

## **Evaluating the Use of MicroPython and the Raspberry Pi Pico in Laboratory Activities for Undergraduate Classes in Engineering Electromagnetics**

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## INTRODUCTION

When creating laboratory activities to support upper-division undergraduate classes in engineering electromagnetics, a straightforward and conceptually useful activity is for undergraduate engineering students to analyze and build a basic electrical component and then learn how it can be used as part of a simple sensor. A variety of microcontrollers can be used to facilitate laboratory activities of this type; this paper examines the use of the Raspberry Pi Pico and MicroPython for these laboratory activities.

The Raspberry Pi Pico is a relatively new board within the Raspberry Pi family; its price (~\$4 - \$15), measurement resolution and ability to run MicroPython and CircuitPython make it a very interesting option for use in an undergraduate engineering laboratory curriculum where a simple microcontroller is required. Presented are a comparison of example laboratory activities where the activity is first structured to utilize Python, MicroPython and the Raspberry Pi Pico and then repeated with the more commonly used Arduino Uno, Arduino C and Matlab.

The use of MicroPython to support sensor activities in engineering electromagnetics allows for the use of Python as the main programming language for the overall set of laboratory activities. Given the increasing popularity of Python as a programming language in both engineering and the sciences, engineering students will benefit from increased familiarity with the Python programming language.

## BACKGROUND

As the student preparation for electrical engineering programs has changed over the past fifty years from amateur radio to being almost entirely computer and digital-focused, it has become necessary to have laboratory activities for classes in engineering electromagnetics to help students to visualize the equations and phenomena that are discussed in this class. There are many great possibilities for laboratory activities in this area; one option is for students who are learning about electrostatics, including charge and field theory, to make basic circuit elements like simple batteries, resistors and capacitors. These activities would be done in coordination with the lecture's coverage of using field expressions to calculate capacitance and resistance of homogeneous structures, and then learning how Laplace and Poisson's theories can be used to help calculate capacitance and resistance of slightly more irregularly shaped structures.

One of the most important lessons that can be taught in an engineering electromagnetics class is that basic electrical components are not just things that are purchased premade; basic electrical components are made of correctly designed pieces of material. Students can learn to design these; they can also use the electrical components that they have constructed as a part of usable devices. Activities which support the development of this type of understanding should be structured to make it as straight-forward as possible for students to use their constructed components as part of a functioning system; it can be useful to evaluate whether new technology can improve existing activities.

## METHODS

Comparing and contrasting the use of the Arduino Uno and the Raspberry Pi Pico in laboratory activities for engineering electromagnetics involves comparing results for equivalent sets of activities.

The following table presents a comparison of two possible laboratory activities for studying capacitance in the context of an undergraduate engineering electromagnetics class.

Capacitance Activity	Arduino Uno [1]	Raspberry Pi Pico
1. Calculation question involving calculating the capacitance of two different structures.	1. Calculation question involving calculating the capacitance of two different structures.	1. Calculation question involving calculating the capacitance of two different structures.
2. Use of Matlab to write simulation code exploring the impact of changing the size of the capacitor structure on the value of capacitance.	2. Use of Python to write simulation code exploring the impact of changing the size of the capacitor structure on the value of capacitance.	2. Use of Python to write simulation code exploring the impact of changing the size of the capacitor structure on the value of capacitance.
3. Use of simple materials to create a capacitor that can be measured using an LCR meter or multimeter. Value of capacitance is estimated using the capacitance equation derived by the student.	3. Use of simple materials to create a capacitor that can be measured using an LCR meter or multimeter. Value of capacitance is estimated using the capacitance equation derived by the student.	3. Use of simple materials to create a capacitor that can be measured using an LCR meter or multimeter. Value of capacitance is estimated using the capacitance equation derived by the student.
4. Use of the Arduino Uno to create a touch capacitor demo using a preexisting Arduino C library [2].	4. Use of the Raspberry Pi Pico to measure the capacitance of several standard capacitors as well as the student-built capacitor by measuring the time constant of an RC circuit with a known resistance value [3].	4. Use of the Raspberry Pi Pico to measure the capacitance of several standard capacitors as well as the student-built capacitor by measuring the time constant of an RC circuit with a known resistance value [3].
5. Follow-up questions analyzing the activity and the practical applications of this activity.	5. Follow-up questions analyzing the activity and the practical applications of this activity.	5. Follow-up questions analyzing the activity and the practical applications of this activity.

