Handbook for Teaching "Circuit Theory"

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Revision date: May 2001

This Handbook is designed for faculty, lecturers, instructors, and teaching assistants as a guide to teach a second course in Circuit Theory. The document is organized based on the topics to be taught, not based on any specific textbook or lesson structure. After the introductory sections listing the topic coverage and suggested textbooks, the guide for each topic is presented in three major classifications:

1. Overall teaching notes for this specific topic.
2. Emphasis: key issues that need to be emphasized in teaching this topic, suggestions on techniques to teach a specific idea in the topic, possible examples to use, etc.
3. Once Over Lightly: topics that only need to be covered minimally since they are not central to the course or are covered in previous courses or are to be covered in subsequent courses. In most cases, the instructor might decide to skip these topics if time runs out in the course.

1. Course contents

1.1 Prerequisites

1.1.1 Skills and topics

This course assumes these prerequisite skills and knowledge from previous courses, typically Mathematics courses and one introductory circuit course in electrical engineering. Students should already know how to:

- Use Kirchhoff's current and voltage laws (KCL and KVL).
- Apply Ohm's law.
- Apply efficient circuit theorems to speed up analysis of circuits containing parallel or series combinations of elements, voltage dividers, and current dividers.
- Use Thevenin and Norton equivalent circuits to simplify the analysis process.
- Work with controlled voltage and current sources.
- Use linearity and superposition. write current and voltage equations resulting from node analysis and mesh (or loop) analysis.
- Analyze circuits containing capacitors and inductors, in addition to resistors.
- Analyze first-order and second-order circuits in the time domain. Integrate and differentiate common functions.
- Solve first and second order linear differential equations.
- Manipulate complex numbers (add, subtract, multiply, divide, complex conjugate, absolute value, phase (argument), etc.).

- Manipulate vectors and matrices up to dimension 3 or 4.

1.1.2 Background survey

To evaluate students' background in prerequisite courses and topics:

- Conduct a background survey. An example of a web-based background survey is enclosed. Make sure there is a processing script to collect and analyze the survey results. At the University of Washington, the survey tools and scripts are provided by Catalyst.
- Assign the first homework based on prerequisite skills and topics.

Use background survey results:

- To set the pace of the course.
- To remind students to review topics they have forgotten. Do not use more than one hour of lecture to review prerequisites!
- To compare with end-of-quarter survey results to check on students' progress and learning outcomes.

1.2 Learning outcomes

At the end of this course, students will be able to:

- Analyze a circuit given sinusoidal inputs.
- Compute average power consumed or supplied by a circuit.
- Design simple circuits for maximum power transfer to a load.
- Apply Laplace transform techniques to simplify the analysis of complex circuits.
- Analyze circuits in the frequency domain.
- Use several alternative techniques in time-domain and frequency-domain to analyze the same circuit.
- Design simple circuits from time-domain and frequency-domain specifications.
- Use two-port models and parameters to simplify the analysis of large circuits.
- Use SPICE as a computer tool to verify a design, and to confirm time-domain and frequency-domain analysis results.
- Use basic laboratory instruments: oscilloscope, power supply, function generator, and multimeter.
- Measure basic signal parameters: amplitude, frequency, etc.
- Measure and compute basic circuit parameters from measurements.

These objectives are not necessarily listed in the order in which they will be accomplished during the course.

1.3 Topic coverage

The topics to be covered to meet the learning objectives above are:

- Sinusoidal excitation (15% of the course): how to analyze and design simple circuits (containing R, L, C, and opamps) when the signals are sinusoidal.
- Average power and maximum power delivery (5% of the course): how to compute average power dissipated in a load and how design a circuit to maximize power delivery to the load.
- Laplace transformation techniques (30% of the course): techniques to work with simple circuits when the signals are more complicated than a step or a sinusoidal signal.
- Transfer functions (25% of the course): techniques to analyze and design simple circuits to distinguish signal from noise or to select a specific signal.
- Frequency response and simple filters (25% of the course): applications of transfer function techniques to a specific class of circuits.
- Simulation of circuits using SPICE simulator, with some design examples: how to use computer-aided simulation tool to verify analysis and design.
- Basic EE laboratory, components and instrumentation: how to design, build, and test simple circuits to verify concepts from lectures and to validate simulation results.

