Bridging the Gap Between Instructor and Textbook

Stephanie Goldberg
Department of Technology
Buffalo State College

Abstract

An engineering-level text was introduced in an electronics course and a linear analog circuits course at the junior/senior level of a four-year Bachelor of Technology program. The book was chosen for its scope, currency, and practical input. Students were alerted up front about the level of difficulty of the book as well as of its strengths. In this paper, we explore a means of providing students with support and guidance to work with a higher level of textbook. The goal is to develop a structure allowing an advanced book to be used in a Technology program.

1. Introduction

With technology changing at lightning speed, textbook selection must be based on providing a broad range of material, currency, practical input, and the provision of a foundation for continued technical growth. A textbook was found that satisfies these criteria for two courses in the four-year Bachelor of Technology program at Buffalo State College. The textbook, however, is written to an engineering student audience. A plan to acclimate a Bachelor of Technology class to an engineering-level text is presented in this paper. The key feature of this plan is a hypertext database containing an information file for each section (of each chapter) of the textbook. The file directs the student to key equations and portions of the section, identifies subsections that are not required, and provides additional explanations where needed. The files in the database have been developed for students to use in conjunction with their reading assignments. The files follow closely with the textbook and provide a guide for the students to organize their studies and help master the required material. The files are accessible to students through the school computer or through the Internet.

The targeted courses are an introduction to electronics and a linear analog circuits course, both required in the Bachelor of Technology, Electronics Option at Buffalo State College. With MOSFET-based designs in integrated circuit technology and numerous applications involving discrete power switching, electronics students must develop a good understanding of MOSFET operation and parameters. In the linear course, students are expected to develop enough insight about op amps to make proper component selections and circuit design/modifications based on practical limitations. Though the selected textbook contains mathematical derivations and some details involving solid state physics, it was chosen for its thorough and practical treatment of MOSFETs and op amps. The textbook seems ideal to provide the required material, and it has enough continuity to ignore rigorous derivations when appropriate. For example, the understanding of MOSFET operation in power-switching applications is a key topic in the electronics curriculum. The calculus-based derivation of the drain-source characteristics included in the textbook is not of immediate concern. In this instance, the students are guided by the supplementary information file to focus on the relationships between the variables in the resulting equations. The derivation of closed-loop gain of an op amp circuit when open-loop gain is finite is extremely important in the design of practical op amp circuits. The derivation in the textbook is complete, however, many algebraic and circuit analysis steps are taken for granted. The hypertext file associated with the derivation identifies what is done in each step, sometimes breaking a step into smaller pieces and identifying those algebraic manipulations and circuit analysis steps that were assumed.

Of long term benefit to students is the ability to work through a "difficult" piece of technical literature. With technology changing so rapidly, students will have to continue their education, and they will depend on various levels of reading materials in their job. It may be necessary to read terse journals, technical support literature, and vendor-supplied documentation. Teachers can help students develop learning strategies by modeling the processes of planning and evaluating the material[1]. Acquiring organizational techniques for technical reading will be an asset to students.

Some observations regarding student attitudes toward textbooks are discussed in the next section. Examples of the hypertext database highlighting the MOSFET and op amp areas mentioned above are found in Section 3. In Section 4, classroom activities to support the textbook are presented. A summary of improvements follows in Section 5.

2. Are There Perfect Textbooks for Technology Programs?

In all aspects of Engineering Technology programs there is a struggle for identity, for the right "slot" in technology, for the right mix of practice and theory to fill the gap between technician and engineer. At Buffalo State College, students with diverse technical backgrounds grapple with their professional identities (those fresh from two-year technical schools, those who have worked in a technical capacity for two to five years, those who have completed some semesters in a BSEE program, and those who complete their full four years in our program). As with job and program definitions, textbooks for Engineering and Technology programs may overlap. There is a middle ground of texts containing practical and theoretical content that seems appropriate to the four-year Bachelor's degree. A rough categorizing of technical textbooks is highlighted below.

