

AN ABSTRACT OF THE THESIS OF

Marjorie Plisch for the degree of Master of Science in Electrical and Computer Engineering presented on June 8, 2007.

Title: A Practical Implementation of Self-efficacy Theory to Improve the Engineering Curriculum.

Abstract approved:

Terri Fiez

What are the most effective ways to improve the engineering curriculum? Improvements should result in increased student retention, undergraduates who are more industry-ready and graduates who are better prepared to be leaders. Current research suggests that the best predictor of persistence is a person's self-efficacy. The focus of this thesis is a practical application of the theory of self-efficacy in an integrated effort to improve the engineering curriculum.

The School of EECS at Oregon State University has already been making an effort to improve the undergraduate educational experience via the introduction of the TekBots[®] program in labs. Labs should be designed and implemented in such a way that the undergraduates have a beneficial experience which may increase their self-efficacy and hence, likelihood to persist in the engineering program as well as better prepare them for industry. A redesign, implementation and evaluation of integration of the TekBots program into a junior-level course, Electronics II, is presented.

Another important factor in improving retention is providing undergraduates with role models who model success and give encouragement. TAs are prime candidates to be mentors. One solution is to rethink the traditional philosophy behind the position of TA. Leadership training for TAs is an innovative and efficient solution because it encompasses more than simple teaching techniques and draws on other disciplines. A design, implementation and evaluation of a leadership training course for TAs is presented. Preliminary results show that course is effective for the purpose of increasing teaching self-efficacy.

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A Practical Implementation of Self-efficacy Theory to Improve the
Engineering Curriculum.

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Marjorie Plisch, Author

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**A practical implementation of self-efficacy theory to improve the
engineering curriculum**

CHAPTER 1 - INTRODUCTION

1.1 Self-efficacy theory applied

This thesis presents work that was done to improve the existing Platform for Learning[®] (PFL) educational program called TekBots, based on the theory of self-efficacy. It is the integration of a Platform for Learning lab into Circuits II (ECE 323) as well as the development, implementation and evaluation of a TA Leadership Training course. The practical end-goal of this work is to improve the self-efficacy of engineering students, their persistence, and thus, their retention in the program. Self-efficacy, a theory which was pioneered by Albert Bandura, is a good predictor of persistence in a given task [1]. It is a person's belief in his or her ability to act to produce a desired goal. The four main factors which influence self-efficacy, in order of strength from greatest to least are:

- ***Mastery experience*** – A previous experience of success at the given task.
- ***Vicarious experience*** – Relying on the experiences of close peers to estimate one's own ability.
- ***Verbal persuasion*** – Convincing people that they possess the capabilities to master given tasks.
- ***Physiological State*** – Judging one's capability based on somatic arousal.

Based on self-efficacy theory, the TekBots program has already done much to improve the likelihood for retention of undergraduates. The labs themselves provide an excellent opportunity for a mastery experience, which is the most influential factor. However, there is still room for improvement. The Platform for Learning labs have spread from beginning to advanced courses and are now being integrated into intermediate level courses. *Circuits II* (ECE 323) was previously an independent lab and in need of revision. One part of this thesis covers the redesign, implementation and evaluation of ECE 323 as a PFL lab.

Although the integration of the PFL into the labs has improved the technical quality of the program, a large portion of a person's self-efficacy is influenced by his or

her interactions with other people. The second part of this thesis work focuses on the work that was done in the creation, implementation and evaluation of *TA Leadership Training* (ECE 507). The training which the TAs received was in the areas of leadership, teaching, communication and mentoring. The goal, related to the factors contributing to self-efficacy, was for them to be better peer mentors, more encouraging to their students and assist students in coping with the stresses of the engineering program.

1.2 Organization

The rest of this thesis is organized as follows. Chapter 2 is a paper which was written about ECE 507, *TA leadership training*. This chapter describes the effect of leadership training on the teaching self-efficacy of the TAs.

Chapter 3 describes the integration of the PFL into ECE 323, *Circuits II*. It describes the process of developing an intermediate level PFL lab course, so that students may have a better mastery experience.

Chapter 4 is a short chapter about additional work which was done on a paper, *Extending a Platform for Learning to Upper Division Electrical and Computer Engineering Courses*, by Adriaan Smit [2].

Chapter 5 is a summary of ideas and plans for further work.

The appendixes which follow include the ECE 323 labs, the TA Leadership Training manual, and various surveys and results.

CHAPTER 2 – LEADERSHIP TRAINING FOR TEACHING ASSISTANTS TO INCREASE SELF-EFFICACY

Abstract – Engineering departments are always striving to improve upon the education which their students receive in order to better prepare them for industry and encourage them to persist. However, technical improvements are not the only factor; Albert Bandura's theory of self-efficacy suggests that peer mentors also play a strong role in influencing persistence.

Oregon State University has introduced a new course in leadership training for TAs to train them in leadership, teaching, communication and mentoring. TAs with better relational skills means better peers for students. This paper explores the benefits of leadership training to graduate and undergraduate TAs for their students

2.1 Introduction and hypotheses

A new course named Leadership Training for TAs was designed, conducted and analyzed in the fall of 2006 in order to test two hypotheses. The first hypothesis is if leadership training is able to influence teaching self-efficacy, then it will have a positive effect on the peer mentoring ability of undergraduate TAs. Albert Bandura's theory of self-efficacy has already established which factors influence self-efficacy and that self-efficacy is a good predictor of persistence [1]. The principles of leadership seem to be a good match for influencing the TAs to be better peer mentors, but research is required to establish that. The applied goal of this research was to influence the engineering curriculum in a positive way, not simply study it. TAs serve many purposes including overlapping roles such as peer mentor, teacher, evaluator, and manager. One main role is that of teacher, especially important because students cite poor teaching as a reason for leaving [3]. The leadership training ideally has a positive effect on the teaching abilities of the TAs. The second hypothesis is that if similar leadership training is given to graduates and undergraduates, then it will be equally beneficial for each group. The

graduate TAs and undergraduate TekBots TAs are two very different groups of TAs based on their selection, demographics, and motivators. The leadership training was designed to positively influence the abilities of the TAs to affect their students, but because the undergraduate and graduate students are so different, it was not clear what the outcome of the training would be for each group.

This document is organized as follows: first, the reader is introduced to the various pedagogical issues involved, the unique contributions of this research to the body of literature, and a comparison of alternative educational approaches. Then, the course environment is explained and the assessment/evaluation data is presented. Finally, lessons learned and further recommendations are given for other universities which are also interested in implementing this solution.

2.2 Pedagogical issues

This research focused on several pedagogical issues including: (1) the testing of leadership training as a practical implementation of self-efficacy theory to improve student retention, (2) the training of TAs to build them into teachers who would be better role models, have better instructional capabilities, be more encouraging toward their students and improve the atmosphere in engineering labs, and (3) the measurement of teaching self-efficacy as a way to verify the hypotheses.

The goal of this research is one for which many other universities are also striving: to improve the retention of the undergraduate engineering students. The overall percentage of undergraduates completing an engineering degree out of total degrees awarded has decreased in recent years, from 5.3% in 1994 to 4.7% in 2001 [4]. The combination of a decrease in engineering grads and a growing need for the same in industry has created a shortage, a growing and significant problem in industry [5]. Bill Gates laments the difficulties which Microsoft has in hiring enough graduates: "...I'm certainly very worried about it. Microsoft is trying to hire every great college graduate who has basic computer science skills and we think is highly talented" [6]. The end goal is not to simply retain every single student who starts out in the engineering program. Some students have genuinely good reasons for switching, such as a stronger interest in

another subject area, which they discover after experiencing classes at the university level. However, some students switch because of general discouragement due to factors such as poor engineering curriculum, inability to connect with peers and mentors and feeling overwhelmed in the face of the difficult challenge of achieving an undergraduate engineering degree [3]. The practical goal of this research is to address the needs of these students.

Retention is a somewhat difficult parameter to measure because of the definitions which surround it and because of the constraint of time. For example, the most straightforward case is students who start and finish at the same university in four years. However, many students start at a community college or switch universities. Students may take a hiatus in their education; some come back and finish in a non-traditional amount of time while others never do. So, as with all statistical measurements, the results are necessarily influenced by the initial definition of the input parameters. In addition to these problems, using retention statistics as the yardstick to measure the effect of any attempt to change the system is ineffective in the short run because it takes so long for the results to appear. The causes for change in retention have four years to take place and are many and varied, and cannot easily be distinguished. Nor is it simple to definitely prove any particular factor as having had an effect on the retention. So, for practical and timely feedback on a particular treatment to improve retention, retention itself is not a practical measure.

Instead of retention, many researchers find it more practical to measure a quality called self-efficacy. Persistence may best be predicted by self-efficacy [1]. It is a relatively new concept in the social sciences field, pioneered by Albert Bandura. In summary, self-efficacy is one's *belief* about one's *ability to act* in such a way as to achieve a *desired result* [1]. It is different from efficacy, a person's actual competence to accomplish a task, in that it is a person's self-perception of his or her abilities. It is self-efficacy, not efficacy, which is related to persistence because a person with high self-efficacy will persist in the face of difficulties, believing them to be a challenge which may be overcome. A person with low self-efficacy will perceive difficulties to be proof that the task is insurmountable and is more likely to give up altogether.

Self-efficacy is affected by four main factors, in order of importance: previous personally experienced success in the task-specific area (mastery experience), a role model which models success (vicarious experience), encouragement toward the specific area (verbal persuasion), and a relaxed, positive or happy mood when thinking about or doing that area (physiological state), as seen in Figure 1 [1]. Of course, a mastery experience is the best factor to increase a person's self-efficacy because a previous success gives confidence for a future one. It is important for a person who is just developing his or her self-efficacy in a given area to have successful experiences because otherwise, he or she may become discouraged early and give up. If a failure comes after a strong sense of self-efficacy has already been established, it is not as detrimental. People who are in the beginning stages of development of their self-efficacy are more sensitive to the vicarious experience. Because they have none of their own, they judge their own abilities by estimating them based on the abilities of their peers. The two keys to establishing a positive self-efficacy lie with the connection to the peer and the success of the peer. Verbal persuasion is effective only if it is followed by a successful attempt in that area. People will quickly lose faith in others' encouragement when their own attempts do not bear that faith out. The last factor, physiological state, is the least significant one by a greater margin than the other three. In a word, it has to do with how anxious people feel when they engage the particular area. People perceive their own physical and emotion reactions as evidence of ability or lack thereof.

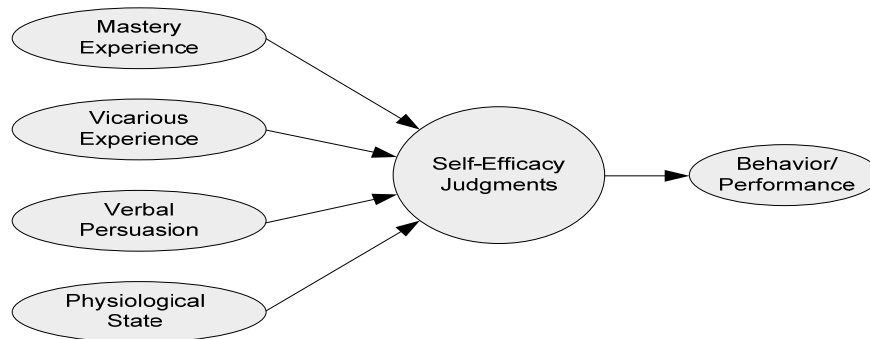


Figure 1. Overview of self-efficacy sources.

The leadership training course was developed as an effort to improve the retention of undergraduates in engineering by influencing the factors of self-efficacy, especially the

last three. The TekBots program, introduced at Oregon State University in 2000, is already aimed at improving the technical experience which the students have. The labs are structured to give students, especially first-year students, a positive mastery experience [7]. Another strength of the TekBots program is the undergraduates who staff the first and second year courses as lab teaching assistants (TAs). They are especially effective because they are excellent peer mentors and connect naturally with their students, being only slightly advanced of them. However, there is always room for improvement. The TekBots TAs were selected for technical and personal excellence, but were untrained. The goal of leadership training was to equip them with practical interpersonal skills to connect even better with their students. In addition, leadership training can give them the foundation of skills to give their students verbal encouragement and help assuage their anxiety in lab.

In addition to the TekBots TAs, the graduate TAs also received the leadership training. Graduate TAs are not naturally as effective peer mentors because their level is further advanced compared to the TekBots TAs. Young undergraduate students who are seeking peers to connect with do not automatically identify with them and their successes. They may perceive graduate TAs' successes as lofty and out of reach, as opposed to undergraduate TekBots' TAs successes, which are recent and tangible. Especially because of this, the graduate TAs are more in need of improved abilities to connect with their students.

2.3 Unique contributions of research to literature

Many solutions have been proposed as the answer to the problem of retention of undergraduate engineering students [8, 9]. Because there are many factors which contribute to the problem, there are many factors which contribute to its solution. One aim of this research is to uniquely contribute to those solutions, with the ultimate goal being to improve the undergraduate engineering curriculum at Oregon State and contribute to those across the nation.

This solution is unique because it uses leadership training of TAs in conjunction with the theory of self-efficacy to improve retention. As social theory, self-efficacy fills

an important place in explaining human behavior, especially regarding persistence and which factors affect it. However, there are many different possible practical implementations of programs to change the self-efficacy of a particular group. Leadership training is commonly implemented as a solution in many other areas [10], but no university gives their TAs leadership training in an effort to affect undergraduate self-efficacy (and retention.)

Leadership training is also a unique solution in that it is efficient because it benefits two groups of people at the same time: TAs and their students. The primary motivation behind training the TAs was to improve the education of their students. Better TAs provide undergraduate students with better mentors. However, it simultaneously provides the TAs with much-needed leadership skills for their futures. Engineers typically have a technical background, but face challenges which require more than technical skills [11]. This situation creates engineering graduates who are not fully prepared to engage the trials of real life. For example, engineers may also be called on to lead a technical group, interact with customers or mentor junior engineers. Leadership training is an ideal course to prepare them for this.