This second table presents a comparison of two possible laboratory activities for studying resistance in the context of an undergraduate engineering electromagnetics class.

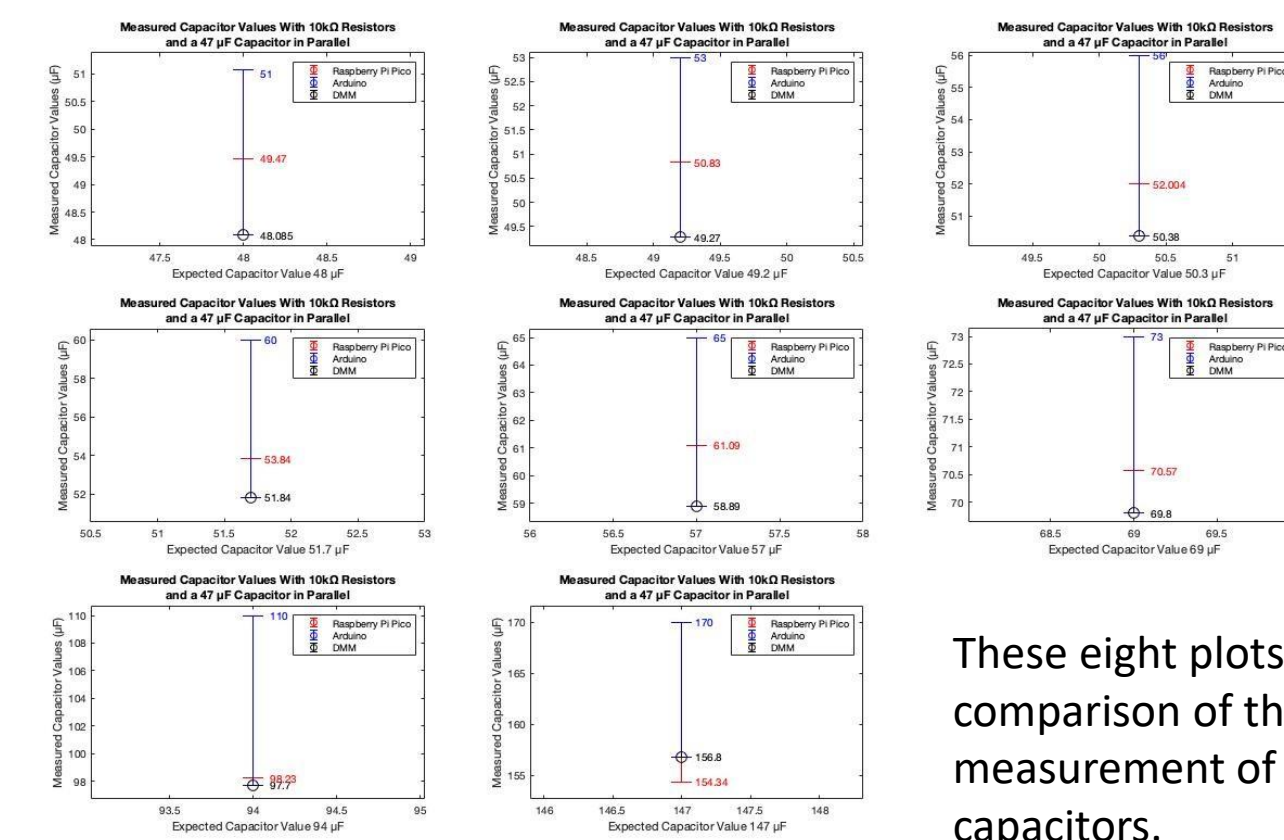
Resistance Activity	Arduino Uno	Raspberry Pi Pico
1. Calculation of the resistance of both regularly and irregularly shaped blocks of material.	1. Calculation of the resistance of both regularly and irregularly shaped blocks of material.	1. Calculation of the resistance of both regularly and irregularly shaped blocks of material.
2. Writing Matlab code using the expression found by the student to explore how changing the parameters of the block of regularly shaped material changes its resistance.	2. Writing Python code using the expression found by the student to explore how changing the parameters of the block of regularly shaped material changes its resistance.	2. Writing Python code using the expression found by the student to explore how changing the parameters of the block of regularly shaped material changes its resistance.
3. Student draws resistor using a graphite pencil that can be measured using a multimeter and with the Arduino using a voltage-divider circuit where the second value is a known resistance. Student additionally estimates value based on equation derived by student.	3. Student draws resistor using a graphite pencil that can be measured using a multimeter and with the Raspberry Pi Pico using a voltage-divider circuit where the second value is a known resistance [4]. Student additionally estimates value based on equation derived by student.	3. Student draws resistor using a graphite pencil that can be measured using a multimeter and with the Raspberry Pi Pico using a voltage-divider circuit where the second value is a known resistance [4]. Student additionally estimates value based on equation derived by student.
5. Follow-up questions analyzing the activity and the practical applications of this activity.	5. Follow-up questions analyzing the activity and the practical applications of this activity.	5. Follow-up questions analyzing the activity and the practical applications of this activity.