- Practical Texts
    - Strictly how-to
    - Requires a good theoretical base to derive benefits
    - Emphasis is practical with theoretical explanations
- Theoretical Texts
    - Strictly theoretical, everything derived from a solid physics and math base
    - Provides a sound theoretical foundation with practical insight

Students, especially those coming from two-year programs, are expecting more practically-based textbooks. Observing the students during the first semester the book was used, it appeared that many had difficulty integrating the textbook into their study. They felt that the particular engineering-level book was overwhelming. Some "turned off" to the book. Most did not make the attempt to overcome this, either by working with the supplementary hypertext files or by asking questions in class. Students are not familiar with textbooks of this type. From previous experiences they expect a textbook to be a vehicle they can use without much effort and to be a substitute for classes that are missed. With proper motivation, the database is expected to be an effective tool in guiding the students through the textbook.

3. The Hypertext Files

The hypertext information files are meant to be used by the student in conjunction with reading assignments. Each file is associated with a small portion of the textbook and has been designed to guide students through the material by: a) pinpointing specific equations and portions of the material that are required b) providing further explanations and details where necessary, and c) identifying information that is not of immediate use.

3.1 Details of the Hypertext Files

The hypertext database contains a set of files organized with respect to the chapter sections of the textbook. The file for each chapter section is in the form of numbered paragraphs that follow sequentially with the material of that section of the textbook. A section of the textbook is typically three to six pages and the associated information file may contain one to three pages.

The main screen of the database links to pages for each chapter. From the chapter page, there is a link to each chapter section file (Figure 1 highlights the Chapter 2 page). Students are encouraged to link to the associated file during their reading assignment of that section. As the section is read, students can identify what level of importance each portion has and be alerted to material requiring additional support. The files provide additional explanations, examples, and references to class lectures. In addition, the files help students organize their studies by identifying what they need to master (for example, an equation may be highlighted by its relationship between two key parameters or a method may be identified as a required step). It is desirable that students can more precisely identify difficult areas. It is suggested[2] that hypertext provides a method of learning that is well suited for an individual to proceed at a rate commensurate with his or her abilities.

There is an introductory file for each chapter (an example of which is shown in Figure 2). This file identifies where the chapter fits in with the work done in class. An overview of the chapter is provided along with the emphasis given to each section.

SUPPLEMENTARY CLASS NOTES FOR
ENT 351 Analog Circuits 1

Return to Main Contents for Analog Circuits I

Chapter 2 Operational Amplifiers

Figure 1 Chapter 2 Main Page

ABOUT CHAPTER 2 INTRODUCTION Return to Chapter 2 Contents

a) A model of a voltage amplifier containing 3 parameters (input resistance Rin, output resistance Rout, and voltage gain Av) was presented in class. These 3 parameters determine the overall voltage gain of an amplifier, from signal to load.

b) A voltage amplifier can be made from just 1 transistor or many. The op amp is an amplifier made of 10-20 transistors. Each transistor has a special job and the overall goal is to produce "close to ideal" amp parameters (High Rin, low Rout, very stable Av).

c) In this chapter, the op amp is treated as an ideal amplifier. In Sections 2.3 to 2.6 we will examine 2 op amp circuits that can be used to provide voltage amplification. In later chapters, the internal design of the op amp will be examined. Knowledge of practical op amps will enable the design of op amp circuits with "close to ideal" conditions.

d) In Section 2.7, the frequency limitations of the op amp are introduced. Given the frequency limitation of the op amp, a method is shown to determine the frequency limitation of the amplifier circuit that uses that op amp. In Section 2.9, the non-ideal (or practical) behavior of the op amp is introduced. Practical methods are given to bring the behavior as close to ideal as possible.

Figure 2 Chapter 2 Introductory Guide

The flow of information in the hypertext files follows that of the textbook. The files may follow the book more closely when necessary, for example, when following the derivation of a proof or the solution to an example problem. Subsections are identified within the hypertext file to break the section into manageable portions.

