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Student Understanding of Filters in Analog Electronics Lab Courses

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Physics Education Research (PER) has helped to identify many student difficulties with specific concepts in introductory physics. Many (introductory) engineering courses cover topics in which basic physics principles are applied or extended. It therefore seems plausible that methods from PER could be applied to investigate student understanding in these engineering courses. Analog electronics is such an example, which uses and extends principles typically covered in an introductory Electricity and Magnetism course. Although there is extensive research on conceptual difficulties with basic electricity, most of the literature concentrates on DC circuits and, only recently, on AC circuits, while very little is known about student understanding of more advanced electronics concepts. In this paper, we present preliminary results on student difficulties with RC filters, in which we expect some of the misconceptions in circuits to be also relevant. The main topics we considered relevant were current and voltage, resistance and sequentional reasoning, where students fail to see the circuit as one entity. The AC-problems we deemed interesting were the difficulties with phase, frequency dependence of impedances and the physical meaning behind the mathematical representation.

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We interviewed 4 undergraduate engineering students about their understanding of 1st order RC filters. Questions probed general understanding in 4 main categories. The first part was about the concept of a filter, to see if students understood its use. A second part probed the understanding of the physical working principle behind a basic filter. The third part went deeper into the operational functioning of the device, asking the students to draw current and voltage graphs. To conclude, we asked the students some design-like questions. All interviews were audio- and videotaped and these recordings and student notes were used for later analysis, aimed at the reconstruction of students' train of thought.

Many misconceptions described in the literature also appeared during our interviews: we saw examples of current based reasoning, difficulties with potential and difficulties with conceptual understanding of mathematical expressions.

On the other hand we also encountered some new difficulties. Only two students could draw a correct Bode plot, and only one seemed to have fully understood its meaning and use. As the main assignment of the laboratory was exactly to simulate and measure a Bode plot, we consider this an important finding.

Only one student took the phase shift between the input and the output voltage into account when asked to draw the output voltage in the suppressed part of the spectrum. This also is rather surprising, as in the lab session there was a specific assignment to simulate as well as to measure the phase-characteristic based on a comparison of the input and the output voltage.

Finally, only one student could make a sketch of a signal with two frequency components and could also show what happened after the signal passed through a filter. As this is the core use of a filter, we consider this a very important topic.

Several difficulties students have with AC- and DC-circuits seem to persist in more advanced circuits. Moreover, we also found indications of new difficulties. Students don't seem to be able to fully understand what a "signal" physically is. They also seem to lack a functional understanding of a frequency-based representation of a filter.

Because these interviews have proven to be an effective way of probing student understanding, we intend to conduct more interviews at different institutions during the next academic year. We hope to get a more complete overview of general student difficulties with basic electronics. ■