Some of these topics are intricately linked (e.g. transfer functions and frequency response) and maybe covered as one single topic depending on the instructor's preference.

These topics should be covered in a 10-week quarter. If the course is taught in a semester system (16 weeks), more topics need to be added. Instructors might examine the faculty handbooks for our other courses to find materials for additional topics if necessary.

1.4 Suggested textbooks

There are numerous textbooks for this course. A representative non-exhaustive list includes:

- J.W. Nilsson and S.A. Riedel. *Electric Circuits*. Prentice Hall.
- R.C. Dorf and J.A. Svoboda. *Introduction to Electric Circuits*. John Wiley & Sons.
- C.K. Alexander and M.N.O. Sadiku. *Fundamentals of Electric Circuits*. McGraw-Hill.

This Handbook does not recommend any specific text and may be used with any text containing materials for the topics in section 1.3 above. The topics map onto different chapters and sections in a specific textbook, and sometimes the coverage of materials might not be in the order of the topics listed above. The instructor has full flexibility in changing the order of topic coverage.

This course is taught on-site at the University of Washington, Department of Electrical Engineering all 3 quarters of the academic year. The textbook for a given year is posted on the department web site and the specific chapters for this textbook are listed in the homepage of the course (EE 233). The department changes texts almost every year, starting with fall quarter.

1.5 Applicable ABET outcomes

With respect to ABET EC 2000 criteria, this course meets the following outcomes:

- Outcome 3 (a) Apply math, science and engineering knowledge.
- Outcome 3 (b) Conduct experiments, as well as to analyze and interpret data.
- Outcome 3 (c) Design simple RC and opamp circuits to meet desired needs.

- Outcome 3 (d) Function and contribute various individual skills in laboratory teams.
- Outcome 3 (e) Identify, formulate, and solve basic RC and opamp circuit problems.
- Outcome 3 (g) Communicate effectively via written laboratory reports.
- Outcome 3 (k) Use the techniques, skills, and modern engineering tools.

2. General teaching notes

The course, like to other fundamental electrical engineering courses, contains significant mathematical techniques. The general challenges are:

- To teach students to analyze and design circuits, not to make the course appear as a continuation of their abstract mathematical study. The key teaching method is to use circuits to motivate the mathematical techniques, and to choose real-life circuit examples familiar to the students. These circuits are covered as part of the motivating experiments and some are also built as the verifying experiments in the laboratory.
- To show students how this course is different from a course in introductory signal analysis, which also covers the Laplace transform. The emphasis on circuit analysis and design for real applications is used to illustrate the differences.
- To make sure students practice the process of analysis and design, which is the only way to learn the topics and build skills. A good quotation to use is by Thomas Edison: “Genius is 1% inspiration and 99% perspiration.”
- To demonstrate various solution techniques as options and emphasize that given a circuit or a design problem, there are many solutions and their trade-offs must be considered for specific applications. It is important to avoid teaching or telling students that only one method is the “best” in solving a problem.
- To force the students to reflect over their own solution techniques and compare with other techniques so they improve their skills while learning to make judgement. Students tend to move on to a new problem after they find the answer to one problem; but they need to go over the process to arrive at the answer to evaluate the problem-solving technique and to abstract the skills from doing that specific problem.