The hypertext file directs the students to important material, especially pertinent equations. Students will be encouraged to work through certain derivations by following closely with the associated hypertext file. The file will further detail the textbook derivations based on circuit laws and techniques that are familiar to our students. Equations are categorized as "must memorize", "must derive", or "must understand". The most important outcome is a sense of what real situation the equation represents and what the important variables are.

3.2 Examples From the Hypertext Database: Introduction to Electronics

In the electronics class, a goal is to understand the operation of enhancement-mode MOSFETs in switching applications. This requires the ability to select a proper component based on the MOSFET parameters of threshold voltage and channel "on resistance". Power dissipation and maximum ratings must be considered to complete the component selection. The first two sections of the textbook chapter on MOSFETs contain an excellent presentation about the structure and operation of MOSFETs, however, it can be overwhelming to a student. The students are encouraged to approach this chapter with an intent to extract the necessary information. The goal is for students to fully understand the results through comprehending the variables and their relationships.

The portion of the hypertext file associated with the section of the textbook that derives the relationship between drain current and drain-to-source voltage is shown in Fig. 3. The textbook goes into significant detail, performing integration along the length of the MOSFET channel to obtain expressions for drain current in the triode and pinchoff regions. The derivation is beyond the scope of the course, however, the two resulting expressions are very important in the DC analysis of MOSFETs and the selection of power MOSFET components. As observed in Figure 3, the guide focuses the students on the resulting expressions and discusses each parameter involved.

3.3 Examples from the Hypertext Database: Analog Circuit Analysis

In the analog circuit analysis and design course, students are introduced to operational amplifiers. The op amp is first studied as an ideal differential amplifier with infinite voltage gain. Students learn how to design simple op amp circuits based on the inverting and noninverting op-amp configurations. Following the study of ideal op amps, practical considerations of finite open-loop gain, frequency limitations, and DC offsets are examined.

k) Don't worry about Subsection "“ Derivation of the i_d-v_{ds} Relationship". We want to be familiar with the results, that is, equations 5.5a and 5.5b, the equations for drain voltage in the triode and saturation region respectively. Note Eqn. 5.3, the value of the effective cap depends on the insulation material and its thickness and the plate area (area under the insulation, which is channel length * channel width). In Eqn. 5.5a, since v_{ds} is small in this region, the term v_{ds}^2 will be much smaller than v_{ds}. If you ignore that term, i_{ds} = constant * v_{ds}, where constant = $k(W/L)(v_{gs}-V_t)$. What is important to note is that the derivative of v_{ds} with respect to i_{ds} is proportional to $1/v_{gs}$, so as v_{gs} increases, v_{ds}/i_{ds} (channel res) decreases. We saw this in Fig. 5.4. Eqn. 5.6a defines the relationship between i_{ds} and v_{ds} in the saturation region. In this region, vds is large enough to pinch off the channel and recall v_{ds} had no effect on further changing channel resistance (Channel res is almost infinite in saturation region). This is highlighted in Eqn. 5.6a by the term v_{ds} not even present. For a given v_{gs}, i_{ds} is a constant value, as observed in Fig. 5.6. Observe in Eqn. 5.6a that (loosely) i_{ds} is proportional to v_{gs} squared. In amplifier applications, the input is v_{gs} and output is ids. The relationship in not linear.
l) The last subsection in 5.1 "Operating the MOSFET in the Subthreshold Region" discusses operation when V_{gs} is below threshold. Ideally we say a channel has not been enhanced and so there is no current. Operation as an open switch is found here. What kind of path exists between the drain and source (our switch path). The drain is n-type, in between the drain and source is p-type and finally, the source is n-type. Basically, there are 2 back to back diodes (diodes facing in opposite directions) between the drain and source. No matter what direction current is expected to flow, one of the diodes will be reverse-biased and so current flow in either direction is not possible. This is the characteristic of an open. When the MOSFET is operated as a switch, there are generally 2 different gate voltages that can be applied, one which is below threshold and does not allow current through, and one which is above threshold, thus providing a channel.