Leadership training is also an efficient solution in that it does not add another item to the already busy graduate student's schedule. The professional life of a graduate student is overloaded with classes, research and TA responsibilities, making leading a balanced life difficult. Instead of adding a separate program to the schedule, leadership training integrates other existing responsibilities and refocuses them. Teaching responsibilities continue to exist, but now become a practical venue for the TAs to practice leadership skills. Basic TA training was absorbed into TA leadership training and taught in place of a currently existing orientation course. The largest additional burden was in the creation and teaching of the course, not on the TAs by taking it.

2.4 Alternative educational approaches compared

The alternative educational approaches which have been used were explored by two different methods: one was by a review of engineering education literature and the other was by surveying the top twenty engineering schools. By now, engineering schools

nationwide are very aware and concerned about issues of retention among their students. Most schools are taking measures in order to do a better job at retention; several of the most popular methods are investigated. In addition to these measures, TA training programs were surveyed to determine if and how schools are leveraging TAs to be a part of the solution. Therefore, a current survey of TA training programs at the most influential universities was the best way to investigate the alternative educational approaches in the academic arena.

One of the most popular and effective ways to influence retention is by getting first-year engineering students involved in hands-on engineering projects. This exposes them to the reality of what engineering actually is, so that their interest is piqued up front and continues to grow. It is also a better model for education as opposed to a previous traditional model where students were exposed to engineering classes for the first time in their junior year, after finishing a math and science core, by then they were already turned off to engineering. By getting involved in hands-on projects, students can also grow confidence that they actually *can* do engineering. (This phenomenon is well-explained by self-efficacy theory.) For example, Oregon State University introduced the TekBots program into the ECE curriculum in 2000 [12]. Students begin building their TekBot, shown in Fig. 2, in the first year (in ECE 112) and continue to add on to it over the course of their undergraduate program. ECE 112 maintains extreme popularity and success. Indiana University, a leader in engineering education, has developed a freshman success course where “small teams of students design, build, program, and test an autonomous mobile robot...” [13]. Similar to the TekBots program at OSU, this program has proven to be successful for the purpose of retaining undergraduate students in engineering.



Figure 2. Learning with TekBots.

Another way to impact undergraduate retention is by introducing active/cooperative learning methods into the classroom [14]. While other disciplines have been quicker to move towards this teaching/learning style, engineering has been reluctant to adopt it, viewing cooperative learning to be a “soft” approach, not appropriate for hard-core engineering courses [15]. However, the effectiveness of such methods cannot be overlooked [16]. Some engineering teachers have tried this approach and generally meet with success [15, 17]. One area this method can be effective in is in combating the sense of isolation that engineering students cite as a barrier to persisting in engineering. In one study, 8.1% of female freshman students perceive isolation to be a barrier and this number grows steadily until the senior year, with 47% of students citing it [18]. Relationships and a sense of team which are started in the classroom can also grow outside of it.

Many universities have introduced special programs over and above the base engineering program. These programs are especially targeted at retaining women and minorities. The retention rate of women and minorities in engineering is even less than that of overall students in engineering and, so, is an issue of special concern. Although a

positive change in the engineering curriculum affects all students positively and vice versa, women and minorities tend to be more sensitive to these factors.

The top twenty graduate programs in engineering in U.S. universities are listed in the ranking by U.S. News and World Report [19]. They all offer some type of TA orientation and/or training, but there is no consistent standard beyond that. It is difficult to say whether departments offer leadership training or not. Some of them offer some topics which are typically identified with leadership development, but none offer leadership training as a part of the graduate engineering curriculum specifically or intentionally.

Some departments (electrical engineering, computer and electrical engineering, or electrical and computer and computer science engineering) conduct their own training, while others rely on TA training from the Graduate School; still others do some combination. Often, the department will conduct an orientation seminar to cover administrative issues which are specific to its graduate students and rely on the Graduate School or some Center for Teaching and Learning to conduct pedagogy and other skills training such as teaching, communication and grading. Graduate students might be taught together as one group or split up into domestic and international students. In one case, TAs could undergo further training for rewards such as a pay increase.

For almost all of the departments, the TA training was mandatory for new TAs. One notable exception was a top ranked engineering school. Although the training there is voluntary, approximately half of the graduate students attend. Most departments were quick to confirm that the training was mandatory, but many did not actually have a way to check attendance or have a policy for noncompliance. Departments offer between two hours and two days of training with an average of six hours. University-wide training from the Graduate School or some sort of Center for Teaching and Learning was slightly longer with an average of eight hours.

Most schools offered a selection of a similar set of topics. These topics may be categorized into administrative topics, pedagogy, and interpersonal skills. Orientations at all the schools covered administrative topics such as the appointment process, professional duties, policies and procedures, grade reporting online, using the copy room

and ordering books. Pedagogy was the next most frequent topic and included specifics such as teaching styles, effective teaching techniques, engineering-specific teaching, assessment, and micro-teaching. Only several of the schools taught interpersonal skills, which may most nearly be classified as leadership skills, and lie outside of administration and pedagogy. Some of the topics were a writing workshop, communication, diversity, a Myers/Briggs personality survey, cooperative learning, presentation skills, and community building.

Most of the approaches to address retention are implemented at the departmental level by changes to the curriculum, course content, and availability of special programs. These changes generally show a positive effect on retention. In addition, engineering teachers are beginning to incorporate different teaching methods into their courses such as cooperative learning. These changes are also effective, but tend to be motivated by individuals who are committed to teaching and learning, not as often by departments. After reviewing the results of the top twenty universities TA training programs, none of them have made an intentional effort to utilize TAs as a part of the solution to the retention problem. There is also no deliberate effort to give TAs leadership training as a part of their graduate-level preparation or as the method by which they are trained to connect better with their undergraduate students.

2.5 Leadership training course environment

There are several aspects of the course environment in which the leadership training took place such as course structure, style and content. One leadership training course was designed and it was taught to two different groups of students: undergraduate TekBots TAs and graduate TAs.

The leadership training course ran the duration of one quarter (a ten-week academic term). TAs met once per week for the standard fifty-minute class period. There was one week of course introduction, eight weeks of course content and a final week to wrap things up. Students were given several homework assignments including writing reflections, a communicator's log, and a conflict styles survey. Because of the structural differences in Oregon State's undergraduate and graduate TA programs (and

because of size limitation), the leadership training course was taught to undergraduates and graduates separately. The graduate TAs enrolled in College Teaching (ECE 507), a one-hour course which was required for all new TAs. The course was graded pass/fail with 70% being passing. The course grade was based on attendance and participation (75%) and five assignments (25%). The TekBots TAs did not enroll in any particular course, but were instead paid for one hour per week at the same hourly rate as they received for their TA work. Attending the course was voluntary, with the only requirement being that if they started the course, then they should also finish it. The graduates were a larger group of 38 students as compared to the undergraduate TAs with only 10 students.

The course was designed to use many different teaching methods. The typical flow of a class was large-group lecture followed by a small-group discussion or practice of skills. A lecture was the most practical and efficient way to deliver some fundamentals and background on each topic and demonstrate a skill to the TAs. After this, they broke down into smaller groups to discuss or practice what they had learned. The students picked triads for themselves at the beginning of the term. A triad is a concept which was borrowed from counselor education. A triad consists of three people who take turns as the observer, counselor and counselee as the counselor practices the skill on the counselee and the observer comments afterward, shown in Figure 3.

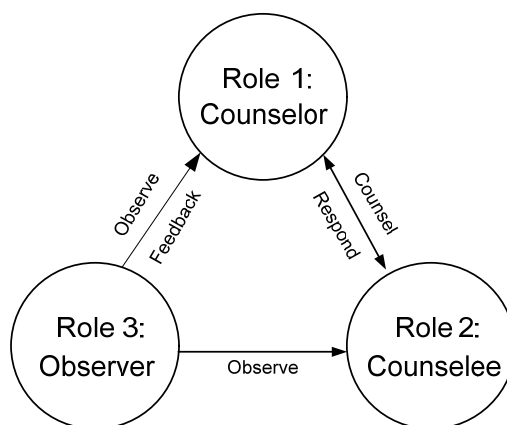


Figure 3. Counseling triad roles.

If students only learn about skills in a lecture setting, they are less likely to retain or practice what they have learned. People learn by doing; they need a chance to actually apply the skill themselves [20]. This method of learning gives the maximum impact because students get to learn the background of a topic, see a skill demonstrated and practice it three ways in triads. An additional benefit of the triad is that it is a relatively safe place to try out a skill. After learning and practicing a skill in class, TAs could try that skill out in their own labs during the week.

The course content of the leadership training course was taken from a broad selection of leadership topics, with the ones most relevant to the goals of the research being chosen. These topics and further details may be found in Table 1 below.

Table 1. TA training course topics and specifics.

<u>TA Training Course Topics and Specifics</u>	
• Leadership	<ul style="list-style-type: none"> ○ Foundations <ul style="list-style-type: none"> ▪ Motivation to be an excellent TA ▪ The role of the classroom leader: responsibilities and privileges ▪ How to use the first lab meeting: building community ○ Skill development <ul style="list-style-type: none"> ▪ Background and understanding of conflict ▪ How to facilitate conflict resolution
• Teaching	<ul style="list-style-type: none"> ○ A day in the lab learning instrumentation ○ Teaching skills: practical tips for the teacher ○ Learner-centered teaching
• Communicating	<ul style="list-style-type: none"> ○ Listening skills <ul style="list-style-type: none"> ▪ Paraphrasing, and perception check ▪ Expression of feelings and emotions ○ Addressing student needs based on identity <ul style="list-style-type: none"> ▪ Race and ethnicity ▪ Gender
• Mentoring	<ul style="list-style-type: none"> ○ Being a role model: connecting with students <ul style="list-style-type: none"> ▪ Personality types: how to interact with students ▪ Help for international TAs: expectations of American culture ○ Boundaries <ul style="list-style-type: none"> ▪ Appropriate boundaries in the student-TA relationship ▪ Resources available for students who need extra help

The core material of the course is composed of two weeks of training in each of the following areas: leadership, teaching, communicating, and mentoring. The leadership unit consisted of responsibilities and privileges of the leader, and dealing with conflict. The teaching unit spent one hour each highlighting skills for the teacher and student-focused learning. Communication consisted of one week of basic listening skills, such as the perception check, and the other week was addressing the needs of students based on gender and ethnic identity. Lastly, the TAs covered mentoring by learning how to connect with students and how to draw appropriate boundaries (assertiveness). The actual course material may be found in Appendix A.

2.6 Assessment/evaluation data presented

The course was evaluated by giving a pre and post teaching self-efficacy survey to the TAs for quantitative data and by keeping copies of assignments (of graduate TAs who gave their permission) for qualitative data. Although the end goal was to increase the retention of students, the method was by affecting their TAs, so it was more appropriate (and practical) to measure the effect of the leadership training course on them. Research shows that an increase in self-efficacy reflects an increase in actual competence [21]. The teaching self-efficacy survey was taken from a Teacher Self-Efficacy Scale composed by Albert Bandura [22]. The original survey was targeted at K-12 teachers, so it was adapted slightly for TAs in the university setting, and may be found in Appendix B.

Four groups of TAs were given the pre- and post- teaching self-efficacy survey and/or participated in the leadership training course. Group 1 and Group 2 were the same set of undergraduate TAs. However, the results of Group 1's pre- and post- surveys are due to their experience as TAs, as well as the leadership training course. Group 2 followed the self-efficacy progress of the same group after one more term of TA experience, but with no further leadership training. Group 3 was undergraduate TAs who did not take the TA training course ever. Group 4 was graduate TAs who also took the leadership training course concurrent to teaching, similar to Group 1. Their demographics are summarized in Table 2 below:

Table 2. Summary of TAs, leadership training and surveys.

Group	Education level	Leadership Training	Total number of TAs	Number of TAs surveyed pre and post
1	Undergraduate	Yes, concurrent to TA experience	10	4
2	Undergraduate	Yes, previous to TA experience	10	4
3	Undergraduate	Never	10	7
4	Graduate	Yes, concurrent to TA experience	38	21

The hypotheses and results are reviewed as follows:

Hypothesis 1: if leadership training is able to influence teaching self-efficacy, then it will have a positive effect on the peer mentoring ability of undergraduate TAs.

The results of the teaching self-efficacy surveys are shown in Figure 4 below:

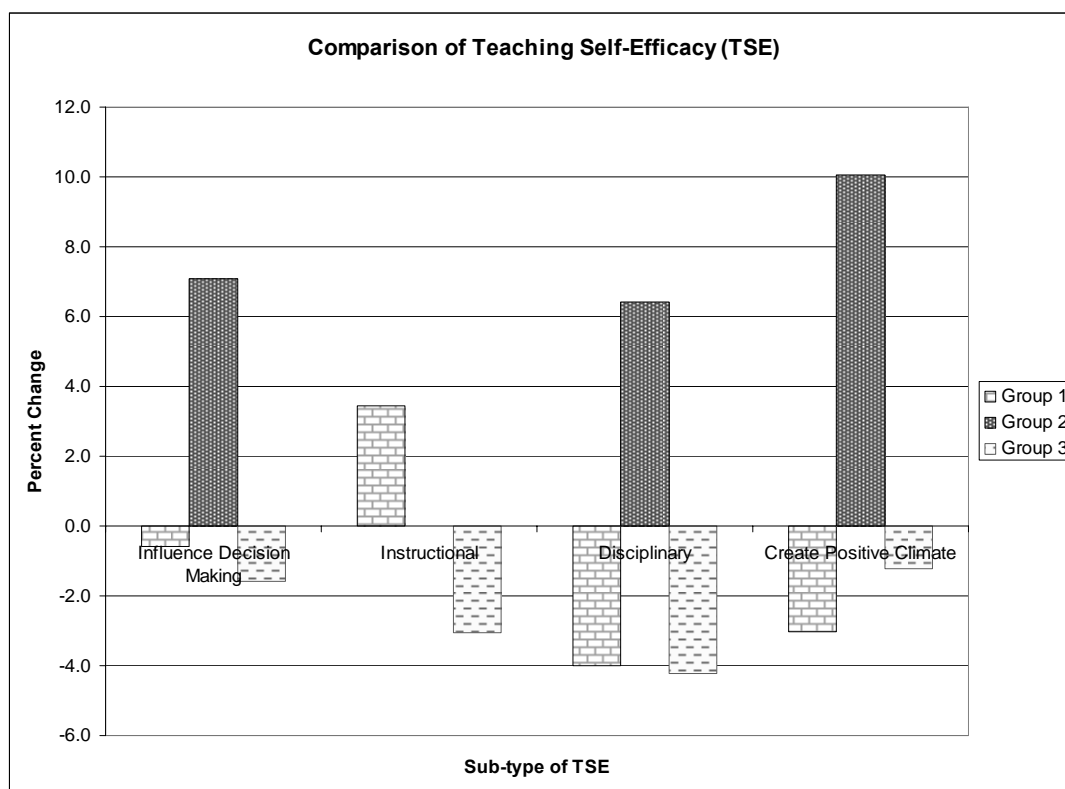


Figure 4. Comparison of TSE for undergraduate TAs.