It should be noted that it is difficult to reach very good agreement between the theoretically suggested values for the student-created resistors and capacitors due to construction irregularity; however, students are able to design, construct, measure and use these basic electrical components.

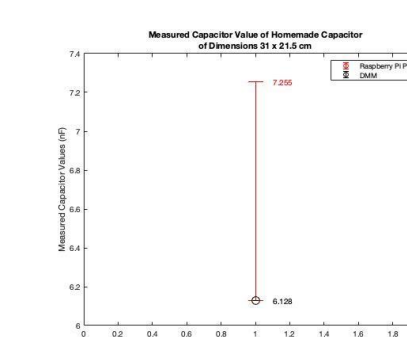
## RESULTS

The following sets of measurements were taken as a part of evaluating the use of the Raspberry Pi Pico as compared to the Arduino Uno.

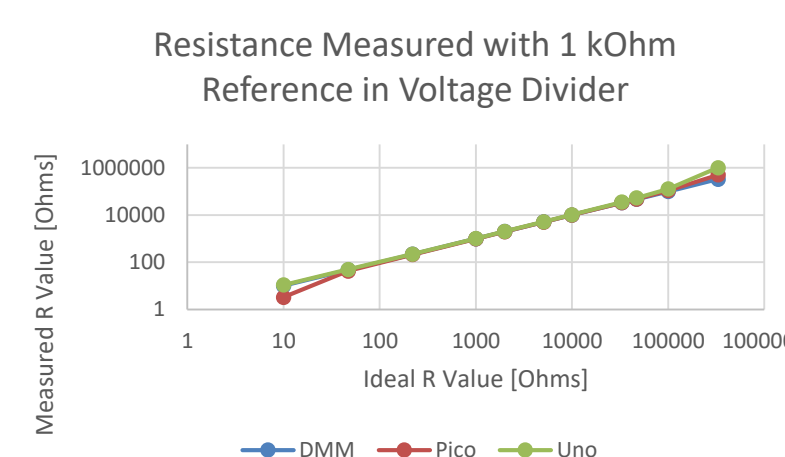
This first set of measurements focuses on using the Raspberry Pi Pico and the Arduino Uno for measuring capacitance by measuring the time constant of an RC circuit with a known resistance. The Raspberry Pi Pico measurements were done using a function written in MicroPython; the Arduino Uno's code was written in Arduino C.



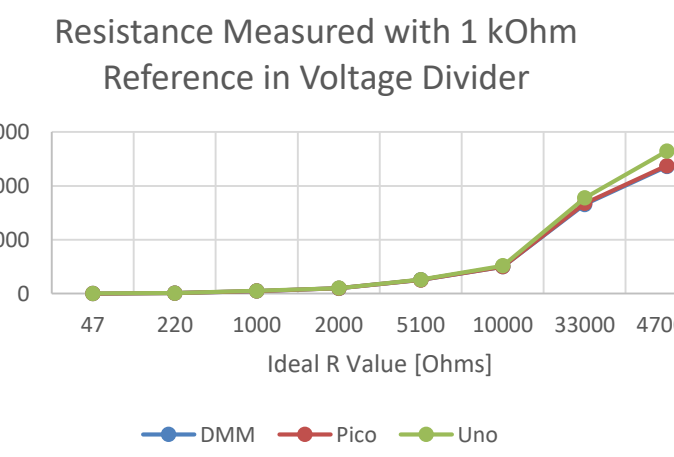
These eight plots show a comparison of the measurement of regular capacitors.