It is a good idea to stick close to the topics, exercises and materials in the textbook for these reasons:

- Students can use the textbook as a guide to practice in-chapter exercises, whose solutions are provided in full.
- Students can work on end-of-chapter problems with provided solutions (sometimes wrong!)
- Students can rely on the textbook as a secure source of materials. With some exceptions (laboratory experiments, outline teaching slides, and this handbook), all materials for this course come from the textbook.
- Students learn how to read a textbook (developing skills in reading technical materials) and when to trust or not to trust the textbook (developing healthy skepticism and confidence in their own ability).

3. Sinusoidal analysis and design

3.1 Overall teaching notes

1. Use the slides file sine.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. State clearly the goals in this topic are both to analyze (to understand how circuits work) and to design (to create circuits for specific tasks) circuits. Students are expected to develop both analysis and design skills. Explain to them the differences between analysis and design.
3. Some students are better with node analysis (using KCL), some better with mesh analysis (using KVL). Let them use their preferred methods as long as they write correct equations. Emphasize that they should know both methods and should be able to mix and match them in problem solving.
4. Make students practice the analysis of small circuits (the network KVL and KCL are straightforward to write) as much as possible to build skills. These practice exercises are from the textbook, with complete step-by-step solutions so students can check their own works.

3.2 Emphasis

1. Motivate the topic by these concepts: music, speech, sound, electric power used at home. The fundamental signal is sinusoidal.
2. Discuss examples of real-life circuits to process sinusoidal signals: CD stereo circuits, computer-generated speech circuits, web-based audio playback, speakers, telephones, etc.
3. Assign students to do research on the characteristics of specific musical instruments and speakers. This is a motivating experiment for this topic.
4. Nifty way to explain "phase" of a sinusoidal signal. Using music as example, students usually understand the physical meaning of "frequency" (how high a musical note is, a soprano voice, etc.) and "amplitude" (loud sound versus soft sound) but they do not understand the physical meaning of "phase" well. A good example to use is stereo-surround-sound at home or in movie theaters: the surround-sound effect is created by sending signals to various speakers with different "time delays," and time delay is an equivalent description of phase.
5. In the analysis process, the key parameters to evaluate, given a circuit and an input sinusoidal signal, are the amplitude and phase of the output of interest. The simple circuits (R, L, C, and opamps) do not change the frequency of the input signal, so the frequency of the output signal is known in advance. This is also the central tenet of the phasor concept (see Method 3 below): the phasor representation explicitly shows the amplitude and phase of a signal, leaving the frequency as an implicit parameter.
6. Teach the analysis of circuits with sinusoidal signals by demonstrating at least three methods to solve circuit problems after they have applied KCL / KVL to write the differential equation (DE) with one unknown (usually the output of the circuit). For each method, use one example circuit and show the method step-by-step so students learn the analysis process in a systematic manner.

- Method 1: look up Math handbook or use Math software (e.g. Maple or Mathematica) to find the solution. Advantage: easy, general technique for all circuit analysis. Disadvantages: cannot be performed in a job interview or design review with customers, Math Handbook might not have the answer for this specific DE.
- Method 2: use techniques learned in Math courses to solve this DE by assuming a known solution form and evaluating the unknown amplitude and phase. They are equivalent and can be transformed into each other. Advantage: plug-and-chug technique, general technique for sinusoidal circuit analysis. Disadvantages: still need to work with DE, technique gets messy with medium-sized or large circuits (set of simultaneous trigonometric equations to be solved).
- Method 3: use complex numbers and phasors to solve problems. Emphasize the fact that the analysis can be performed without any DE at all. Sell this method based on this avoidance since students are pretty sick of DE in Math courses. Advantages: no DE, techniques suitable for medium-sized or large circuits (set of simultaneous algebraic equations can be solved using matrix techniques). Disadvantage: technique works only for sinusoidal signals.