The undergraduate students who received leadership training simultaneous to serving as TAs (Group 1) demonstrated an improvement in just one sub-type of teaching

self-efficacy: instructional. Compared with Group 3, who received no leadership training, it appears that the only area in which the course was a benefit was instructional. However, after another term of TAing, Group 2 showed strong improvement of self-efficacy. The only change in teaching self-efficacy in Group 3 was due to their experience TAing. Having less life-experience caused the undergraduates to initially overestimate their ability. The negative change shows that the experience of being a TA adjusted that estimation to one which was more realistic.

Hypothesis 2: if similar leadership training is given to graduates and undergraduates, then it will be equally beneficial for each group.

The results of the survey for graduates and undergraduates are shown below in Figure 5.

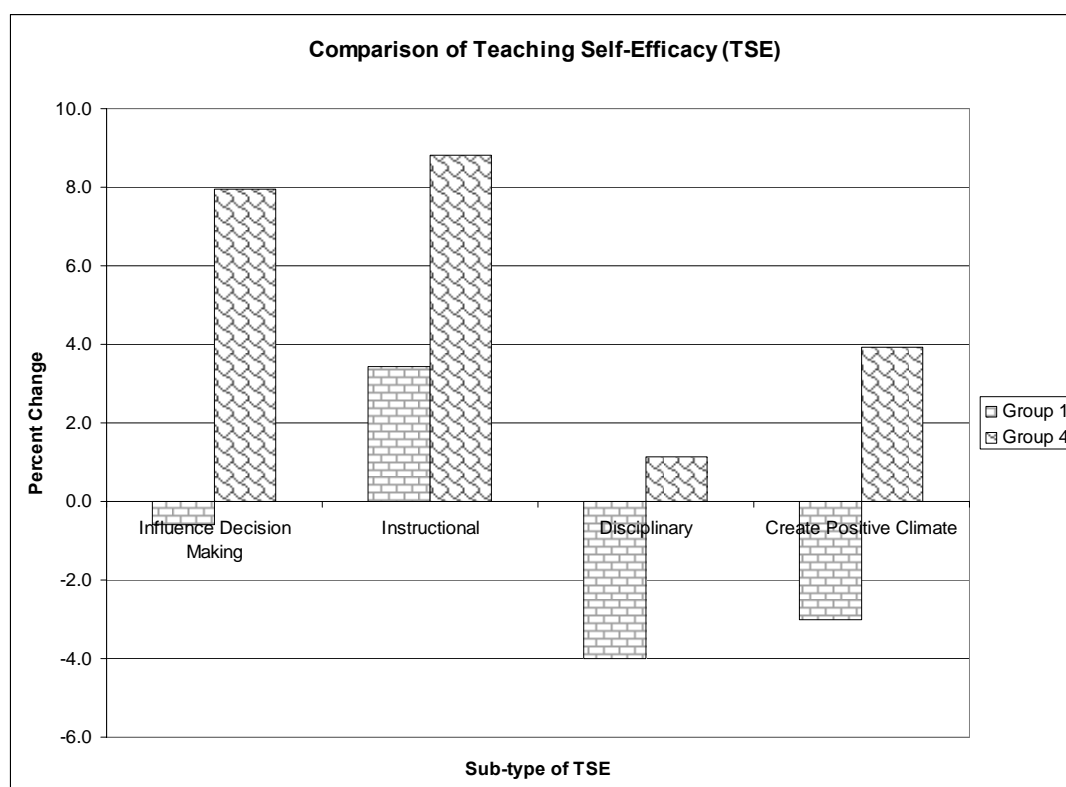


Figure 5. TSE for graduate vs. undergraduate TAs.

The undergraduates (Group 1) showed a similar relative trend to the graduate TAs (Group 4), but actually improved in only one area: instructional. The graduate TAs were

much more conservative than the undergraduate TAs in their pre-survey data. Having more life experience, they were more aware of how much they did not know. This caution influenced their initial judgment as well as their appreciation of the course. Being more aware of their need for it, they generally stayed more focused during class time and made a greater effort than the undergraduates to learn the material.

Qualitatively, the graduates showed positive growth in every area. Most of their homework was reflective assignments. In the final reflection assignment, students were asked which topics were most and least useful. They were all weighted equally as most useful, showing that the original selection of leadership topics was good. For which topic was least useful, almost all the students reported that it was only because that topic simply was not utilized during the term. For example, one student did not find the conflict section to be helpful, because no conflict situation was encountered with the students. The following are some quotes from students from their final reflection assignment:

“I believe I experienced the most growth in my ability to listen actively with students and being able to connect with students, earning their trust. Being in constant contact with them, I have the opportunity to listen to their many ideas, questions, and complaints, and I have grown because of it.”

“The most useful skills I learned were those that applied to relating to students and encouraging them to be active learners. I found these skills were very useful, because my position involved a significant amount of interaction with the different groups of students. This term has definitely been a great learning experience for me, and an opportunity to work on my leadership skills.”

“Given the same problem, different students come up with different solutions. Some of them might be even out of track. In such cases, we should encourage them by saying that there can be multiple ways of solving a problem and it is good that they can come with some unconventional solution, but at the same time tell them if they are doing something wrong. Encouraging in such situations helps them becoming more creative and better problem solvers.”

“I found the conflict resolution skill taught in this class pretty useful. Using the PAUSE principle, I was able to successfully negotiate conflict in

several situations, in the classroom as well as disputes regarding grading. And on each occasion, we were able to come up with ways that satisfied both the student and me.”

Although the preliminary results of the study illustrate that leadership training for TAs shows promise as one part of the solution to improving engineering retention, the treatment should be repeated and studied further for a more complete conclusion.

2.7 Lessons learned and further recommendations

As with all new ventures, there was a steep learning curve and many lessons learned. At the same time, many of the students gave very positive feedback, so the course felt like a success even though there was no previous leadership training course to compare it to.

2.7.1 Building the course via collaboration with faculty

If the school has faculty who have more expertise in a particular area, it is good to get them to collaborate. In preparing and teaching a course on leadership, it is evident that no one person is an expert in all the different areas. For example, out of leadership, communicating, teaching and mentoring, the instructor’s greatest weakness was in the area of teaching. Teaching is one level of complexity, but teaching teachers how to teach is a topic which requires a great deal of experience and skill. So, students were invited to attend a one-hour seminar from the director of the Center for Teaching and Learning, which counted as attendance for one leadership training class period. In the final reflection assignment, many students had very positive things to say about this seminar. The main point, after all, is for TAs to get exposed to the best teachers and training, not simply to keep the training “in-house.”

2.7.2 Benefits of the triad structure

One of the best things about the course was using the triad structure to teach skills. Research already points to this being the most effective way to learn a new skill and it worked extremely well. The students understood the foundation of theory of a

skill, saw it demonstrated and got to practice it themselves from three different angles. In a course which is about interpersonal skills and good teaching, these things must necessarily be modeled. The assignments also gave the graduate TAs a chance to think about and continue applying their skills outside of class. Although the triads worked well, one mistake was in allowing the students to pick triads themselves. If students are allowed to do this, they tend to stick to their own gender and cultural background and cannot learn as much from others, or be as motivated to stay on-task. Some triads were occasionally noncompliant, preferring instead to simply talk instead of doing the exercise. As the instructor, it was helpful to keep circulating the room during exercises to encourage students to stay on track.

2.7.3 Collecting statistically complete data from surveys

For the most statistically significant results, all TAs should be included in the results of the survey. It was difficult to survey all the TAs because of the normal transition at the beginning of the term. Some TAs did not attend the first leadership training class, which is when the pre-survey was given. It is also common for students to skip the last class, which is when the post-survey was given. Therefore, the results of the survey give some idea of the effectiveness of the leadership training course, but are not complete.

2.7.4 Advertising the course to TAs

It is advisable to be careful in how the course is presented to students. There is already a very positive TA culture built up around the undergraduate TekBots program. Most of the TAs were already experienced when they took the course. Some of them were sensitive to the name *TA Training*, as they felt insulted to be trained in something they were already experienced in. However, when it was clarified that it was *TA Leadership Training* and that their previous experience was valued and would only be augmented, they were much more enthusiastic about the course. Also, the engineering culture of learning is often resistive to being educated in non-technical topics, so it is good to be strategic with the introduction of leadership training in any case.

2.7.5 Motivating factors for graduate and undergraduate TAs

The leadership training course was beneficial for most graduate TAs. As with all learning, the people who got the most out of it were those who also put the most into it, i.e., those with a sense of personal motivation. Most TAs recognized this course as a great opportunity to learn much-needed skills, but some simply signed the attendance roster and participated minimally. Although disappointing because the course was intended to benefit them and their students, it also raised the question of motivation. How could things be changed to motivate students to enthusiastically learn and apply leadership skills? Motivation means consequences for an unsatisfactory effort and rewards for satisfactory work. The course itself is pass/fail and there is no further room to create such consequences or rewards. In designing such a course into the curriculum, one must consider and live within what systematic limitations exist or change that system. For example, a negative consequence may be the possibility of being fired as a TA. A reward may be stepping up the pay scale for more training and experience, as with University of Wisconsin, Madison. Neither the personal motivation of the TAs nor the motivation which the TA program structure provides may be entirely controlled, but they may be influenced to a point.

The lessons learned from teaching the undergraduate section of TA leadership training were entirely different. Because of the structural differences, such as pay vs. grade, undergraduate TAs were not as motivated. They did not turn in any of the assignments and there was essentially no way to motivate them to do so. In addition to this, they seemed to get less out of the course because they had less life experience and responsibilities. The grad TAs, on the other hand, knew that they needed to know the information and readily took it in. One good idea for further development would be to design the same course, but on two different levels, targeted for grads and undergrads. Another possibility would be to mix the grads and undergrads together in one course. It is an issue for further exploration.

2.7.6 Integration for international students

This course became a positive point of integration for international students. Many of them responded well to it and used it as a platform for learning about the culture of American education and how they fit into that. Because it was a course for first time TAs, many of the international students were also in their first term of grad school. They enjoyed connecting with their American peers and spending an hour of their week that encouraged them and learning a non-technical topic. However, some international students were quite shy and one mentioned, after the course was over unfortunately, that the instructor spoke too quickly to understand. It is helpful to ask for feedback regularly and listen especially to the international students.

CHAPTER 3 – THE REDESIGN OF *CIRCUITS II* AS A PLATFORM FOR LEARNING LAB

Abstract – The EECS department at Oregon State has been revitalizing the engineering curriculum by introducing an educational innovation called a Platform for Learning[®] (PFL). The Platform has already been successfully introduced into freshman, sophomore and senior-level courses and is now being introduced into junior-level courses. This paper describes the process of integration of a PFL into Circuits II, a junior-level course which teaches concepts of frequency response in circuits. The process includes multiple cycles of design, implementation and evaluation.

3.1 Introduction and background

Preparing industry-ready engineering students is an increasingly difficult challenge, which today's educators face. The field of engineering is continuously growing more complicated and graduates are expected to be technically proficient, independent thinkers and innovative problem solvers [23]. In the face of these challenges, fewer students are persisting in their electrical engineering education [24].

There is no one source for the problem of retention of engineering students, so the solution is not particularly simple. Educators can only continue to assess and address the most serious problems. Part of the solution at Oregon State University (OSU) has been to revise its curriculum around the Platform for Learning[®] (PFL) concept [12]. A Platform for Learning is a “set of common, unifying objects or experiences that weave together the various classes in a curriculum” [12]. The EECS department uses the TekBot[®], an autonomous robot on which students build on throughout their four year curriculum, Figure 6. The PFL is already a proven success as the backbone of many EECS lab courses. It was first integrated into the lower level courses, then spread to senior level courses and is now filling in at the junior-level. At OSU, two junior-level courses are

Circuits I and *Circuits II* (ECE 322 and ECE 323, respectively). ECE 322 has already been revised to include a PFL lab which is building a DC power supply.

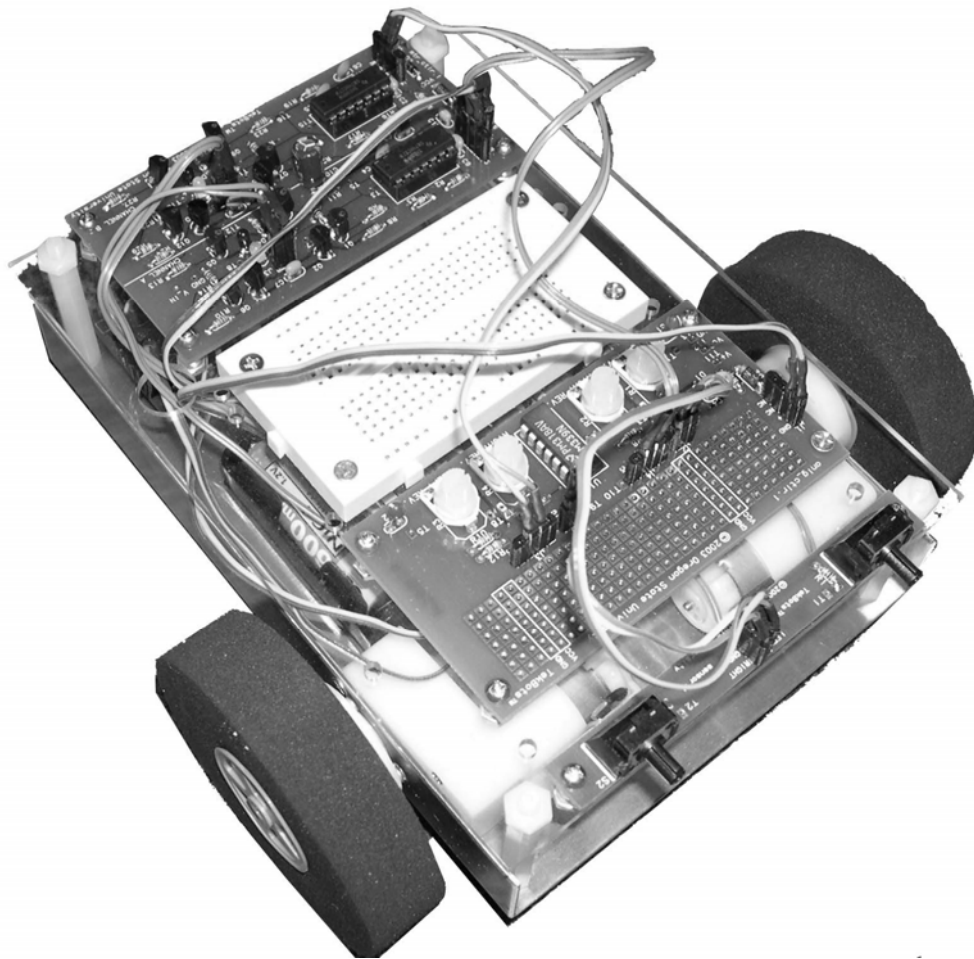


Figure 6. The basic TekBot.

