Teaching Problem Solving Techniques in a Circuits Analysis Course

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Abstract

The ECET program at New Jersey Institute of Technology is an upper division program, accepting students from a variety of community colleges. One of the first courses these students take is ECET 303, which is a circuits measurements course. While the course covers standard measurement techniques and circuit theory, the author found that student skills in areas such as problem solving needed to be enhanced.

Rather than create problems that students could solve, the author incorporated various aspects of problem solving approaches for laboratory-based course in the lecture part of this course. This paper describes the multi-step approach in dealing with creative problem solving techniques for EET laboratory based courses that was presented to these students. Student experiences with these concepts and laboratories that incorporate these steps are also discussed.

Introduction

Too often, the concept of problem solving skills is confused with the ability of students to solve problems. How a student approaches the problem, whether it is a calculus assignment or a lab experiment, is more important than just finding the correct solution. Understanding these skills can aid the student in a variety of other courses.

When the author first taught this course, it was apparent that the problem solving skills of the students were very poor. They performed the experiments with no understanding of what they were doing, nor had any methodology to solve the problem. They basically built a circuit, took data, and wrote a report.

In another ECET course, the author developed a ten-step approach for solving computer application problems in an introductory microprocessor course[1]. A similar approach for laboratory-based courses was developed, and this paper will address a six-phase approach that was used in an upper division circuit analysis course.

The students were divided into groups of three, and were expected to work out the problem solving concepts among the group. This six-phase approach can be used in a variety of courses, and by starting these engineering technology transfer students early in their upper division curriculum with this approach, the hope is that they will continue to use this methodology in other courses.

Step 1 - Understand the Problem statement

The first step in this multi-step problem solving approach is to understand the problem statement. If a student does not know what needs to be solved, it is impossible for that student to complete the assignment, whether it is a homework assignment or a laboratory. However, when the students were asked what they were trying to solve, most student groups had a difficult time stating the problem. This is usually the most difficult part of problem solving – developing the ability to recognize and define the problem precisely.[2]

While laboratories might have a "problem statement" already listed, the expectation for each student was to express the problem statement in his/her own words. The laboratory problem statement for this course was purposely defined in very general terms, since as part of a pre-lab assignment, each group must define what is really required.

Problem statements should be broken down into two parts – a main problem statement and subtopics. The main problem statement should consist of one or two sentences describing what needs to be done. The subtopics would list the top-level steps that would be required to achieve the main problem statement. The importance of this step is to get the student group to focus on the main problem, and not be sidetracked with minor steps.

Step 2 - Define the variables

In any technical problem, there will always be inputs and outputs. For a circuit analysis laboratory course, what is in between these elements is usually the circuit or system under test. The inputs may include external signals from a transducer or external signals for signal generators. Students were instructed that inputs could also include power supply voltages. The definition of these inputs was based on both the units and the type of equipment that could generate these inputs.

A similar statement exists for the outputs. Once the outputs are defined, then the method of observing and recording these parameters can be defined.

Therefore, to adequately solve a problem, the inputs and outputs must be identified, their ranges specified, and their respective units known. Also, there should be a determination as to whether the outputs are a result of calculations that will need to be made. The best way to understand what are the inputs and outputs would be to draw a box, or series of interrelated boxes, that show lines from the left as inputs and lines to the right as outputs. The outputs can then be labeled as to whether they are observable using a particular device, or calculated. It is important to understand that this diagram concept does not include drawing a schematic. The focus is on a system's approach, not a circuits approach. However, for this course, the box represented a specific circuit.

For example, one of the laboratories in this course deals with Bode plots. After reading about how a Bode plot can be developed, an input-output diagram might look like Figure 1.

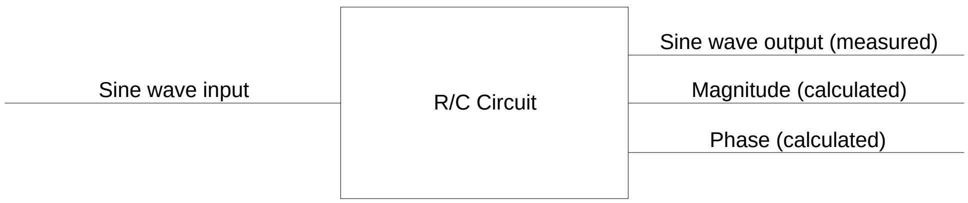

Figure 1. Input/Output diagram of a Bode plot

Note that there is one input, and three outputs. These inputs/outputs are defined as to whether they are measured (not labeled) or calculated (labeled). This type of drawing can give the student an overview of what is expected in the laboratory, and is required of each group before they continue. This step is important, since students like to "plunge" into an experiment, rather than think about it. This step is not very long, but will help students complete the experiment.

Once the diagram is complete, the groups now need to define the ranges and their respective units. The range would be based on a pre-lab theory, and is defined in the next section. However, the type of theoretical analysis that would be required to determine the range should be listed in this step. For the diagram in figure 1, a typical chart would look like the Table 1.