7. Item 6 is the core of this topic: systematic procedures to analyze circuits with sinusoidal signals, and the emphasis is on Method 3. Emphasize problem-solving skills as much as possible, making it clear that math is used only as a tool, not the central idea of this topic.
8. As students develop analysis skills, use larger circuits and demonstrate techniques to work with large circuits:
   - Combine parallel or series elements (prerequisite topics) to simplify the circuit before the analysis begins.
   - Use Norton equivalent or Thevenin equivalent (prerequisite topics) to simplify the circuit before the analysis begins.
   - Use superposition to analyze circuits with 2 or more input signals (apply one signal at a time). This topic is also from prerequisite courses.
9. Teach how to design simple circuits with sinusoidal signals. Keep in mind that it is very likely that students have not been taught how to design up to this point in their previous courses. Go over step-by-step the simplest design process (slide “Analysis vs. Design,” row labeled “Design (easy)”) where the input signal, the circuit diagram, and the required output signal are given, and the only components to be designed are the passive components. “Design” in this case means “select component values” to meet the given specifications. Use the design example in the slides to illustrate this process.
10. Emphasize these critical points in circuit design and compare them with circuit analysis:
    - Design process is just as systematic as analysis process.
    - Design usually has many possible solutions (many component values make a design work), while analysis has only one possible answer. The components must be selected from existing catalogs. Component catalogs are available from many sources: your school’s electronic store, DigiKey, the local RadioShack stores, and many web-based electronic stores.

- Design might not have any solution at all if the specifications are not realistic. In this case, there are no components in catalogs that can be used to build the circuit. Demonstrate one example of this type of design requirements.

3.3 Once Over Lightly

1. The graphical representation of a phasor is not too critical. Some students like it; some do not. The graphical representation generally does not add much understanding. The step-by-step analysis process is much more important.
2. Skip all materials not related to sinusoidal signals. Some textbooks might contain these materials in this topic, probably to confuse the students.
3. Do not cover the procedure to compute the RMS value of signals (to be covered in later topics). No need to detract from the focus on analysis and design.
4. Some textbooks use phrases like "phasor transform" or "inverse phasor transform." Ignore these terms. They are not conventional. The key is to use phasors as a problem-solving method.
5. Do not prove KVL and KCL in the phasor form. State that these two laws work in the phasor form just like in time domain, which students learned from previous courses. The proofs are strictly mathematical and detract from the focus on circuit analysis and design.
6. Teach series and parallel combinations of element impedances and / or admittances. Skip other combinations such as delta-wye.
7. Skip all transformer materials.

4. Average power

4.1 Overall teaching notes

1. Use the slides file power.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. State clearly the goals in this topic are to provide methods to analyze and design circuits to deliver power from a source signal to the load.
3. Make students practice the process of working with power as much as possible to build skills. These practice exercises are from the textbook, with complete step-by-step solutions so students can check their own works.

4.2 Emphasis

1. Motivate the topic by these concepts: how much students pay per month for power in their apartments, power delivered from the stereo receiver to the speakers, etc.
2. Discuss examples of real-life circuits to optimize power delivery: stereo receiver driving many speakers, reduction of power wasted in transmission of power over long distance, etc.
3. Assign students to do research on the characteristics of speaker impedances and how they relate to power.
4. Demonstrate alternative methods to compute average power in case of sinusoidal signals (plug in formulas, compute from instantaneous power definition, use RMS formula, etc.)

5. Emphasize that the RMS formula is more general and can apply for any signal type, not just sinusoidal.
6. Demonstrate at least one design example to maximize power delivery to the load, using exercises or problems in the textbook.
7. Demonstrate also a case where the design fails (e.g. a circuit cannot deliver a specified power to the load) since the specifications are not realistic.

