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The iPad as a virtual oscilloscope for measuring time constants in RC and LR circuits

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Abstract

In a university introductory physics laboratory, the measurement of time constants in RC and LR circuits usually employ a conventional oscilloscope. The standard oscilloscope with its many knobs and switches often intimidate first-time users and can cause anxiety especially among non-physics and non-engineering majors. On the other hand, an iPad has a more familiar, less intimidating and friendlier touch-pad interface. We report our experience in using the iPad as a virtual oscilloscope in an introductory algebra-based physics laboratory course. We used a commercial electronic accessory called Oscium iMSO that turns the iPad into a virtual oscilloscope. Using blind surveys and direct observation, we report student responses to this pedagogical tool.

1. The oscilloscope in the Introductory Physics Labs

The oscilloscope is a powerful tool for analyzing periodic waveforms in a university introductory physics laboratory. It is often first used by second-year physics students in measuring the relaxation time constants in a RC, LR or LRC circuit. For example, a 'square wave' voltage signal from a function generator is typically fed into the student-assembled circuit, while the output voltage or 'response' is measured by the oscilloscope. For an RC circuit, the time dependence of output voltage across the capacitor is measured using the oscilloscope, demonstrating the ability of a capacitor to store or discharge energy through the resistor at an exponential rate with a characteristic time constant

$$\tau = \mathrm{RC} \tag{1}$$

where R is the resistance and C is the capacitance of the circuit (see figure 1).

However, a conventional oscilloscope, with its collection of knobs and switches for selecting voltage and time scales, triggering modes, channel, DC or AC coupling, etc can be overwhelming and intimidating to first-time users and especially students majoring in biology, chemistry, pre-med, and non-science majors (see figure 2). While this situation is often mediated by a section showing how to operate an oscilloscope, student frustration and likely cognitive load can be reduced using a more user-friendly interface. In this article, we report our use of the iPad as a virtual oscilloscope in the measurement of RC and LR circuit time constants and the student response to it.

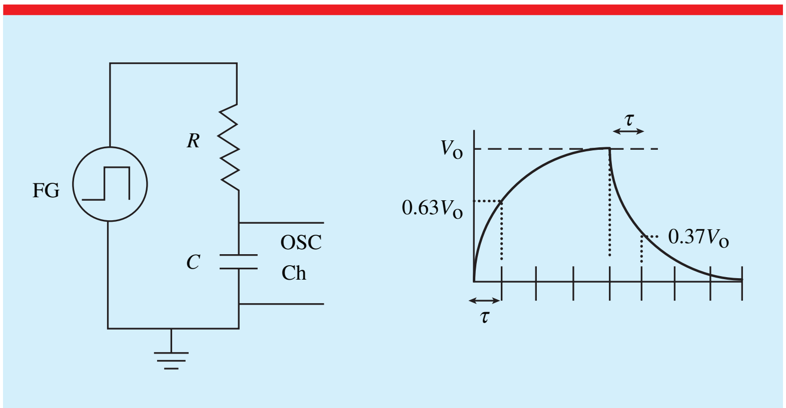

Figure 1. (Left) Schematic of an RC circuit fed excited by a square wave input voltage signal provided by a function generator FG. (Right) Voltage across capacitor showing charging and discharging with relaxation time constant $\tau = \mathrm{RC}$.

2. The iPad as a virtual oscilloscope for measuring time constants in RC and LR circuits

Because of their portability and the range of sensors they carry, smartphones and tablets have become widely used for performing physics experiments in and out of the classroom [1–3]. Using the headphone port on a smartphone used as a portable oscilloscope to receive data from a circuit has previously been reported [4]. In our case, we replaced the conventional oscilloscope with an iPad connected to an electronic accessory called Oscium iMSO that converts the iPad into a 'virtual oscilloscope' (see figure 3) [5]. Specifically, we used the iMSO-104—the single-analog channel version of the iMSO (The results of this study was used by Oscium and helped lead to development of the two-channel version, the iMSO-204) [6]. The iMSO-104 has a 50 MS s^{-1} sampling rate, 5 MHz bandwith and an input for the 1 × /10 × analog probe that came with it. The Oscium software used to read voltage is free and downloadable to the iPad. The software is simple and intuitive, allowing students to zoom in and out of the waveform by pinching the iPad screen and change the analog trigger positions by swiping.

Two sections of a university algebra-based introductory physics laboratory class participated in the study. Twenty-seven students, mostly second-year students majoring in biology, chemistry, pre-med and non-science majors were asked to perform RC and LR circuit time constant experiments, first using the conventional oscilloscope setup and then the iPad virtual oscilloscope. The objective of the experiment was to measure the relaxation times $\tau = \mathrm{RC}$ of the charging process, which is the time it takes for the capacitor to charge through the resistor from zero voltage to 63.2% of the applied DC voltage, or to discharge the capacitor to 36.8% of its initial voltage. Typically, a 10 μF capacitor was used with a 10 kΩ resistor to produce a time constant of 100 ms. Similar experiments were conducted for measuring the time constant

$$\tau = L/R \tag{2}$$

in LR circuits where the inductor was energized with current. Students recorded data using screenshots of the iPAD which they then emailed to their accounts.