The Circuits II course (ECE 323) at OSU was redesigned to better reflect new methods of student learning and improve student innovation. The lab was designed to strongly reflect the lecture content and schedule. It was also designed to be a real world design experience by making each week's lab a functional block which was a part of an entire system, integrated and assembled by the end of the term. The lab built on previous knowledge of the students from other PFL labs, so that they were able to complete a more advanced project. The ECE 323 course previous to revision was independent from other engineering courses and had been unchanged since 1998.

The course was also designed in light of modern self-efficacy theory. According to this theory, the mastery experience is the greatest influencing factor [1]. Because people with higher self-efficacy tend to persist in a given task-specific area, it is desirable to increase the engineering self-efficacy of undergraduate students. However, once some amount of self-efficacy is established, it is not catastrophically detrimental to their persistence to experience some failures and setbacks [1]. This is the frame of reference in which the new ECE 323 lab was designed. The foundations of students' engineering self-efficacy had already been laid down during their freshman and sophomore years. This means that a junior-level lab may be designed as less complete and more open-ended, with room for students to make and learn from mistakes. This experience would ideally better prepare them for success in their Senior Design project, which is almost entirely open-ended.

The rest of this paper explains the process of the ECE 323 lab creation: preparation, design, implementation and evaluation, followed by a conclusion.

3.2 Process of ECE 323 Lab Creation

One difficulty with the traditional curriculum is that there is often no intentional continuity between lab courses within the engineering department. So, even if a professor creates one excellent lab course, students could not be prepared beforehand or benefit from a continuation in further courses.

Creating a new lab course is a complicated process which involves design, implementation and evaluation. Once the first pass is completed, the course should be refined by further cycles of redesign, implementation and evaluation, Figure 7.

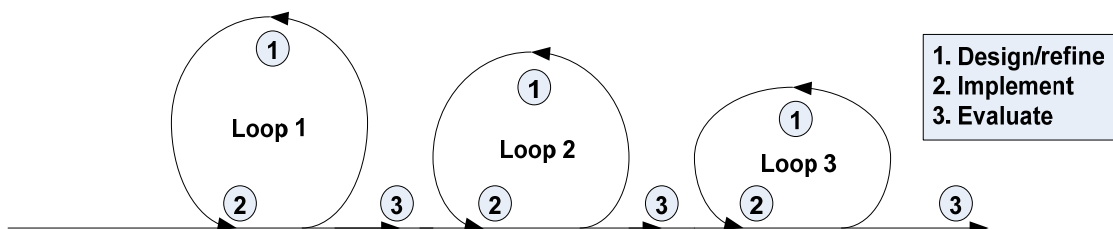


Figure 7. Process of lab creation.

3.3 Loop 1

The following is a description of the first loop of development: designing, evaluating, and implementing the new lab.

3.3.1 Phase 1: Designing the new lab

In preparing to design the new lab, there were many aspects to consider. Before even brainstorming any ideas for the project, it was necessary to take stock of the given constraints. Some of these constraints included: being a PFL lab, official ABET requirements, course learning objectives, program outcomes, student course load, practical points of integration with the lecture, and requirements from the professor.

To integrate the PFL into the ECE 323 course, the key values were reviewed. The key values, which formed the setting for the design of the new lab, are: ownership, continuity, context, fun, and hands-on learning, Table 3 [7]. These values left the scope of the design fairly open, except for continuity because there were already quite a few PFL labs in place at the lower level. In order to improve continuity between courses, some hardware and knowledge from previous courses was reused in this one.

Table 3. Aspects of a Platform for Learning which enhance a curriculum.

A Platform for Learning core values	Description
Ownership	Each student has his or her own platform. They are a show piece of students' accomplishments.
Continuity	Implementation of theory from various classes towards a common platform helps students see the connections between various courses.
Context	Students learn and come to understand theory through application and hands-on experience.
Fun	Exciting hands-on experiences inspire students to learn.
Hands-on Learning	Implementation can be other than what theory predicts.

The course was also designed with major program educational objectives in mind, also called cross-cutting competencies, Table 4. They are depth, breadth,

professionalism, troubleshooting, innovation, and community. The objectives were gathered from ABET requirements, faculty, and industry representatives. For the course to meet these requirements, the content and scope must be appropriate. Also, it must provide the opportunity for a reasonable amount of troubleshooting within the structure of the lab as well as the possibility for innovation above and beyond the standard structure. Lastly, the written rules, regulations, and course culture should foster community and professionalism.

Table 4: Educational objectives in enhancing engineering education.

Educational Objectives	Description
Depth	The core concepts underlying a particular topic.
Breadth	How core topics are interrelated.
Professionalism	Exhibiting good skills in communication, teamwork, project management, and ethical issues. Having a courteous and generally businesslike manner in the workplace.
Troubleshooting	The process by which problems are identified, isolated, and resolved.
Innovation	The ability to solve problems in a new or unique way.
Community	The ability to work together as one team where each member of the team still functions as an individual with their own responsibilities.

It was important to consider where the new ECE 323 course would fit into the existing PFL curriculum in terms of level of difficulty and topic, Figure 8. ECE 323 is a junior-level course, so the level of difficulty should be between sophomore and senior levels. The content included the following:

- New commands in SPICE
- Dynamic operation of digital circuits
- Transistor implementation of logic gates
- Clock generators and oscillators
- Frequency response
- Multistage amplifiers
- Feedback in circuits and analysis

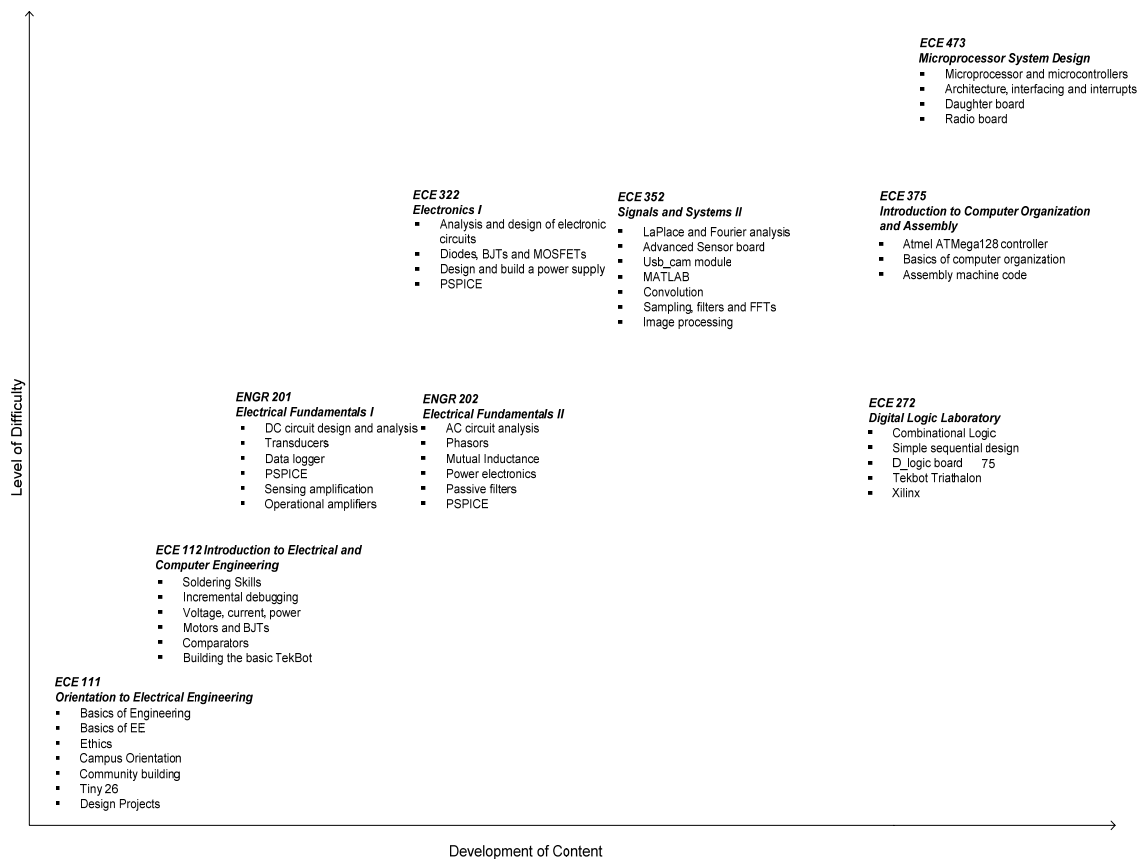


Figure 8. PFL curriculum

In order to make sure that the new lab was an improvement, as well as gather ideas, the previous lab materials were reviewed. The previous labs were written in a straight-forward manner, but they lacked a practical context for design and an intentional continuity. There was no opportunity to practice professionalism, community, or innovation. There was a survey from the last term the old lab was offered, see Appendix C for the survey and results. Some relevant findings from the survey show that students did not feel that pre-labs were valuable or see the connection between the lecture and the lab.

Although the lab portion of the course was extensively redesigned, the lecture was initially not altered, so it was important to research it. A common frustration for students occurs when lab material is not aligned with the lecture material. To avoid this, the professor provided his lecture schedule so that topics in lab could be scheduled to come during or after they had been presented in lecture. In addition to this, the content of the

lecture portion of the course, including homework assignments, midterms and projects, provided ideas for the lab. Once the lab was redesigned, the professor also slightly altered his lecture to best prepare students for lab. In this way, the lab and lecture may mutually reinforce the learning which takes place in each setting.

After laying the ground work, the next step was to actually design the new lab. This involved much collaboration from many people and was a strong team effort. There were at least four phases of development which can generally be categorized as: people, ideas, research and design, and documentation.

3.3.1.1 People phase

The first step was to build a strong PFL lab design team; the people phase. Undergraduates were interviewed and two were selected for summer work. Their perspective was invaluable because one student had not yet taken the course and the other had taken the old course. They also served as a reality check on the level of difficulty of the lab being developed. In addition to this, the main purpose of the TekBots group is to educate students, and this summer work was an excellent opportunity to develop the students' technical skills. There were several experienced designers among the group to act as technical consultants. Their input was critical, especially at the beginning stages to help shape what was feasible. There was also a documentation person hired to write up the labs after being developed, so that that the labs were as professional as possible, lending visible credibility. Last, but not least, there was one manager to oversee the entire project, and to keep it moving forward on track.

Initially, it was important to get input from many parties, such as the current lecture professor, future lecture professor, department head, and many others. This served at least two purposes. For one, getting all these people involved from the beginning gave the greatest amount of ideas for the new course. The collective experiences of all these people are vast and varied and they had a great deal to say. The second purpose was that each person that would be involved with the course would have a sense of personal interest, ownership and buy-in to the new lab. This involved a certain amount of relational finesse via continued communication.

3.3.1.2 Ideas phase

The ideas phase began with a brainstorming session for the core concept of the new PFL lab. All key personnel such as the course professor, related professors, the design team, the department director, the educational director and other technical professionals were invited. Each person was asked to come with at least one idea for a new lab. The design team came with one solid idea to present for criticism. With so many perspectives, one solid idea emerged from the meeting and was thoroughly critiqued from every angle. Some angles included fit into PFL curriculum, level of difficulty, relationship to lecture and ‘realness’ of the project. The idea which emerged was for students to design and build an audio transmitter and receiver, using some PFL boards from previous courses, to remotely control the movements of their TekBot. The final block diagram is shown below in Figure 9.

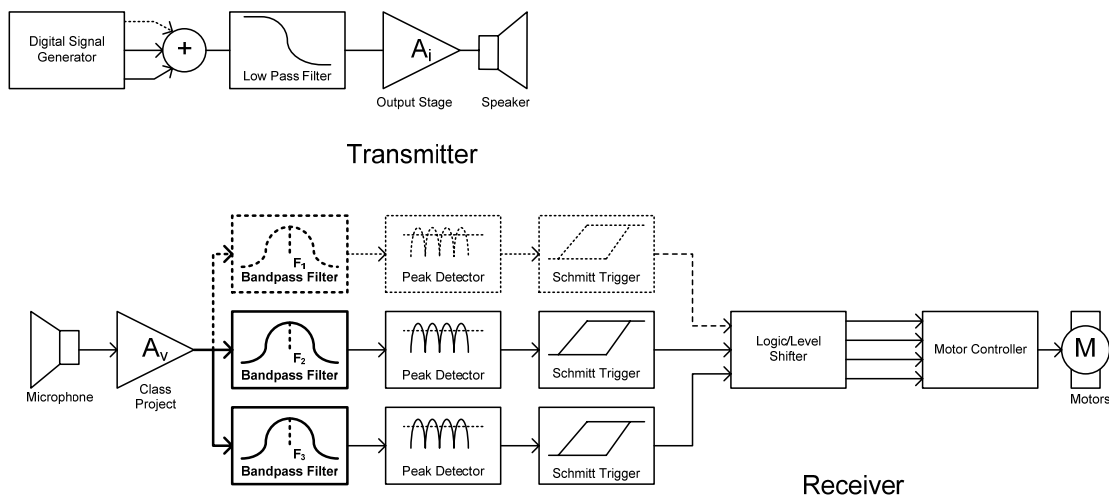


Figure 9. Transmitter and receiver block diagrams.