4.3 Once Over Lightly

1. Skip all materials related to reactive power, 3-phase power (except as motivating examples), complex power, etc.

5. Laplace transform technique

5.1 Overall teaching notes

1. Use the slides file laplace.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. State clearly the goals in this topic are to provide methods to analyze and understand circuits when the input signal has more complicated form (e.g. an FM signal from a radio station, a speech signal, etc.).
3. Many textbooks go from sinusoidal analysis directly into transfer functions and filters before Laplace transform. The instructor may choose his/her order to teach these topics.
4. The greatest challenge in teaching this topic is to relate it to electrical engineering. Textbook materials are almost strictly mathematics. The key is to use the Laplace transform and inverse transform for realistic engineering signals or functions, especially signals that appear frequently in circuit analysis and design.
5. After proving a theorem, try to do one circuit example and explain what the theorem means in that circuit.
6. Check the theorem proofs from the textbook, especially those related to initial conditions and differentiation, where the lower limit may not be handled well. If some proofs are mathematically sloppy, explain the sloppiness to students and provide better proofs.
7. After a few exercises where students practice the integral definition to find the transform, let them use the tables and apply transform theorems. They need to learn how to look things up and apply theorems properly.
8. Make students practice the process of finding transform and inverse transform of signals as much as possible to build skills. These practice exercises are from the textbook, with complete step-by-step solutions so students can check their own works.

5.2 Emphasis

1. Motivate the use of transforms by asking students how to analyze a circuit where the input signal is not a DC signal, a step signal, or a sinusoidal signal. Show them a signal from their favorite FM radio station as an example. They could analyze the circuits using differential

equations but the process is very difficult and tedious (maybe let them do this for a small circuit). Use this to justify the Laplace transform as a better way to analyze these circuits.

2. Explain clearly the process of employing the Laplace transform in circuit analysis (see the slides) before jumping into all the mathematical equations.
3. Explain clearly the lower limit of 0- for the one-sided transform: why it is not 0 or 0+. Check the textbook arguments and use them consistently.
4. Explain clearly the difference between this one-sided transform and the two-sided transform used in signal analysis. Use the textbook materials.
5. Try to relate the impulse function to something more physical to help students understand. For example, the short intense pain caused by hitting your knee or elbow against a sharp corner is similar to an impulse.
6. The best way to remind them about partial fraction expansion in inverse transform is to do exercises. For the multiple root case, use the repeat order of 2 to explain how the expansion works. Assign exercises with repeat order of 2 and 3 (at the most).
7. Transform simple circuit components without and with initial conditions so that you can use circuits to demonstrate how the Laplace transform works in solving problems. Emphasize the advantage of automatic inclusion of initial circuit conditions in the Laplace transform technique. Students previously had to solve for the output signal first then apply the initial conditions. The Laplace transform technique does it in one single process.
8. Teach the techniques to deal with large circuits (combination of elements, Thevenin’s and Norton’s equivalents, and superposition) and remind students that they are similar to the same techniques covered in section 3. The key difference is that the Laplace techniques apply to any type of signals, not just sinusoidal.
9. Try to assign homeworks and exercises related to signals used in real circuits, not just mathematical manipulations.
10. Use the Laplace transform in circuit design. Pick one or two exercises from the text and apply the design procedure taught in section 3, but this time use the Laplace transform to derive the equations relating the input to the output.

5.3 Once Over Lightly

1. Skip all existence and uniqueness proofs of the transform or inverse transform. Real-life signals in circuits do have transforms and they are unique.
2. Do not try to use the integral definition for the inverse transform. Explain that for circuits, the partial fraction expansion process is sufficient to find the inverse transform.
3. Skip all materials related to mutual inductance.
4. Do not prove KCL and KVL in the s-domain. Just state that these laws still work, similar to the time domain.
5. Skip all materials related to mutual inductance.
6. Many textbooks show circuits with impulsive signals, which do not exist in real life. It is recommended that realistic signals and circuits be used in teaching this course.

6. Transfer functions: circuit analysis with Laplace transform

6.1 Overall teaching notes

1. Use the slides file transfer.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. State clearly the goals in this topic are to provide methods to analyze circuits using the Laplace transform and compare these methods with time-domain methods. These methods are complementary and students should practice all of them.
3. Design with transfer function will be covered as part of the frequency response topic.
4. It might be somewhat difficult to totally decouple this topic with the topic on frequency response (see section 7). The instructor might want to mix materials between these two topics.
5. Make students practice the analysis of circuits using transform technique as much as possible to build skills. These practice exercises are from the textbook, with complete step-by-step solutions so students can check their own works.