Figure 3 Portion of Hypertext File for Derivation of MOSFET Drain Current

The internal circuitry of the op amp is studied later in the semester to determine causes of non-ideal behavior. The goal of the course is to develop design skills for op-amp-based circuits and to be make intelligent component decisions regarding the strength of one op amp over another. An example of an important derivation in the textbook and the associated portion of the hypertext database is discussed below.

In Figure 4a, a portion of the textbook[3] is shown in which the impact of finite open-loop gain on the closed loop gain of the inverting op-amp configuration is derived. The portion of the database associated with this is shown in Fig. 4b. The textbook derives its result with circuit analysis steps and algebraic manipulation. Many fundamental steps are assumed. The hypertext file serves as a guide to help identify what is being done, dividing the textbook steps into smaller ones that correspond to a single circuit law or involve a smaller number of algebraic steps.

Effect of Finite Open-Loop Gain

The points just made are more clearly illustrated by deriving an expression for the closed-loop gain under the assumption that the op amp open-loop gain A is finite. Figure 2.6 shows the analysis. If we denote the output voltage v_O, then the voltage between the two input terminals of the op amp will be v_O/A. Since the positive input terminal is grounded, the voltage at the negative input terminal must be $-v_O/A$. The current i_1 through R_1 can now be found from

$$i_1 = \frac{v_I - (-v_O/A)}{R_1} = \frac{v_I + v_O/A}{R_1}$$

The infinite input impedance of the op amp forces the current i_1 to flow entirely through R_2. The output voltage v_O can thus be determined from

$$\begin{aligned} v_O &= -\frac{v_O}{A} - i_1 R_2 \\ &= -\frac{v_O}{A} - \left(\frac{v_I + v_O/A}{R_1}\right) R_2 \end{aligned}$$

Collecting terms, the closed-loop gain G is found as

$$G = \frac{v_O}{v_I} = \frac{-R_2/R_1}{1 + (1 + R_2/R_1)/A} \qquad (2.1)$$

We note that as A approaches ∞, G approaches the ideal value of $-R_2/R_1$. Also from Fig. 2.6 we see that as A approaches ∞, the voltage at the inverting input terminal approaches

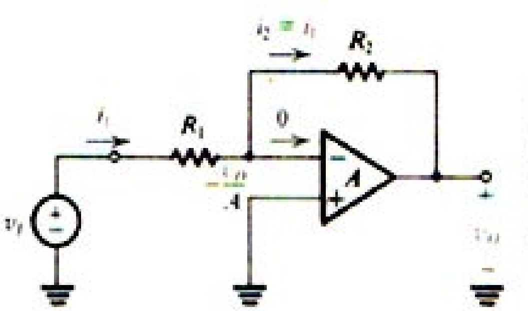

Fig. 2.6 Analysis of the inverting configuration taking into account the finite open-loop gain of the op amp.

Figure 4a Example From Textbook

Previously, the op amp was described in terms of the relationship between its 2 inputs and single output, $V_o = A_o * (V^+ - V^-)$. A_o is the differential voltage gain of the op amp (differential refers to the fact that the difference in voltage between the 2 inputs is the quantity that is amplified). No matter what situation the op amp is in, it will attempt to provide an output voltage that is A_0 times the difference between its positive and negative input.

a. In the previous subsection, the closed-loop voltage gain of the inverting op-amp configuration voltage amplifier was derived. Recall, the closed loop gain is the actual voltage gain that your signal is amplified by when it uses this particular single-input single-output amplifier circuit. Key to this derivation was the assumption that the differential voltage gain of the op amp was infinitely high. The inverting configuration was introduced as one type of single-input single-output amplifier that makes use of an op amp along with 2 resistors (Fig. 2.6 in the book highlights the inverting configuration showing signal input and amp output.)