3.3.1.3 Research and design phase

Research and design was, time-wise, the main part of this project. The end goal was to build one functioning transmitter and receiver to verify the feasibility of the project as well as get ideas for individual labs. During this phase, many problems were encountered and solved, which required many hours in the lab. Research and design is a process that cycles through creating ideas, testing them and refining them. Most of the time, these stages overlap and may easily get messy and disorganized. It is critical for the

manager to give such a project continuous direction, clarify ideas and organization, and motivate the team by pointing out intermediate successes.

During development, the team also kept track of the design process, so that labs could be designed around leading students through the same processes. Design solutions were sometimes selected which would make educationally better labs, as opposed to the best technical solution. Consideration was given to appropriate level of technical difficulty, cost, amount of time for one lab, and usefulness of lab to demonstrate PFL and course concepts.

3.3.1.4 Documentation phase

The final development stage was to devise and document the written labs, Appendix D. This stage is as critical as the actual content because it has to do with how the content is presented. In terms of presenting background and purpose, and grading criteria the labs were made to be as straightforward as possible. A lab which is otherwise organized allows students to focus on learning the material. In order to develop students' independent thinking skills and prepare them for the senior design course, they were given a solid framework, but not all the details needed for the lab. For example, the blocks are thoroughly defined, but some blocks require bypass capacitors between stages for DC decoupling. These capacitors are not explicitly mentioned, but they are a detail which is required in order for the entire system to function properly when integrated. In addition to this, two labs require students to design topologies for that particular block, but the input and output signals and functionality are defined. The experience of searching out designs better prepares students for senior design, when they must search out and design an entire project.

3.3.2 Phase 2: Implementing the new lab

The labs themselves (also called 'Sections') are summarized as follows:

1. Introduction to PSPICE and Bode plots (1 week)
2. Frequency generator, summing circuit, and low pass filter (1 week)
3. Single-stage amplifiers and active filters (2 weeks)
4. Output stages (1 week)

5. Peak detector and Schmitt trigger (1 week)
6. Microphone and class project (1 week)
7. Building the receiver (2 weeks)

3.3.2.1 Section One: Introduction to PSPICE and Bode plots

Section One was designed to build confidence by easing students back into concepts which they had been exposed to in previous courses, while at the same time teaching relevant frequency response concepts. Homework assignments and the class project from lecture required a working knowledge of SPICE, so it was also advantageous to students to refresh their knowledge of this tool. The lab requires students to create Bode plots of several simple single-pole filters. Although the lab relies on previous knowledge and relates strongly to lecture content, it is the only one which does not explicitly build a block of the system from Figure 9. Instead, it introduces the system. During this lab, students also play a get-to-know-one-another game, receive lab kits and take care of other normal first lab business.

3.3.2.2 Section Two: Frequency generator, summing circuit, and low pass filter

The front-end of the transmitter is built out of a frequency generator, summing circuit and low pass filter. The transmitter uses a style of communication known as on-off-keying (OOK). It should generate two or three frequencies, depending on the desired complexity of control. Students are required to have a minimum of two frequencies, but may choose three for a challenge. A simple method to generate the frequencies was to reuse the digital logic board from a previous course. This board is reprogrammable and students simply download code which generates a selection of audio frequencies and move on to explore further frequency response concepts. The frequency generator is a counter which is clocked at 100kHz and generates square waves, Figure 10.

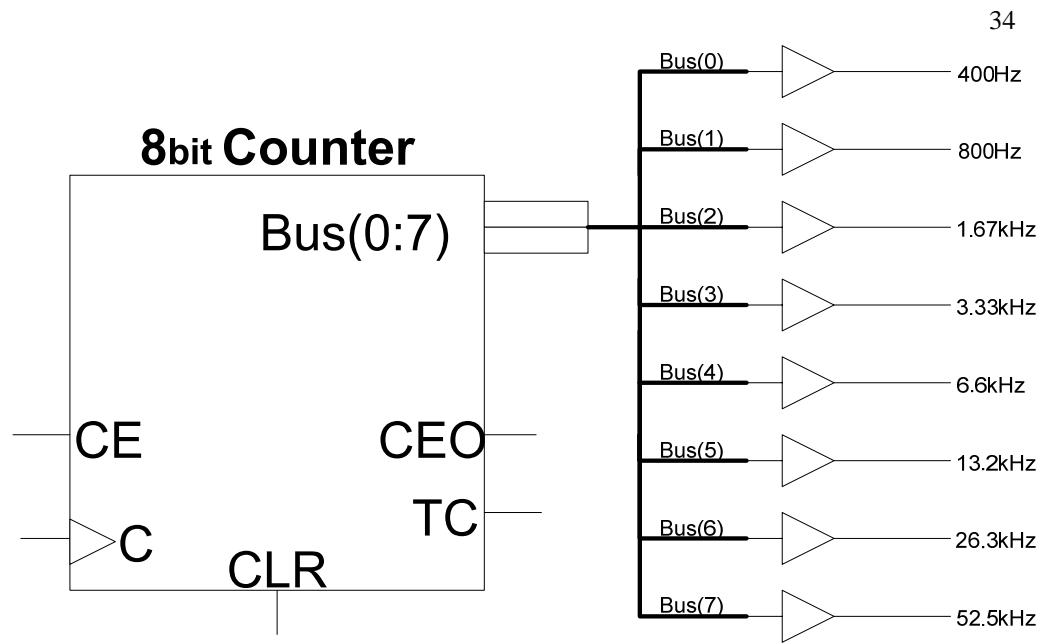


Figure 10. Schematic for generating selected audio frequencies.

Students learn how to design their circuits by being presented with two different topologies, one of which accomplishes the summing and the other, which is a low pass filter, as shown in Figure 11. They must design the integrated topology and calculate the appropriate values for the resistors and capacitor.

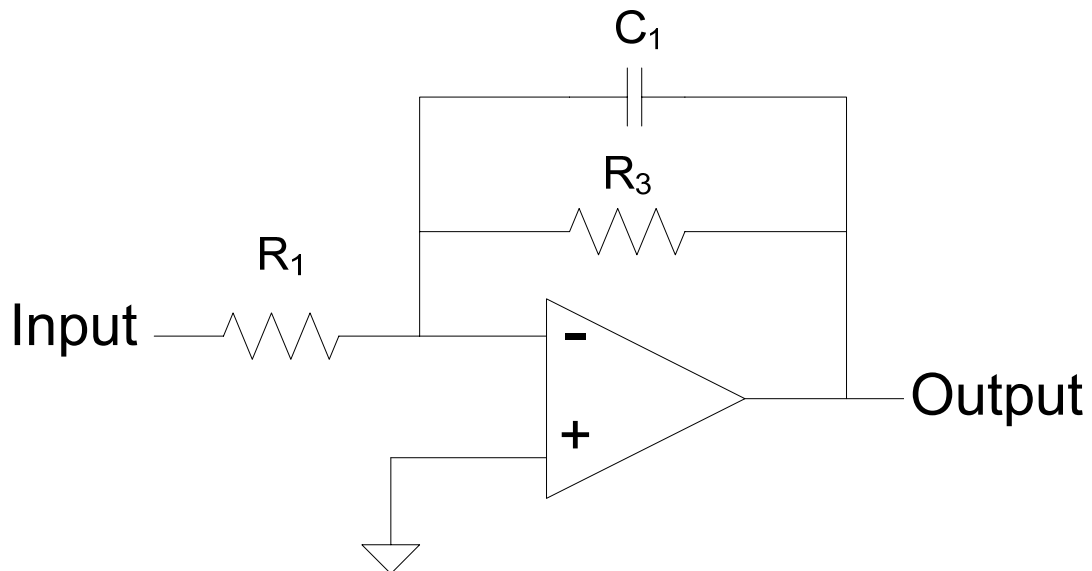


Figure 11. Topology for low pass filter.

3.3.2.3 Section Three: Single-stage amplifiers and active filters

Instead of completing the transmitter, students next learn about single-stage amplifiers and build their active filters, a part of the receiver because it follows the progression of the lecture topics. In addition to this, exploring single-stage amplifiers prepares the students for the class project, which is a three-stage amplifier. The single-stage amplifier forms the basis for an active filter, as shown in Figure 12. Students also explore the effect of frequency on the impedance of capacitors and inductors due to parasitic components.

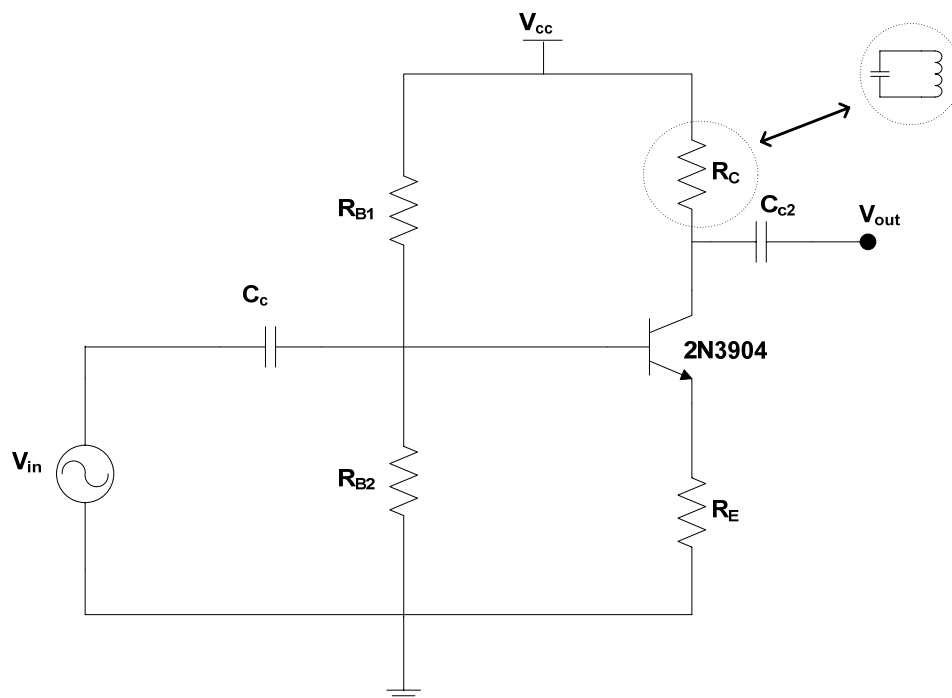


Figure 12. Building an active filter.

3.3.2.4 Section Four: Output stages

Students' engineering self-efficacy is pressured in Section Four when they must find, test and build the topology for an output stage. Only the input and output signals, load and power requirements are given, Figure 13.

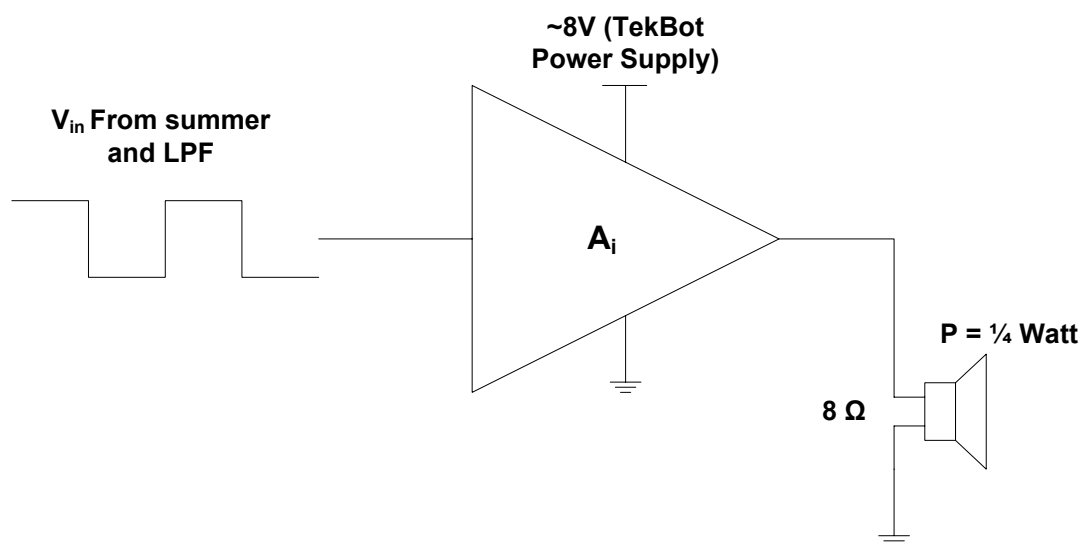


Figure 13. Output stage requirements.

Their task is simply to find the design for an output stage which meets the requirements of their design. This lab is designed to prepare them for the challenges of Senior Design, which is an entire year of building an unknown project. This lab also completes the transmitter. With a milestone in the project achieved, students experience some success early on in the term and are thus motivated to conquer the receiver.

3.3.2.5 Section Five: Peak detector and Schmitt trigger

The peak detector and Schmitt trigger are blocks in the receiver design which illustrate the lecture concepts of frequency response and positive feedback. As in Section Four, students must find or create their own design for a peak detector.

3.3.2.6 Section Six: Microphone and class project

The course includes a design project of a three-stage amplifier, Figure 14. Previous to redesign, students only completed the project by hand calculations and SPICE simulations. After the redesign, the project was integrated into the lab, so that they also physically built and characterized it. Then, they proceeded to use it as a block in a greater system, giving the course project a greater purpose and context. The concept of frequency response in amplifiers was handed off between lecture and lab as the settings worked together to clarify the concept.

ECE 323

Design Project

Due: Nov. 29, 2005

Note: This design project is equivalent to a take-home exam. You are to *do your own work* and you may not consult with others. If you need help you may consult your instructor or the TA.



The activist group SUCCR\$ (Students for Undergraduate Curriculum Cost Reductions) is seeking a circuit for an inexpensive megaphone to help them shout their slogans around the administration building.

You are to design an audio amplifier to amplify the signal from a high impedance (15 k Ω) microphone and directly drive an 8-ohm speaker.