6.2 Emphasis

1. Motivate the use of transfer functions by asking students to analyze the same circuit with 3 or 4 different input signals. This is very tedious.
2. Introduce the transfer function H(s) and show how it can be used in circuit analysis. Once H(s) is derived for a circuit, there is no need to re-analyze the same circuit for different input signals. The outputs can be computed quickly based on H(s).
3. Introduce the convolution process as part of the analysis of a circuit. Do the direct convolution integral only once or twice at most. For circuits, the use of Vo(s) = H(s)Vi(s) is more common to solve for the output signal Vo(t).
4. Show how the Laplace transform technique is applicable to all types of signals while the techniques in section 3 apply only to sinusoidal signals.
5. Key note: H(s) does not include initial conditions. If a circuit has to be solved with initial conditions, use the standard Laplace method instead of plugging in values in H(s).
6. Demonstrate the technique by using many short examples, showing clearly time-domain waveforms at both the input and the output of the circuits. Explain the physical operations of the circuits. Students need to be taught to “feel” how a circuit works instead of blindly relying on math equations.
7. Demonstrate how to use the transfer function in circuit design by one or two short examples. Derive H(s) from the circuit and use it and the specifications to select component values.

6.3 Once Over Lightly

1. It is up to the instructor to decide how much time to devote to the graphic process of convolution. No more than one lecture session (1 hour) is recommended.
2. Skip all advanced explanations of convolution based on weighting functions.
3. Skip all materials on filters for the time being. See more below in the topic on simple filters.

4. Do not prove KCL and KVL in the s-domain. Just state that these laws still work, similar to the time domain.

7. Frequency response

7.1 Overall teaching notes

1. Use the slides file freqresp.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. Relate the time-domain output signals to the frequency-domain plots of H(s) as clearly as possible.
3. Make students practice the Bode amplitude plot technique as much as possible to build skills. These practice exercises are from the textbook, with complete step-by-step solutions so students can check their own works.

7.2 Emphasis

1. Emphasize the advantage of the Laplace transform techniques and H(s) in analyzing circuits with sinusoidal signals. With one circuit as example, analyze it with the techniques in section 3 and again with H(s). Discuss similarities and differences. Relate the gain and phase shift in sinusoidal analysis to the amplitude and phase of H(s).
2. Emphasize clearly, for the sinusoidal case, the differences between transient solutions and steady-state solutions. The Laplace method provides both, while the sinusoidal method in section 3 only provides steady-state solutions.
3. Focus on the steady-state case for the rest of this topic.
4. Illustrate the Bode approximate plotting technique using simple examples of H(s). Use textbook examples. Show students how to read a Bode plot.
5. Link frequency response with PSPICE AC analysis.
6. Be careful in the definitions of "3-dB point," "corner frequency," and "bandwidth." They mean the same thing in simple H(s) but if there are repeated roots at one frequency, different textbooks use these terms differently. Check the text you use and if you decide not to employ the same terminology, explain clearly to the students.
7. Cover the resonant circuits well and relate the time-domain output signals to the frequency-domain plots of H(s) as clearly as possible.
8. Demonstrate the technique by using many short examples, showing clearly time-domain waveforms and frequency-domain techniques to relate both domains.
9. Apply these concepts in interpreting the specifications of a realistic opamp and its frequency response.
10. Demonstrate a design procedure for a circuit given gain, bandwidth, etc. Pick one or two exercises from the textbook for this demonstration.

7.3 Once Over Lightly

1. Approximate phase plotting using the Bode technique is complicated for second-order or higher-order circuits. It is better to have students use computer-aided plotting tools to plot the phase function directly.
2. Approximate amplitude plotting using the Bode technique in case of overshoots at the corner frequency is rather messy. It is better to have students use computer-aided plotting tools to plot the amplitude function directly.