3. Student response to the iPad virtual oscilloscope

Students were asked to compare their experiences using the conventional oscilloscope and the iPad using a blind survey. A five-point Likert scale was used on the survey that included the choices Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. About 85% of students surveyed strongly agreed and 15% agreed that the iPad interface was friendlier than the conventional oscilloscope. About 80% strongly agreed and 20% agreed to recommend using the iPad-based experiment for future RC and LR circuit labs. Finally, only 20% thought that not having a second analog

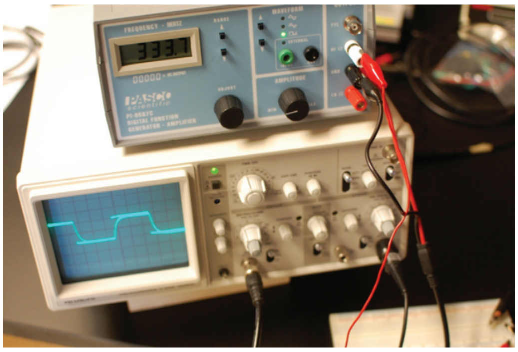

Figure 2. Typical measurement setup of RC time constant measurement using a conventional oscilloscope. The conventional oscilloscope has many knobs and switches that intimidate many first-time users.

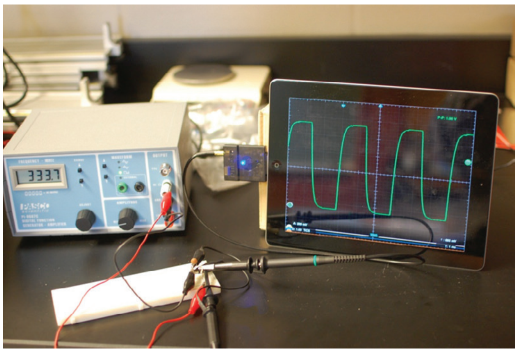

Figure 3. The RC-circuit experiment uses an iPad oscilloscope enabled by the Oscium oscilloscope accessory (shown attached to the iPad). The portable, touch-screen interface of the iPad-Oscium assembly allows the user to zoom in on the signal with the pinch of a finger and change trigger settings by swiping, making it user-friendly to biology, chemistry, premed and non-science majors who will otherwise deal with the many knobs and switches of a conventional oscilloscope.

channel in the iMSO-104 device impacted their measurements. Generally, students appeared to enjoy the lab, and many expressed excitement at the integration of the familiar iPad platform with their lab. Anecdotal student comments included the iPad setup being ‘less complicated’, ‘user-friendly’, ‘intuitive’, having ‘no knobs to turn’ and had a ‘shorter learning curve’. Because their familiarity with the iPad platform, students were eager to tinker with the experiment setup.

4. Summary

As a pedagogical tool, the iPad oscilloscope was readily accepted by students and likely contributed positively to student engagement. Students, especially non-science and non-engineering majors, found that they did not have to worry about the functions of the various knobs of a conventional oscilloscope. With the iPad’s powerful yet minimalist interface, they only had to swipe or pinch the surface to manipulate the data.

Since this data were collected, Oscium has marketed a two analog channel version of their accessory, that can now be used on an Android platform as well. The two-channel iMSO-204 is particularly important in making measurements that display relative phase changes and time delays between input and output signals or between different signals from different parts of the circuit. The device also has mixed signal capabilities, which makes it useful for digital electronics classes. Moreover, there are also less expensive options now available—Sainsmart’s Dual Channel PC Oscilloscope or PicoScope USB oscilloscope [7, 8].

The pedagogical value of using tablet-based oscilloscopes needs further exploration but this study provides a starting point. Due to the mobility and user-friendly interface, the use of virtual oscilloscopes can promote student engaement and reduce student anxiety (and likely cognitive load) in introductory physics circuit experiments.

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References

[1] Monteiro M and Martí A 2016 Using smartphone pressure sensors to measure vertical velocities of elevators, stairways, and drones *Phys. Educ.* **52** 015010

[2] González M, González M, Martin E, Llamas C, Martínez Ó, Vegas J, Herguedas M and Hernández C 2015 Teaching and learning physics with smartphones *J. Cases Inf. Technol.* **17** 31–50

[3] Garriott A, Bush L and Ramos R C 2012 The iPad as a pedagogical tool in an algebra-based introductory physics class *Bull. Am.*

Phys. Soc. **57** 1 (http://meetings.aps.org/link/BAPS.2012.MAR.T37.6)

[4] Forinash K and Wisman R F 2012 Smartphones as portable oscilloscopes for physics labs *Phys. Teach.* **50** 242

[5] Oscium Website www.oscium.com/oscilloscopes/imso204

[6] Lee B 2019 private communication (Oscium President)

[7] Sainsmart Virtual Oscilloscope www.sainsmart.com/products/sainsmart-ds802-dual-channel-virtual-pc-oscilloscope

[8] Pico Tech www.picotech.com/products/oscilloscope

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