The amplifier will have the following specifications:

- Midband gain (v_o/v_i) of $100 \pm 15\%$. (Note: This includes the effect of source and load resistance. To achieve this gain, your input resistance must be quite large and output resistance must be low. Assume 8-ohm load.)
- Operate with a source resistance (of microphone) of 15 k Ω .
- Output resistance should be less than 10 Ω (for good power transfer).
- Bandpass frequency response from 20 Hz to 20 kHz. Frequencies indicated are -3dB cutoff points.
- Use only capacitors, 1% resistors (see appendix G), and 2N3904 transistors.
- Operate on a single 12 V battery.
- AC couple the input and output.
- Above specifications must be met for the full range (min to max) of transistor parameters indicated on the data sheets.
- -3dB cutoff points of the frequency response should not depend on capacitances of the transistor.
- Output voltage swing must be at least 2 V p-p.

Submit a report, which includes:

- Schematic diagram of your final design with all component values indicated.
- Analysis **clearly** demonstrating that your design meets the above requirements for the full range of transistor parameters.
- SPICE simulation results showing mid-band gain and -3dB cutoff frequencies.

Note: You will be graded not only on correct design but also on the clarity with which you present it. I should be able to easily follow your analysis. Your report should not be a play-by-play of how you arrived at your design; rather, it should be a concise analysis of your final design demonstrating that it meets the specifications.

Resist the temptation to "design by SPICE", i.e. blindly adjusting your circuit until SPICE gives you the desired results. SPICE simulation is for verification only. A design that meets spec. in SPICE but has no supporting analysis will get no credit! However, if SPICE gives you results much different from your analysis it *usually* indicates that either your analysis is wrong or that your SPICE netlist/diagram is mis-wired.

Although not required for the report, you may find it useful to use SPICE to verify that your DC bias conditions are correct.

For designs that meet the specifications, extra credit will be given for clever design to reduce component count or cost.

Figure 14. ECE 323 class project.

3.3.2.7 Section Seven: Building the receiver

This was the final lab in which students integrated the receiver to control the movements of the TekBot. The receiver decodes the signals from the transmitter and determines how to move the TekBot around. The lab is conceptually simple, but leaves ample time for students to fully integrate the project and rework sections that failed previously.

3.3.3 Phase 3: Evaluating the new lab and continuing improvements

The last phase in the first pass was to evaluate the new lab. In order to accomplish this, the students were given a detailed survey on the lab portion of the course; see Appendix E for the survey and results [25]. Although the survey results were slightly disappointing, the students themselves must also be taken into consideration. Many of the students were just returning from the MECOP internship program and readjusting to being students. They also had legacy TekBots boards which were not compatible with the new labs and caused a good deal of frustration. One student was actually retaking the lab because the student did not pass the course. Having experienced both the previous and redesigned lab, this student was in an ideal position to comment on the revision. This student made very favorable comments on the new lab such as liking that labs were composed of blocks which together built an entire project over the term, and that labs were solving practical problems as opposed to experiments with little connection to real world problems, and the clear connection to lecture.

While the overall content, flow, level and connection with lecture were successfully implemented, there were some details which needed to be addressed. For example, the grading guidelines were not as clearly defined as the students would like. They were very concerned with precisely where every single point came from. Also, the TAs needed a consistent grading rubric, so that they would grade fairly from section to section.

3.4 Loop 2

The following is a description of the second loop of development: designing, evaluating, and implementing the new lab.

3.4.1 Phase 1: Refining the lab

The lab required redesign in several areas: addition of grading guidelines, revision of the written lab, addition of project specification and presentation requirements and revision of Section Six.

Grading guidelines were created to make the scoring more fair for students and TAs alike. Each lab is worth ten points per week and is broken down into the following categories: professionalism, pre-lab, lab and study questions, and demonstration. Professionalism includes leaving a clean lab station, making a neat, typed lab report, turning in the lab report on time and stapled and bringing the necessary equipment to lab, i.e. coming prepared. Pre-lab must be completed before the lab in order to be graded afterwards, verified by a TAs signature. Lab and study questions are graded based on correctness. The demonstration is a piece of functionality which the student must demonstrate to the TA for credit. The demonstration is specified in the lab manual with a detailed break-down of functionality and points.

The written lab contained some minor flaws. After designing and creating a lab, the team itself is typically too close to the material to catch small mistakes and errors, but a student, reading through the lab for the first time will find each and every one! These errors were tracked by simply leaving a copy of the lab manual in the lab room and noting student comments. In addition to this, students pointed out concepts which were not clear. This is a more subtle and difficult problem to fix because there is a fine balance between making the lab fair and clear, and requiring students to be responsible for their own learning.

In order for students to grow in more than the technical area, a project specification and final presentation were introduced to the course requirements. The project specification is a document which is modeled on a real-world one, but is specific to the ECE 323 project. Students add functional descriptions, a schematic and verbal

description of each block week by week. They also give a final presentation about their project. The main focus of the presentation is on their verbal skills, clarity, organization and professionalism but they are also graded on their technical understanding and ability to field questions.

Due to a change in lecture professors, Section Six was modified. The new professor no longer assigned an extensive project to design a three-stage amplifier, so the lab was shortened to one week and students use a simple op-amp to build the amplifier.

3.4.2 Phase2: Implementing the lab

Implementing revisions required much time and attention to details. The grading guidelines were designed and created to be fair and clear about the distribution of points and simple to use. An outline of the project specification document was created for students to complete and the final presentation was specified.

3.4.3 Phase 3: Evaluating the lab and continuing improvements

The course continued to improve based on these changes. In the Spring of 2007, the class did not have the problem of legacy TekBots parts, which caused for much less frustration. Also, they had been in school for the last two terms and were accustomed to being students as opposed to working on an internship, so they did not experience any extra transition in the course. Students mentioned in lab their appreciation for the clarity of the grading guidelines. They were able to relax about points, normally a high-stress topic, because they knew exactly how they would be assigned. TAs also appreciated the clear standard for grading and having a reason for the grades they gave.

Students in the spring also had the additional course requirements of a writing a project specification document as well as giving a final presentation about their project. The project specification document was designed to build technical writing and documentation skills and give them a more integrated real-world project experience. Students are given a framework for the document which they complete with the details of their own individual projects. They include content such as block diagrams, signal definitions, schematics, and a written description of the circuit. The project specification document was an opportunity for students to summarize their work and prepare for the

final presentation. In the final presentation, students presented their projects in groups. The presentations are designed to get them accustomed to preparing and giving formal presentations of their technical work. The content included at least an overview of the project, any innovations to the standard design, and problems encountered and solutions implemented. Most students did an excellent job on both the project specification document and the presentation. Other PFL course also have these requirements and students are getting accustomed to what is expected and improving on their performance with experience.

3.5 Conclusions and lessons learned

After evaluation, the course did not require much redesign, only some refinement. Any new course needs attention to details which only become clear upon implementation. The overall focus, content and schedule of the new lab as originally targeted was well-achieved. Many of the lessons learned had to do more with effective teaching methods.

Because this lab was very different from the old one, it was important to set students up with appropriate expectations. As the curriculum becomes infused with TekBots labs, students are getting a more uniform feel for labs, but any transition still requires a good deal of effort. As more and more students take the course, it is gaining a reputation with a standard set of expectations. At the beginning, when these expectations are in flux is the most ideal time to set a positive standard and be proactive about addressing issues. Students had an especially difficult time with labs which defined the functionality, but provided no circuit topology. Even though the rationale behind such labs was clearly stated at the beginning of the labs, most students do not actually read labs, but instead rush ahead to see *what* they must accomplish, not *why* they must do it. As it has always been, the learning must be done by the student, with assistance from the teacher. The most excellent teacher cannot reach every student and the poorest teacher cannot stop students from learning.

It was good to design a course which builds an entire project over the term. Students saw the challenges of building a large design, the advantages of breaking it down into small blocks and the difficulties associated with integration. This style of lab

exposed them to many aspects of real world engineering so that they may be prepared for it. Students experienced many frustrations, but benefited greatly.

CHAPTER 4 – ADDITIONAL RESEARCH AND REVISION FOR 'EXTENDING A PLATFORM FOR LEARNING TO UPPER DIVISION ELECTRICAL AND COMPUTER ENGINEERING COURSES'

4.1 Introduction

A thesis previously written by Adriaan Smith, *Extending a Platform for Learning to Upper Division Electrical and Computer Engineering Courses*, required additional survey data. This chapter briefly describes the survey and analysis of the impact of this work based on the course changes developed for ECE 375 and ECE 473.

4.2 Editorial suggestions

The original work covered an introduction to the PFL concept, integration of TekBots into *Computer Architecture and Assembly Language Programming* (ECE 375), *Microprocessor System Design* (ECE 473) and *Signals and Systems II* (ECE 352). Each section included a description of the course content. ECE 375 was assessed by reviewing student labs and tabulating how many times a PFL concept was mentioned and to what depth.

In order to provide additional assessment, a survey was designed to assess ECE 473 over the past five years, from 2002 to 2006. The PFL was first introduced in 2004, so this covered data from both before and after its introduction.

4.3 Survey design

The survey was designed to cover two main areas: the effect which ECE 473 had on the PFL core values, and on the Course Learning Objectives (CLOs). In addition, students were surveyed on how well they remembered the course and its general

usefulness. The survey itself may be found in Appendix F. By comparing the effect of the introduction of the PFL, it was expected that the PFL core values would be improved.

Surveys were mailed out to students who had taken ECE 473 between 2002 and 2006 except for those currently living abroad. The following table illustrates how many surveys were sent out and returned for each cohort.

Table 5. Survey statistics

Cohort	Number of surveys sent out	Number of surveys returned
2002	50	4
2003	51	3
2004	52	3
2005	53	9
2006	44	3

4.4 Result of surveys

The survey results reflected the greatest improvement in PFL core values in 2004 when the lab course was introduced. The Course Learning Objectives followed a similar trend. The tabulated results may be found in Appendix G.

It was important to ascertain whether students clearly remembered the lab portion of the course. As can be seen from the results of Figure 15, the students who took the course in the near past as opposed to the far past remembered the course more clearly. However, they all remembered the course adequately well, especially for the purposes of this survey.

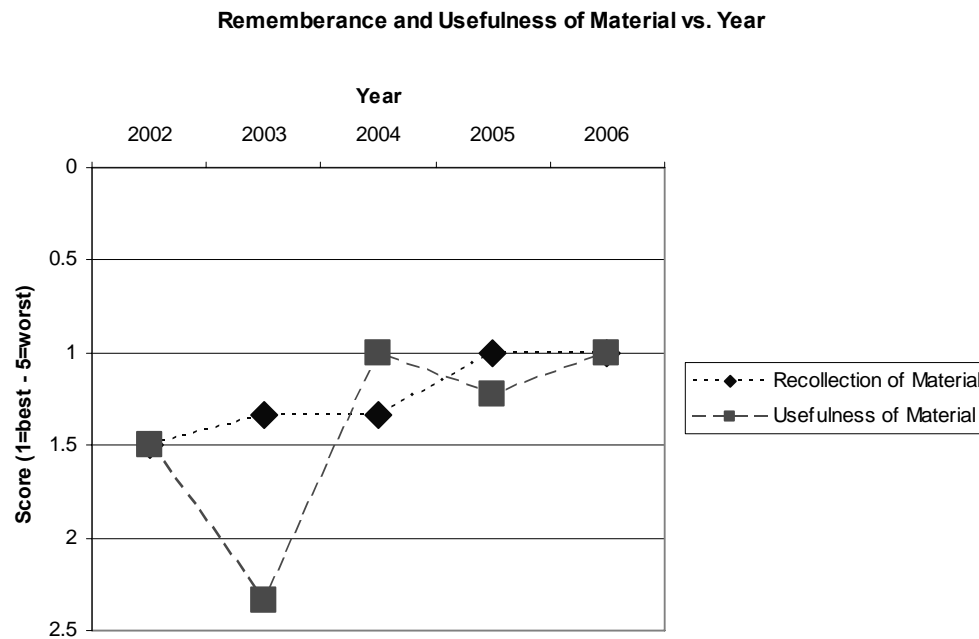


Figure 15. Recollection and usefulness of material versus academic year.

There is a large leap in how students rated the general usefulness of the course from 2003 to 2004, when the course was introduced. This is important to measure because it shows that the introduction of the PFL improved the general value of the course, not only PFL core values.

From 2003 to 2004, the PFL core values made a significant and noticeable trend upwards, especially compared to other years, as can be seen in Figure 16. Both years, the course was taught by the same professor, so it is impossible that a change in professors is responsible for this trend. However, a teacher does typically make the most improvement in-between the first and second teaching of a course. The most likely reason for the improvement is the introduction of the TekBots PFL in a major course revision in 2004. The TekBots core values would naturally experience a dramatic increase because the course itself was designed with the core values in mind.

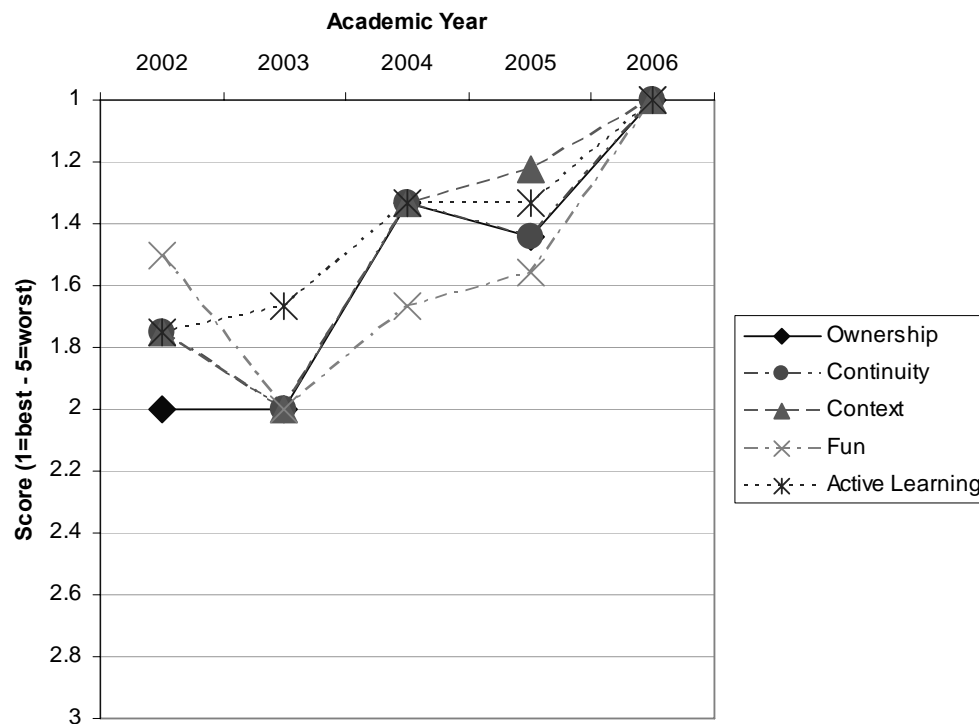


Figure 16. PFL core values versus academic year.