b. In this section of the textbook, another derivation is presented that does not make the assumption that the open loop gain of the op amp is infinite. The results of this derivation will highlight the importance of having high open-loop gain (for example, why is an open-loop gain of at least 50,000 necessary when amplifying a signal by the closed-loop gain of 20?). The derivation highlights the role of open-loop gain on the closed-loop gain in the inverting configuration.

c. Observe in Fig. 2.6, in the inverting configuration V^+ is at ground. From the fundamental op-amp equation $V_o = A_o * (V^+ - V^-)$, we get $V_o = A_o * (-V^-)$. V^- can then be expressed as $-V_o / A_o$.

d. The derivation is based on applying Kirchoff's current law to node V-. Note, there are 3 currents associated with that node (Fig. 2.6), one of which is the current into the op amp. This current is assumed to be zero in keeping with the ideal features of the op amp. The current through R_1 is expressed in the first equation of the subsection as V_{R1} / R_1, where V_{R1} is the voltage drop across R_1. Since one side of R_1 is connected to the signal (V_I) , and the other at terminal V^-, $V_{R1} = V_I - V^-$, or $V_I - (-V_0/A_o)$. As a result, $i_1 = [V_I - (-V_0/A_0)]/R_1$

e. The current through R2 can be expressed as V_{R2} / R_2, where V_{R2} is observed to be $-V_0/A_0 - V_0$. We then have $i_2 = (-V_0/A_0 - V_0)/R_2$ or $R_2 * I_{R2} = (V_o/A_0 - V_0)$. Subtracting V_o / A_0 to both sides, $V_0 = V_0/A_0 - R_2 * i_2$.

f. Since the current into the op amp is assumed to be 0, Kirchoff's current law tells us that $i_1 = i_2$. The expression for i_1 is substituted for i_2 in the previous step, giving the final expression for V_0 in the 2nd equation of the subsection. The result, Equation 2.1, is obtained by solving for V_0/V_I. The term G is used as the gain of the amplifier (V_0/V_I) . Observe, if R_2 is 20k and R_1 is 1k, with an open-loop op-amp gain of 50k, the closed-loop gain is -19.992. If A_0 .is 1000, the closed loop gain would be -19.589.

Figure 4b Portion of Hypertext File Associated with Text in Fig. 3a

The examples of the database highlighted in this section are typical examples of how the textbook material is treated.

4. Classroom Support

Students are told up front about the level of difficulty the textbook, the benefits that can be derived from mastering the required portions of the book, and how to access the database. Frequent references are made to the database in class, especially when a new section is started. The database reinforces the lectures and vice versa. When starting a new section, the information file associated with that section is reviewed in class to motivate students to use the database.

The database is accessible through the school computer as well as the Internet. Several computer labs on campus as well as dial-in capabilities are available to all students. Presently, the campus network supports over 2000 user connections including workstations, terminals, printers and various other user devices. The Electrical Engineering Technology program has its own Linux-based network with *7* Pentium computers on PC carts. Students have convenient access to this network as well.

5. Improvements for the Next Semester

Student attitudes toward the text were discussed above. Based on the observations made during the first semester of implementation, it appears that students did not incorporate the text into their study and did not make substantial use of the database files.

The most important goal is to keep students involved with the textbook. More class time will be spent referring to the textbook and database. Lectures and laboratories will involve the textbook whenever possible. An interactive component may be added to the course requirements. Links to manufacturers' data sheets, professional organizations and IEEE journal abstracts will be added to the database.

1. J. J. Bellon, E. C. Bellon, and M. A., Blank, Teaching from a Research Knowledge Base, Macmillan, 1992.

2. R. D. Murphy, "Hypertext and the EET Student", in Proc. ASEE Annual Conference, pp. 69-70, 1992.

3. A. S. Sedra and K. C. Smith, Microelectronic Circuits, Oxford University Press, 1998.

Stephanie Goldberg is an assistant professor in the Technology Department at Buffalo State College. Her responsibilities include courses in analog and digital electronics. Goldberg received her MS and Ph.D. in Electrical and Computer Engineering from the State University of New York at Buffalo. Her email address is goldbesr@buffalostate.edu.