8. Simple filters

8.1 Overall teaching notes

1. Use the slides file filters.pdf as a guide to teach this topic, together with the more extensive materials from the textbook. Please review this file as you follow the notes below.
2. This course covers only a brief introduction to simple filters, mostly passive filters of low-orders (no higher than 3) and active filters with one opamp. The idea is to demonstrate the applications of the transfer function and frequency response methods in analysis and design.
3. Integrate the analysis and design methods taught in the materials, PSPICE simulation, and laboratory experiments in teaching this topic. This is the time to tie all materials together.

8.2 Emphasis

1. Discuss all 4 types of filters, using passive RLC circuits. The textbook has all these examples. Emphasize the differences between ideal filter characteristics and real-life filter characteristics.
2. Given a simple passive filter circuit (order 3 or lower), try to get students to reason (using component impedance and admittance as function of frequency) which filter it is without doing any mathematical analysis. After they make this first classification based on reasoning, do the math to verify their result. Teach students to do "back-of-envelope" calculations to estimate circuit behavior without a lot of math. Practice this method as many times as possible.
3. Analyze active filter circuits with only one opamp to simplify the process and demonstrate the methods rather than the complex math. The Sallen-Key filter is a good example for all 4 filter types in one topology. All textbooks have this filter.
4. Demonstrate a simple design example given a filter circuit and specifications.

8.3 Once Over Lightly

1. Skip all advanced filter topics. There will be higher-level courses focusing on filter design.
2. Avoid as much math as possible. Focus on methods and link to physical behavior.

9. SPICE

9.1 Overall teaching notes

1. Use PSPICE Student Version on the PC as the main tool since it is free and most likely comes in a CDROM with the textbook. The CDROM contains the software and the PSPICE

User's Guide. It also has links to the latest web site with updated documentation and free download instruction. Other versions of SPICE (Berkeley SPICE, HSPICE, etc.) are similar. If you have access to these versions and students can get them for free, it is acceptable to use these versions, as long as they are SPICE-based. SPICE is a standard industry simulation tool and must be taught to students. Do not use non-SPICE tools.

2. Use at most one session to show students how to run PSPICE on the PC: the best way is to demonstrate on the PC itself. The PSPICE User's Guide has a step-by-step example on how to construct a circuit, how to run a simulation, how to get output results. Use this example.
3. Start assigning PSPICE simulation as part of the weekly homeworks (add this to the homework problems in the textbook) after the PSPICE teaching session, no later than 20% into the course. If the course has 8 to 10 homeworks, begin to assign PSPICE with homework 2 or no later than homework 3. Keep it up for all subsequent homeworks.
4. This is the first course teaching PSPICE as a computer-aided tool for circuit analysis and design. Go slow at first but students must know how to run PSPICE well by the end of the course. Make them practice simulations as much as possible.

9.2 Emphasis

1. Use PSPICE to simulate circuits with components (R, L, C) and waveforms (DC, step, sine) covered in the lectures.
2. Cover DC analysis and transient analysis, and relate them to the time-domain solutions that the students do by hand. Always ask students to compare their manual solutions with PSPICE solutions, and to explain any differences.
3. Later in the course, cover AC analysis to go along with transfer function and frequency response topics. Always ask students to compare their manual solutions with PSPICE solutions, and to explain any differences.
4. Emphasize that PSPICE, like all computer-aided tools, sometimes fails and why. Try to instill in students a sense of skepticism of computer-aided tools.
5. Explain and demonstrate in one or two examples how PSPICE can be used to verify a design, after the component values have been selected. Ask students to verify their designs in homeworks using PSPICE.
6. Setting the Ground node or Initial Condition on a node takes some work in opening specific component libraries in PSPICE. The User's Guide covers the procedure to open these libraries. Check the Index and show students how to do these settings for their circuits.
7. Other component libraries contain opamp models. Show students how to open these libraries and use the components. All of these processes (items 6 and 7) can be done in one or two examples demonstrated on a PC as mentioned in section 9.1 (item 2) above.
8. The PSPICE User's Guide is an extensive document (hundreds of pages). There is no need to read it all. Use the examples provided in the Guide and the Index to look up specific topics and procedures. The Acrobat version of the User's Guide is excellent for this purpose.