From Year 2003 to Year 2004, the value of ‘depth’ showed the most significant improvement of all values surveyed. It showed an improvement of 1 point on a scale of 1 point to 5 points. The actual question from the survey was “*The effect that ECE 473 had on my understanding of the core concepts underlying microprocessor system design was...*” The most likely cause for this improvement is the nature of the lab. With a PFL lab in place, students have the opportunity to explore the practicalities and realities of microprocessor system design. Nothing hits a lesson home like a hands-on lab, especially when things don’t work at first.

The course was also redesigned with the Course Learning Objectives closely in mind. From 2003 to 2004, they rose sharply, as with the PFL core values. (See Figure 17). They experience a dip from 2004 to 2005, when a new instructor took over the class.

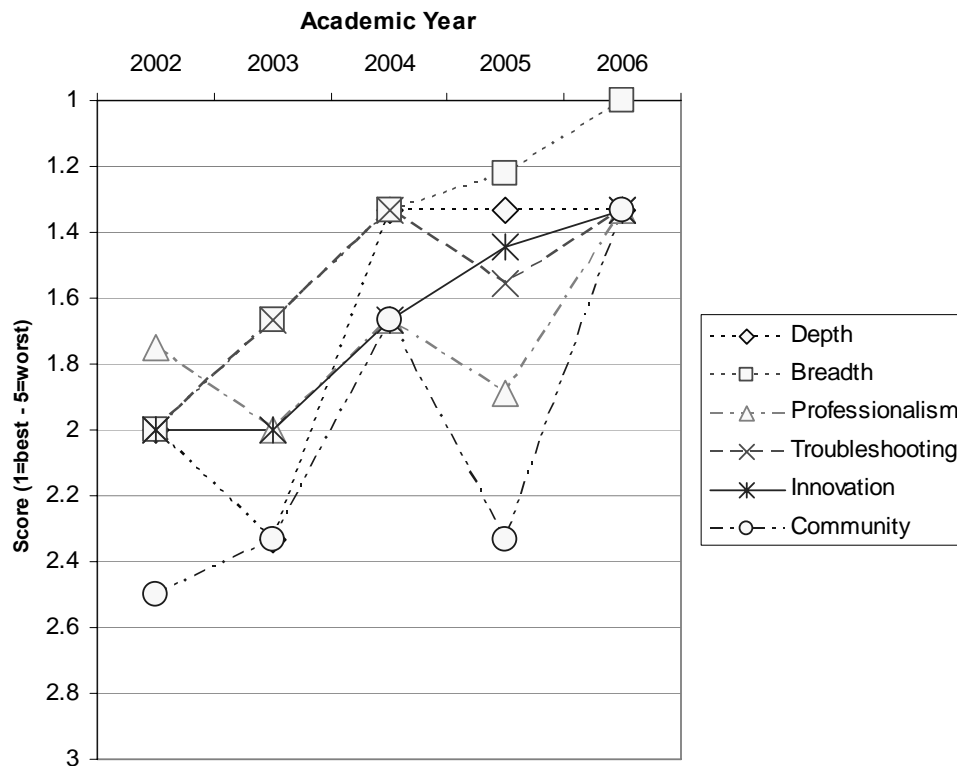


Figure 17. Course learning objectives versus year.

4.5 Conclusions

The changes as rated by students may be explained by three different factors: the course, the students and the professor. Overall, it appears that the course has improved, because of a general upward trend in PFL values as well as achievement of course learning objectives and the general usefulness of the course. The students seem to appreciate the course better when they have had a little more time to reflect on it, and get some distance from the sharp memories of the difficulties they experienced in the course itself.

CHAPTER 5 – FUTURE WORK

This research has raised more questions than it has answered. There are many points for continued research and exploration, but a few of the most interesting ones are as follows: continued evaluation of ECE 323 *Circuits II*, continued evaluation of ECE 507 *TA Leadership Training* via teaching self-efficacy surveys, restructuring the TA program for greater effectiveness, self-regulation of students, and the relationship between collaborative learning and self-efficacy.

5.1 Continuing research on ECE 323

The lab portion of ECE 323 underwent a major revision during the Summer of 2006 and was integrated into the existing PFL labs at OSU. Especially because it is so new, it is necessary to continue evaluating, refining and implementing changes to the course. There are, of course, some typos and explanations which could be more clear in the manual, which students and TAs have continued to point out and are being continuously updated. The effect of the new course is changing as the students who take the course change. When it was first offered, many of the students who took it were returning from an internship program. They also had legacy TekBot parts and the lab was designed around current PFL platforms. Even if the lab remained unchanged, the students who are going through the course are having a better and better experience because they have the latest PFL hardware and experience. It is necessary to evaluate the effect of the new lab separately to this.

5.2 Continuing research on ECE 507

It was difficult to evaluate ECE 507 *TA Leadership Training* because there are few TAs and the evaluation requires pre and post teaching self-efficacy surveys. For a thorough evaluation, all the TAs who go through the training must take both surveys. This is a tricky goal to accomplish because the IRB requires that such experiments and surveys be non-mandatory. However, it is an extremely worthwhile line of research. Most universities do not consider TAs to be a very high priority, but there is great

untapped potential both for the TAs themselves and for their students if they receive leadership training.

5.3 Restructuring the TA program

Although TAs may be trained for greater effectiveness as role models, the structure of the TA program itself should be updated for greater benefits to students and TAs. One area for further study is the best way to utilize undergraduate versus graduate TAs. Another area is to create a fair policy which would encourage graduate TAs to do an excellent job, as well as provide them with consequences for the converse.

The TekBots program is already quite strong regarding the second factor of self-efficacy, having an engineering role model. The real workhorse of the TekBots program is the undergraduate TA. They are ideally suited to improving students' self-efficacy for several reasons. One reason is that the crème of the crop is selected to be undergraduate TAs. They are naturally the strongest candidates, academically and socially, who have the desire to participate in the program, as evidenced by their initiative to apply. Also, they have just had a very positive experience in some TekBots classes and are very enthusiastic about it. Being undergrads, they have more time and enthusiasm to volunteer to the program. Over time, the TekBots program has become somewhat of a 'club' for undergraduate TAs, which provides them with a positive piece of their identities in a large university setting as well as further opportunities for technical mentoring and growth as leaders. However, this factor also has room for improvement. In ECE272, graduate TAs form the top level of leadership. This is where the TekBots class structure and culture begins to break down and is a point for exploration. The graduate TAs are not familiar with the physical TekBot itself, TekBots culture and yet, are in charge of administrating the lab atmosphere, class policy and managing the undergraduate TAs. The TekBots program is strongest at the lower level classes, but does not flow forward consistently in that original strength. This is a major setback for the undergrad students who had learned to love engineering in ECE 112. Students consistently comment that they connect more with and get more help from the undergrad TAs in their labs. Possible solutions include further training of the graduate TAs as in

ECE 507, and creation of consistent policy via written lab instructions. The other TekBots classes should also be evaluated for the structure and implications of teaching assistants.

In regard to the third factor in self-efficacy, encouragement, the TekBots program has done nothing particularly intentional to impact it. Obviously, being a positive and encouraging TA is an understood part of the responsibilities and culture, but it is not particularly emphasized. This happens naturally quite well on the part of the undergrad TAs because they are in a good position to do it. They are only a year or two ahead of the students and are a naturally credible source of encouragement. The graduate TAs are of variable temperament and quality. They may have a natural inclination to be positive and involved in encouraging students or prefer to sit back and read the newspaper. Ultimately, a policy must have teeth (consequences) standing behind it if it is to be taken seriously, implemented and followed. The consequence for an undergrad TA who is not performing well is somewhat loose, but they may be fired. The consequences for graduate TAs are regulated by the graduate school and up to the advising professors. It is not necessarily a problem that the undergraduate TAs and graduate TAs have a different set of guidelines. What is important is that they actually *have* guidelines, that they are *clearly defined*, and that they are *implemented*. This solution requires further research into policy details, input from professors who teach TekBots courses and the time and energy for the program director to manage it. However, I strongly believe that a clear and firm policy will stop many problems before they start. On the flip side, there is no policy which motivates TAs to do an exemplary job above and beyond what is required. This is also a good concept for further exploration.

5.4 Self-regulation of engineering students

Another topic which has surfaced in the creation of the self-efficacy survey is that of self-regulation. As I was creating the self-efficacy survey, I realized that there are more than strictly academic issues which go into the success or failure of an engineering student. Of course, that is the major factor, but there are also other ones, such as the social aspect. Can the student connect with study partners, mentors in the field, etc.? So,

in the survey, I also included the topic of ‘social self-efficacy.’ In addition to this, there are a number of challenges to the character which every student must overcome in order to graduate. Prof. Enochs read these questions and told me that this is a concept which is known as ‘self-regulation.’ Self-regulated learning “refers to learning that occurs largely from the influence of students’ self-generated thoughts, feelings, strategies, and behaviors, which are oriented toward the attainment of goals.” I believe that this quality is an important key to an engineering students’ success, but it seems highly unlikely that the TekBots program has the resources to address it. For one thing, the program is an academic program which is staffed by people trained in academic subjects. So, while the topic is tremendously interesting, it may be only possible to answer it with assistance from the Department of Math and Science Education.

5.5 Relationship between collaborative learning and self-efficacy

Student retention is mainly affected by a quality called self-efficacy. Self-efficacy is a relatively new concept in the social sciences field, pioneered by Albert Bandura. In summary, it is one’s *belief* about one’s *ability to act* in such a way as to achieve a *desired result*. The thesis work is reshaped around this concept. Self-efficacy is affected by four main things: previous personally experienced success in the task-specific area, a role model which models success, encouragement, toward the specific area, verbal or otherwise, and a relaxed, positive or happy mood when thinking about or doing that area.

Based on the four factors which affect self-efficacy, changes were implemented to the TekBots program. Regarding the first factor, previous success, the TekBots program is already quite strong. Students are able to put a TekBot together and observe the success of their efforts. However, there is still progress to be made in this area. For example, just because a student has had a success, he must also perceive this success to be the result of his own effort. The current lab is strictly technical and provides no opportunity for processing ability as an engineer. It is questionable to ask TAs, who have no relational training to facilitate such processing, but it may be possible to have students reflect upon their successes in lab questions. Also, in ECE112, each individual student

puts his or her own TekBot together. This is very important to the concept of an individual having experienced success due to the results of his or her own hands. However, this concept breaks down a little in ECE272. Students are allowed to work in groups, which facilitates collaboration, but hinders the experience of individual success and accomplishment. One question I would like to answer is what the best way to balance individual success with collaboration is. Also, the guidelines for how individual versus group is regulated are non-existent. Each head lab TA regulates his or her own class. So, for example, a more laid-back TA may let a lazy individual slide by within a group or a more involved TA may require individual work from a student who would benefit from group interaction. This is an important area to explore and possibly write into the labs, so that grad TAs are not entirely responsible for those decisions. Also, it would make the policy consistent.

BIBLIOGRAPHY

- [1] A. Bandura, Social Foundations of Thought and Action: A Social Cognitive Theory, New Jersey: Prentice-Hall, Inc., 1986.
- [2] A. Smit, R. Traylor, D. Heer, T. Thompson and T.S. Fiez, "Extending a Platform for Learning to Upper Division Electrical and Computer Engineering Courses," *IEEE Transactions on Education*, in review.
- [3] E. Seymour and N. Hewitt, Talking about leaving: why undergraduates leave the sciences, Boulder, Colorado: Westview Press, 1997.
- [4] National Science Foundation, Division of Science Resources Statistics, special tabulations of U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, Fall Enrollment Survey, 1994-2000.
- [5] M. Klawe, "Microsoft Research Faculty Summit 2005," [Online document] July 2005, [2007 May 3], Available at HTTP: <http://www.microsoft.com/presspass/exec/billg/speeches/2005/07-18FacultySummit.aspx>
- [6] B. Gates, "Microsoft Research Faculty Summit 2005," [Online document] July 2005, [2007 May 3], Available at HTTP: <http://www.microsoft.com/presspass/exec/billg/speeches/2005/07-18FacultySummit.aspx>
- [7] R. Traylor, D. Heer and T.S. Fiez, "Enhancing the Freshman and Sophomore ECE Student Experience Using a Platform for Learning," *IEEE Trans. on Education*, vol. 46, no. 4, Nov., pp.434-433.
- [8] R. Felder, G. Felder, M. Mauney, C. Hamrin and E.J. Dietz, "A Longitudinal Study of Engineering Student Performance and Retention," Journal of Engineering Education, vol. 87, no. 4, pp. 469-480.
- [9] A. Agogino, S. Sheppard and A. Oladipupo, "Making Connections to Engineering during the first two years," presented at the 22nd Annual Frontiers in Education Conf. Nashville, TN, 1992.
- [10] J. Conger, "The Brave New World of Leadership Training," Organizational Dynamics, vol. 21, no. 3, pp.46-58.