Input/Output	**Units**	**Determination of range**	**Equipment needed**
Sine wave input	Amplitude - volts Frequency - Hz	Calculate based on break frequency	Oscilloscope
Sine wave output	Amplitude - volts Frequency - Hz	Calculation may be frequency dependent	Oscilloscope
Magnitude	Unitless	Bode analysis	Oscilloscope – either digital display or read from screen
Phase	Radians	Bode analysis	Oscilloscope – either digital display or read from screen

Table 1 Illustration of chart for Bode plot experiment

Although this table appears simple, it helps focus the student on what is needed for the experiment, both from a theoretical viewpoint as well as from equipment requirements. Students understand that they will need to understand the theory to calculate two of the three outputs, and will need to understand the theory to determine if the measured sinusoidal output is correct. Since most of the laboratories have digital oscilloscopes, students realized that they must understand some of the digital readout capabilities, before they performed the experiment.

Step 3 - Develop a Hypothesis

Before theoretical results are developed, students are expected to develop a hypothesis, or expectation, as to what they would expect to find. This is done the week before the actual experiment, prior to any pre-lab analysis. This hypothesis stage is not intended to have the students analyze what they expect will happen, but basically come up with a best guess as to what will be expected.

Part of the reason for this step is to also encourage students to develop a general concept of what should occur, rather than being focused on getting a specific answer. The support for this hypothesis must be in the form of words, not equations. This directs the students away from trying to obtain a precise answer.

For the Bode plot example, students are given general information as to how the impedance of both a capacitor and inductor might change, without any specific formulas. The students are expected to just look at the extreme conditions (either very low frequencies or very high frequencies), and come up with a hypothesis as to what would be expected for this circuit.

This sometimes is the most difficult step, since students have been taught in previous classes to get the formula, plug in the data, and obtain the results. It took three lab sessions before students felt comfortable not obtaining an exact solution first.

Step 4 - Pre-lab Analysis

Once a hypothesis has been formulated, and prior to starting the laboratory, the student groups review the theory behind the experiment. This review helps them understand the equations needed to solve the problem statement and the resources needed for the laboratory, which could include device specification sheets. There are two methods used to perform the pre-lab analysis in this course – standard calculations and simulation using PSpice.

By performing these pre-lab calculations, the groups could understand what are the ranges of data, for both input and outputs. During the experimental process, errors from such conditions as wiring errors or misreading instrumentation can occur. However, if the student groups first perform these calculations, they can achieve an understanding of what range of data should be expected. Therefore, errors will become apparent.

PSpice simulation is a method that helps students visualize the input and outputs that should occur in a properly designed experiment. This application also enables students to easily modify an experiment, and determine both the potential for problems as well as the results with varied tolerances for the components.

Each of the two methods has their own advantages. The theoretical calculations allow students to work with "pencil and paper", and break the reliance on computer analysis. It is important for students to use their creative mind. PSpice helps with the visualization of the proper input/output waveforms. In both cases, students begin the actual experiment with a firm understanding of the level and appearance of the inputs and outputs. Therefore, errors that normally occur during the experimental process are apparent.

Step 5 - Anticipate potential problems

Prior to performing the experiment, students are expected to create a sheet with a list of potential problems that could occur during the experiment. Initially, this also was a difficult task for many of the students. However, after a few experiments, students began to understand where many of the potential problems in experimentation could occur. Eventually, this step turned out to be a checklist of what not to do, and the number of errors in experiments was greatly reduced as compared to similar experiments in prior semesters.

PSpice can be used effectively in this area, and students were encouraged to develop incomplete circuits, and understand the output response from these types of circuits. The instructor prior to the laboratory discussed other potential measurement problems, such as scope calibration and AC coupling.

Step 6 - Development of Procedures

Several of the laboratory experiments were designed to be general in nature, and specific steps were not defined. At this point, students had an understanding of the inputs/outputs, a general expectation of the results, and understanding of the theoretical and simulated circuit, and potential problems.

Prior to starting these labs, students were required to develop their own procedures on how they would complete the laboratory. The first two laboratory assignments were well structured, so students were able to view proper procedure outlines. For the first unstructured laboratory, a classroom discussion covered the basics behind understanding how to develop these procedures, and then the instructor served as a moderator for the entire class. The entire class took part in developing the procedures for the next lab. Each student group was responsible for subsequent unstructured labs.

Student Assessment

At first, there was resistance by a number of students, who felt that all they wanted to do was "complete the lab". During the term, the instructor tried to develop a "champion" in each group, who would support this procedure. Most groups had at least one champion.

Eventually, those students who offered some resistance found that, contrary to initial beliefs, the laboratory assignments actually took less time to complete, if the procedures were followed. Some students told the instructor that they applied this problem solving approach to other lab based courses.

Conclusion

A six- step method of problem solving for laboratory based classes was presented. Students were initially resistant to completing all the steps prior to performing the experiment. However, student assessment, at the end of the semester, was very favorable to the method. It is hoped that these students in future classes will use this problem solving approach.

Bibliography

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