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Maybe I Could Use this Again! Two IDEAL Labs Introducing Instrumentation

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Maybe I could use this again! Two IDEAL labs introducing instrumentation

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ABSTRACT
Physics lab students are introduced to custom instrumentation using Arduino-like microcontrollers which have allowed us to implement two labs of particular utility for life-science majors. Constructing a fluid circuit using the sponge-resistor model, flow sensors and an LCD display show the current through each section of pipe. The instrument can simultaneously measure and record 18 voltages, which enables us to record high-frequency “snap shots” of a signal generated on an RC-circuit model of an axon. The IDEAL lab collaboration is developing labs that are open, applied to life, and rigorously quantitative.

DIY INSTRUMENTATION

• Advantages of Arduino(s, Tiva C, and similar microcontrollers
• Economical: ($13 to $20)
• Simple to program (Board: C/C++ Interface Python or Javascript)
• Students may use them in further research

Disadvantages compared to commercial
• Narrow range of measurement values
• Development time

IDEAL LAB PROJECT

I Didn’t Expect Applications to Life! (IDEAL)

• Transferable research, computation, and analysis experience
• Pre-PT students and life-science learn about instrumentation
• Exclusive use of spreadsheet and free software for analysis
• Emphasis on interpreting data with quantitative conclusions

• Life-science and personal health applications

www.southern.edu/physicslab

FLUID CIRCUIT ANALOGY WITH FLOW SENSORS

A COMPLETE ANALOGY

Electrical circuit Fluid circuit
Voltage Pressure/Column height
Electron current Fluid current
Resistance Sponge length

INSTRUMENT

We use a Tiva C Launchpad from TI ($13)
Liquid flow meter ($10 from adafruit)
Measuring current: as simple as counting pulses?
Has both analog and digital inputs

Simple connectivity between sensor and board

REFERENCES

The sponge resistor model was developed in [1]
Adding flow sensors and "pressure sensors" allows the study of Kirchoff’s rules with more complex circuits

ENHANCED RESOLUTION OF THE AXON RC CIRCUIT MODEL

AXON CIRCUIT MODEL

Passive conduction, or “able model”
Inside of axon conducts with resistance
Axon membrane has resistance and capacitance
“Depolarized” axon has higher potential inside

R Resistance        FASTER?
Doesn’t resistance “slow everything down”?
Mylenation of axons increases membrane resistance $R_{\text{mem}}$
Doesn’t resistance “slow everything down”?
We adapt lab procedure from Ref. [3], adding the ability to
1. Make 1-20 rapid, simultaneous voltage measurements
2. Directly measure position vs time for propagating signal
3. Record or animate signal with 20-point resolution

Mylenation doesn’t really change time constant $v$ in $v(t)=V_0 e^{-t/\tau}$
• Where $\tau = R_{\text{tiss}} C_{\text{tiss}}$
• $R_{\text{tiss}}$ increases, but $C_{\text{tiss}}$ decreases (depolarizes in series)
• We record voltage vs time for a resistor and capacitor in parallel
• Trigger start; does not record noise

Myleneation increases length constant $\lambda$ in $v(x)=V_0 e^{-x/\lambda}$
• where $\lambda = \sqrt{R_{\text{tiss}} C_{\text{tiss}}}$

Therefore increasing resistance increases the length constant.

RESISTANCE ➞ FASTER?

REFERENCES

The RC circuit model of axon conduction has been used by several authors
[2-4]. We add the ability to make many rapid, simultaneous measurements of voltage.
[2] Project NEXUS UMCP (K. Moore, J. Giannini and W. Lost, UMBC), which was adapted from C. Crouch (Swarthmore College), which was adapted from Eric Anderson and Lib Cul, UMBC.
[4] Robinson, et. al., J. Vis. Exp. (47); and references therein

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