The plot to the right shows measurement result for a measurement of a student-constructed capacitor by the Raspberry Pi Pico and by a multimeter. The Arduino Uno yielded an invalid result for this measurement.



The two plots above show a comparison of standard resistors measured with the Raspberry Pi Pico, the Arduino Uno and a multimeter. The plot to the right shows a comparison of measurements of a student-constructed resistor.



## CONCLUSIONS

The purpose of this project was to evaluate the use of the Raspberry Pi Pico versus the Arduino Uno for laboratory activities for an undergraduate class on engineering electromagnetics. Both microcontrollers can be used to create interesting practical applications of basic electrical components.

As a part of this evaluation, measurements of capacitance and resistance were made of the type which might be made in these lab activities. When measuring standard capacitors, the Raspberry Pi Pico's measurements were closer in value to those of the multimeter than were the measurements made with the Arduino Uno. When measuring the student-constructed capacitor, the Raspberry Pi Pico was able to take a measurement that was reasonably close to that of the microcontroller; the Arduino Uno yielded an invalid result for this measurement. With regards to the resistance measurements, the Arduino Uno had better agreement with the multimeter than the Raspberry Pi Pico; this is likely to the scaling equation used to calculate voltage using the Raspberry Pi Pico [4]. The Raspberry Pi Pico showed better agreement with the multimeter's measurements for mid-range resistance values; this resulted in the Raspberry Pi Pico having better agreement with the multimeter for the student-constructed resistor. Both microcontrollers showed measurements that diverged from the multimeter for very large values.

Based on these measurements and additionally considering that the Raspberry Pi Pico is also a less expensive board than the Arduino Uno, the Raspberry Pi Pico has been selected by the authors for use in future engineering electromagnetics laboratory activities where homemade electrical components are measured and/or used with a microcontroller as a sensor. However, the Arduino Uno continues to be a good option for these types of activities; when used in capacitance lab activities, a touch capacitor activity can be substituted for an RC time constant measurement as a demonstration project.

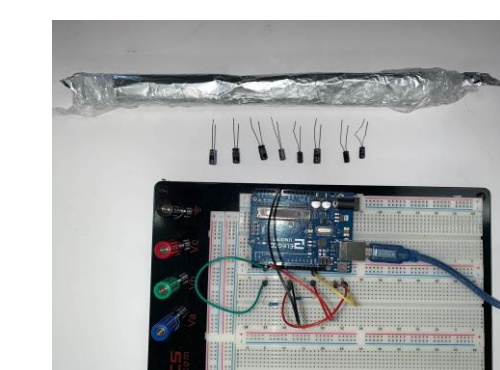


Image 1: Arduino Uno

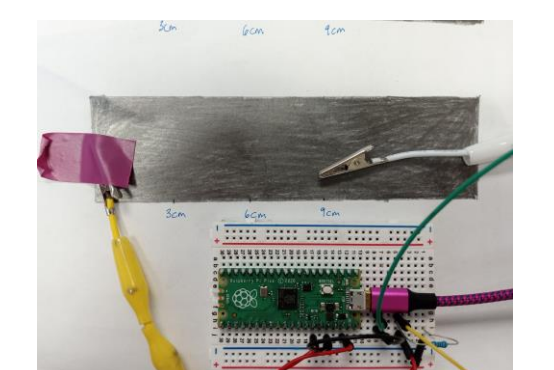


Image 2: Raspberry Pi Pico

## REFERENCES

- [1] Eve Klopf and Aaron Scher, 'Implementation of a Lab Section for Electricity and Magnetism with Transmission Lines', 87th Annual Pacific Northwest Section ASEE Conference, 2019.
- [2] John Keefe, 'Family Projects for smart Objects', Maker Media, San Francisco, California, 2016.
- [3] Manoj Thakur, 'Measurement Made Simple with Arduino', Kindle Edition, 2006.
- [4] Simon Monk, 'Programming the Pico: Learn Coding and Electronics with the Raspberry Pi Pico', MonkMakes Press, 2022.