their continuing usefulness in the field. In the multimeter, the analog display is based on an electromechanical device called a galvanometer. Externally, the galvanometer consists of an incrementally marked face and a needle indicator, similar to that of a clock or tachometer. The deflection of a needle indicates the intensity of the flow of a very small direct current passing through the device. This project utilizes a galvanometer, a ribbon cable with a breadboard connector, 3 external terminals, a 12-position switch and a fuse, within a 3D-printed enclosure to produce a kit for laboratory experiments. Students use the kit to design a multi-scale DC voltmeter, DC ammeter, AC voltmeter, and Ohmmeter. Finally, the kit allows the use of an internal printed circuit board instead of an external prototyping board for a completely enclosed multimeter implementation.

Background
Our multimeter kit was designed to combine the functionality of a voltmeter, ammeter, and ohmmeter into a single tool. The functionality of the multimeter is determined by the configuration of resistor networks in series and parallel with the galvanometer. These networks are implemented on a PB-505 prototyping board. The 12-position rotary switch is used to divide its functionality to produce varying scales between the four modes of operation. It generally consists of various scales to adjust the precision of the instrument.

Objective
- Develop an understanding of the construction and implementation of a multimeter.
- Facilitate the mathematical models of Ohm’s law, voltage division, and current division to develop standardized scales for measuring inputs of various magnitudes.
- Construct a completely reproducible and cost-effective design.
- Use this kit in laboratory experiments of meter design.
- Allow a student to build his/her own portable multimeter with a custom 3D printed switch position plate.

Methodology
- 3D modeling of the enclosure using Solidworks software
- 3D printing of STL files sliced using Curate
- Prototyping board extension (wire harness) for scaled design
- 20-pin IC chip and the ribbon (wire harness) constituting the needed connections for creating the scales on the PB-505 prototyping board
- 12-position rotary switch to provide easy scale manipulation.
- Integrated printed circuit board (PCB) for portable “plug and measure” functionality, mounted on the back plate.
- Galvanometer to provide analog feedback for instantaneous visual display of input.
- Internally configured 9V battery to provide the needed power source for Ohmmeter functionality and other functions.

Results
The design, shown in figure 1, offers the scaled functionality of a DC voltmeter, DC ammeter, AC voltmeter, and an Ohmmeter. Figure 2 shows a view of the inside of the enclosure. A complete breakdown of all parts involved in its construction can be seen in figure 3, constituting a completely reproducible design. As an extension, this would also include the .STL files for the 3D printed enclosure, rotary knob, and switch position reference plate. The primary educational implementation of the design can be seen in figure 4, where the 20-pin IC chip is plugged into the PB-505 prototyping board. Also seen in this figure is a network of resistors in series and in parallel, routed through particular pins of the IC chip according to a particular desired design. These connections compose the needed scales for the different functions. Once all scales are verified, a PCB can be fabricated with the needed components and mounted on the back plate to produce a completely enclosed and portable meter.

Conclusions
This design provides a number of key features. Educationally, it provides the individual with a hands-on understanding of this common multi-tool. Successful design and implementation requires the knowledge and application of circuit theory. Specifically, the concepts crucial to design are those of voltage division, current division, and Ohm’s Law to be realized physically. This process, in turn, reinforces the concepts learned in lecture and provides a thorough understanding of this tool beyond its simple operation. Another key feature of this design pertains to its cost-effectiveness. This design provides a viable option for those who share the same passion for engineering as we do and desire a cost-efficient means for obtaining such an essential tool. A complete list of all components and where to obtain/purchase them are provided in the laboratory for students to pursue the option of constructing one for themselves to keep.

Acknowledgements:
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