9.3 Once Over Lightly

1. PSPICE has many other components (bipolar transistors, MOS, mutual inductance, etc.), many other waveforms (pulse, piecewise-linear, etc.) and many other analysis types (Monte Carlo, sensitivity, transfer function, etc.). Do not cover these topics since it would confuse students. These topics will be covered in subsequent courses.
2. Do not cover other advanced topics in PSPICE.

10. Laboratory

10.1 Overall teaching notes

1. The laboratory materials for the course consist of the motivating experiments (taught in an interactive manner), the laboratory instrumentation manual (how to use the instruments in the lab to apply and measure waveforms), and the verifying experiments (building circuits and measuring their characteristics).
2. The course has several motivating experiments, and the number of motivating experiments to be used depends on the instructor's selection. One motivating experiment (e.g. the DSL modem) might cover all the topics in the entire course, while another motivating experiment (e.g. musical instrument sound characteristics) might cover only one or two topics.
3. The laboratory instrumentation manual is provided for the specific instruments available at the University of Washington, and for the Pandora box. If the local facilities use different instruments, the instructor needs to provide the manual to the students. Our manual format can be re-used and the MS Word file for the manual will be provided to the local instructor for editing. See the web site below.
4. The laboratory instrumentation manual and the verifying experiments are posted at this public web site in Acrobat format: http://faculty.washington.edu/manisoma/labs. Instructors who prefer to use local experiments are welcome to do so. There are also many laboratory texts suitable for this course.
5. These experiments are written for general instrument (e.g. oscilloscope is used, but not a specific model or manufacturer) so they can be used in local laboratories with any set of instruments.
6. Instructors who want to modify the experiments should follow the instructions on the web site to request the source MS Word files.
7. The course must cover at least 4 experiments over 10 weeks.
8. Since students work in teams in the laboratory, there is a need to verify that each student has experimental skills. Each student must take an individual hands-on laboratory exam at the end of the course to demonstrate these skills to the instructor.

10.2 Emphasis

1. Always link the motivating and verifying experiments with the concepts, circuits, analysis procedures, and design practices covered in the lectures.
2. Later verifying experiments incorporate PSPICE simulations. Emphasize the comparison and differences between students' manual calculations, PSPICE results, and experimental data.

3. Emphasize real-world variations in component values and measured values of signals. Students are used to calculators with a large number of significant digits (e.g. 3.1415926535..) and must adapt to the view that in real life, they cannot do so. Two significant digits are usually sufficient in experimental data collection. Keep reinforcing this point in the lectures, labs, and homeworks!!
4. Emphasize that a design must work in the lab (real life). A design that works only on paper or in PSPICE is useless.
5. Select the experiments from the web site by reading the sections “Objectives” and “Reference” at the beginning of each experiment. These materials indicate the prerequisite topics students should have had and what they will learn in a specific experiment. When the course is taught at the University of Washington, the course web site will contain a specific sequence of four to five experiments to be used in that quarter. This selection needs to be done at the beginning of the quarter so the students can purchase the components for the entire quarter (as one lab kit).
6. Without a local instructor, it is difficult to teach a student how to diagnose a circuit when it is not working. We are exploring procedures to develop remote diagnostic procedures and will release them when available.

10.3 Once Over Lightly

1. Do not use the laboratory as additional lecture time!!
2. Do not use very specialized hard-to-find costly components. The lab kit should cost about $10 (or even less) for all 4 to 5 experiments.