- [11] C.G. Masi, "Re-engineering engineering education," IEEE Spectrum, vol. 32, no. 9, pp.44-47.
- [12] R. Traylor, D. Heer, and T.S. Fiez, "Using an Integrated Platform for Learning to Reinvent Engineering Education," IEEE Transactions on Education, vol. 46, no. 4, pp.409-419.
- [13] C.A. Pomalaza-Raez, and B.H. Groff, "Retention 101: Where Robots Go... Students Follow," Journal of Engineering Education, vol. 92, no. 1, Jan., pp. 85-90.
- [14] N.J. Nourtos, "The nuts and bolts of cooperative learning in engineering," presented at the 24th Annual Frontiers in Education Conference, San Jose, CA, 1994.
- [15] L. Welch, S. Gradin and K. Sandell, "Enhancing Engineering Education with Writing-to-learn and Cooperative Learning: Experiences from a Software Engineering Course," presented at the Proceedings of the A.S.E.E. Conference & Exposition, Montreal, Quebec, 2002.
- [16] R.E. Slavin, "Research on Cooperative Learning and Achievement: What we know, what we need to know," Contemporary Educational Psychology, vol. 21, no. 1 Jan., pp.43-69.
- [17] R.M. Felder, and R. Brent, "Cooperative Learning in Technical Courses: Procedures, Pitfalls, and Payoffs," ERIC Document Reproduction Service ED 377038, 1994.
- [18] S. G. Brainard, and L. Carlin, "A Longitudinal Study of Undergraduate Women in Engineering and Science," Journal of Engineering Education, vol. 87, no. 4, Oct., pp.369-375.
- [19] "Schools of Engineering," U.S. News & World Report, 12 Apr., p.68, 2004.
- [20] M.E. Gist, "The Influence of Training Method on Self-Efficacy and Idea Generation among Managers," Personnel Psychology, vol. 42, no. 4, Dec., pp.787-805.
- [21] M.E. Gist, and T.R. Mitchell, "Self-Efficacy: A Theoretical Analysis of its determinants and malleability," The Academy of Management Review, vol. 17, no. 2 Apr., pp.183-211.

- [22] A. Bandura, "Guide for Constructing Self-efficacy scales," in Self-efficacy beliefs of adolescents. Pajares and T. Urdan, Eds. Greenwich, Connecticut: Information Age Publishing, 2006. p.328.
- [23] J.D. Lang, S. Cruse, F. McVey, J. McMasters, "Industry expectations of new engineers: A survey to assist curriculum designers," Journal of Engineering Education, vol. 88, no. 1, Jan., pp. 43-51.
- [24] National Science Foundation, Division of Science Resource Statistics, 2006. Science and Engineering Degrees: 1966-2004. Jan. 2007. M.M. Green, project officer, Arlington, VA.
- [25] M.J. Plisch, "Laboratory Evaluation Form".

APPENDICIES

APPENDIX A – ECE 507 TA LEADERSHIP TRAINING MANUAL

This section contains in entirety the TA Leadership Training Manual which is offered at Oregon State University as ECE 507. It is a 1-hour course which all new TAs are required to complete. The manual is designed for the teacher. Each section contains the following:

- A plan for teaching
- Handouts, including homework assignments
- Reference materials

SCHOOL OF EECS

TA Leadership Training Manual

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School of Electrical Engineering & Computer Science (EECS)

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Overview of the manual

Each chapter in this manual covers leadership training under the following sections:

- ❖ A plan for teaching.
- ❖ Handouts, including a homework assignment.
- ❖ Reference materials.

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CHAPTER ONE

Foundations of Leadership

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Cover the *Motivation to be an excellent TA* outline.
- Step Two: Discuss the *Role of a TA in a large group*.
- Step Three: Cover *How to use Lab One time effectively*.

Step One: Cover the Motivation to be an Excellent TA outline

1. How much time will you spend with the students as compared to the professor?

In a typical class with 150 students total and 24 students per lab, spending 2 hours per week in lecture and 3 hours per week in lab, the TA spends almost 10 times as much time per student than does the professor. That is a tremendous amount of influence!

2. How important are you to the students?

Quotes from some OSU undergraduate students:

- a. "In cases where the instructor is bad, it is really important that the TA is good because they will become the student's *primary tool for learning*."
- b. "TAs can sometimes *make or break classes*. For example, Math TAs are imperative to how I learn math because they can take their time to explain problems step by step."
- c. "In classes with hard labs, quality TAs are *definitely important* to the usefulness of the lab in demonstrating concepts."

3. Testimony from a former TA.

Have a former TA share about his or her experience as a TA. It should be short, approximately 5-10 minutes. The talk should include:

- a. How being a TA is fun: This includes the aspect of play and the enjoyment of helping students in the process of solving problems, (e.g. motivating the SP).
- b. How being a TA is important: This includes the satisfaction of running a classroom efficiently and producing students who know their stuff, (e.g. motivating the SJ).
- c. How being a TA is a challenge: The University is at the cutting edge of research and a TA facilitates a student's learning and exploration of ideas in that environment, (e.g. motivating the NT).
- d. How being a TA is an opportunity: This includes connecting relationally with younger students who are just starting out on their journey of education to help them succeed, (e.g. motivating the NF).
- e. Give an example or two.
- f. How have you grown, personally, from the experience of being a TA?

4. Does anybody have a story about how a TA positively impacted them?

Step Two: Discuss the role of a TA in a large group

This is a time for the TAs to define, as a group, what it means to be a TA. The main idea is that the TA fills a leadership role, which comes with privileges and responsibilities. They should create a list of specific privileges and responsibilities and discuss some examples, if they have them.

The privileges and responsibilities listed below are just some ideas to help get them started, if needed, but they should come up with the terms themselves:

1. What is the role of a TA? (Mention the privileges and responsibilities of a leader).
 - a. What are some privileges?
 - i. Authority.
 - ii. Power.
 - iii. Influence over the next generation.
 - b. What are some responsibilities?
 - i. Service.
 - ii. Providing guidance.
 - iii. Deal with opposition.
 - iv. Initiate plans for progress.
 - v. Self-starter.
2. How does a TA use the responsibilities and privileges of the leadership position to connect with and encourage young students?

Step Three: How to use Lab One time effectively

One privilege of leadership is that you can influence the students positively! For example, the first lab is usually unused, but as the leader TA, you can change that. During the term, the students will have one another as one of their most important resources. You can use the first lab to facilitate it as a time where they get to know one another.

1. *Get to know your neighbor* exercise.
2. *Community building* exercise.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix A: Handouts for Chapter One*.

- *Key Principles of Leadership*.
- *Get to know your Neighbor* ice-breaker.
- Example syllabus.
- First lab session: Introductions.
- **HW Assignment:** Reflection on a key principle.

REFERENCE MATERIALS

- “Spiritual Leadership”, by J. Oswald Sanders.
- “Courageous Leadership”, by Bill Hybels.
- “Developing the Leaders around You”, by John C. Maxwell.

CHAPTER TWO

Developing conflict resolution skills

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Cover the *Conflict Resolution in the Classroom* outline.
- Step Two: Select the sources of stress that students are experiencing from the *Social Readjustment Rating Scale*, and discuss them.
- Step Three: Play a few scenes from the Web-site and discuss them.

Step One: Cover the Conflict Resolution in the Classroom outline

See *Appendix B: Handouts for Chapter Two* for the same.

Step Two: Select the sources of stress that students are experiencing from the *Social Readjustment Rating Scale*, and discuss them

The Holmes and Rahe *Social Readjustment Rating Scale* measures the likelihood of serious illness based on changes in life-situations. This scale shows the relative severity of events causing stress. Blue Cross Blue Shield estimates that a stress sum of more than 300 points accumulated within one year results in a 90% chance of health change within two years (McSwain and Treadwell, *Conflict*, p. 55).

Social Readjustment Rating Scale
Holmes and Rahe

Rank	Life Event	Mean Value
1	Death of spouse	100
2	Divorce	73
3	Marital separation	65
4	Jail term	63
5	Death of close family member	63
6	Personal injury or illness	53
7	Marriage	50
8	Fired at work	47
9	Marital reconciliation	45
10	Retirement	45
11	Change in health of family member	44
12	Pregnancy	40
12	Sex difficulties	39
14	Gain of new family member	39
15	Business readjustment	39
16	Change in financial state	38
17	Death of close friend	37
18	Change to different line of work	36
19	Change in no. of arguments with spouse	35
20	Mortgage over \$10,000 (*1967 rates)	31
21	Foreclosure of mortgage or loan	30
22	Change in responsibilities at work	29
23	So or daughter leaving home	29
24	Trouble with in-laws	29
25	Outstanding personal achievement	28
26	Wife begin or stop work	26
27	Begin or end school	26
28	Change in living conditions	25
29	Revision of personal habits	24
30	Trouble with boss	23
31	Change in work hours or conditions	20
32	Change in residence	20
33	Change in schools	20
34	Change in recreation	19
35	Change in church activities	19
36	Change in social activities	18
37	Mortgage or loan less than \$10,000 (*1967 rates)	17
38	Change in sleeping habits	16
39	Change in number of family get-togethers	15
40	Change in eating habits	15
41	Vacation	13
42	Christmas	12
43	Minor violations of the law	11

Chapter Two: Developing conflict resolution skills

Step Three: Play a few scenes from the Web-site and discuss them

Play a few scenes from the Web-site <http://www1.umn.edu/ohr/teachlearn/tutorials/conflict/> and discuss the following questions for each scene:

1. Scene 1: *Why did you take points off?*
2. Scene 3: *Could you talk to the Professor for us?*
3. Scene 10: *You never told us that!*
 - a. How would you engage this situation using the PAUSE principle?
 - b. How does your personal conflict style affect how you would engage the situation?

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix B: Handouts for Chapter Two* except for the documents from Shawchuck. Those materials are copyright by Shawchuck and are not reprinted here. The title of his booklet is given in the reference materials.

- *Conflict Resolution in the Classroom*.
- Copy of *Conflict Style* from Shawchuck.
- **HW Assignment:** Complete *Conflict Styles Survey* from Shawchuck. (**Note:** This assignment should be completed before the class).

REFERENCE MATERIALS

- “The Peacemaker”, by Ken Sande.
- “Discover your conflict management style”, by Speed B. Leas.
- “How to Manage Conflict in the Church”, by Norman Shawchuck.
- “Academic Administrator’s Guide to Conflict Resolution”.
- “Scenes from a Classroom: managing Conflict”. <http://www1.umn.edu/ohr/teachlearn/tutorials/conflict/>

CHAPTER THREE

Teaching Skills

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Cover the *Teaching Tips for the TA* outline.
- Step Two: Go over the teaching example.

Step One: Cover the *Teaching Tips for the TA* outline

See *Appendix C: Handouts for Chapter Three* for the same.

Step Two: Go over the teaching example

The Teaching Example, which may be found in *Appendix C: Handouts for Chapter Three*, consists of a simple concept that TAs will teach one another in triads (or groups of three). In order to do this exercise, implement the following steps:

1. Get into triads. Each member gets one concept to explain.
2. Explain the concept to your triad.
3. Ask if anybody has questions and wait 10 seconds.
4. Ask three questions from the 'Effective questioning' chart.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix C: Handouts for Chapter Three*.

- Teaching Tips for the TA.
- Teaching Examples.

REFERENCE MATERIALS

- "Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing and Mathematics", by Allan Collins, John Brown and Susan Newman.
- "Ideas on Teaching". <http://www.cdtl.nus.edu.sg/Ideas/iot2.htm>
- "Teaching Tips for TAs: Grading Rubrics". <http://www.oic.id.ucsb.edu/TA/tips/rubric.html>
- "Teaching Tips for TAs: Recommendations for First Time TAs". <http://www.id.ucsb.edu/ic/ta/ta.html>
- "The Chicago Handbook for Teachers", Chapter 8: Teaching as a Graduate Student, by Brinkley, etc.
- "The Torch or the Firehose: A guide to section teaching", by Arthur P. Mattuck.

CHAPTER FOUR

Student-focused teaching

Chapter Four: Student-focused teaching

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Lecture about teacher-centered teaching vs. student-centered learning.
- Step Two: Brainstorm with your triad.

Step One: Lecture about teacher-centered learning vs. student-centered learning

1. Features of teacher-centered teaching.
 - a. The focus is on the teacher in a traditional lecture style.
 - b. There are some advantages. For example, it's very efficient and someone with greater knowledge shares with those who have less.
 - c. Unfortunately, a major problem with this style is that the teacher teaching is not equal to the students learning!
2. Features of student-centered learning.
 - a. The focus is on the student and may incorporate collaborative learning or active learning.
 - b. Some benefits thereof are in the following areas: academic, social and psychological.
3. The main point of student-centered learning is for the teacher to assign students a task which requires them to process the new knowledge. Examples of receiving knowledge include listening to a lecture, reading a book, or watching another student in lab. In order to actually process the knowledge, the student should be required to somehow transmit it. Examples include working a homework problem, writing an essay or explaining the concept to another student.

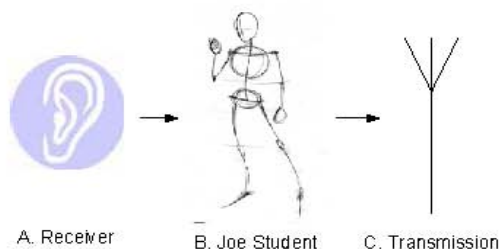


Figure 1. Illustration of Student learning

Step Two: Brainstorm with your triad

Answer the following questions while in triads:

1. What is a class you had in the past that you remember a lot of material from? How did that teacher teach?
2. Fill in the blanks for A, B and C.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix D: Handouts for Chapter Four*.

- *Seven Principles for Good Practice in Undergraduate Education*.
- **HW Assignment:** Reflecting on *Seven Principles for Good Practice in Undergraduate Education*.

REFERENCE MATERIALS

- “The Chicago Handbook for Teachers”, Chapter 8: Teaching as a Graduate Student, by Brinkley, etc.
- “The Torch or the Firehose: A guide to section teaching”, by Arthur P. Mattuck.

CHAPTER FIVE

Knowing the lab equipment

A PLAN FOR TEACHING

This lesson is different from all the others in that it consists of the TAs meeting in an actual lab and going through the *TA training fun lab*. Make sure to come to lab prepared with all the material the TAs will need to go through the lab including: breadboards, cables, op amps, etc.

It is not critical that the TAs actually get through the lab, but just that they get exposed to all the equipment including the oscilloscope, multi-meter, signal generator and power supply. The purpose is to give them a chance to experiment with the lab equipment and make mistakes without the pressure of a student watching. Working with lab partners should also cause them to remember first-hand the pros and cons of working together with others.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix E: Handouts for Chapter Five*.

- *TA Training Fun Lab*.
- *Connector reference sheet*.
- *Summary of Labs and Equipment in Dearborn*.

CHAPTER SIX

Listening Skills for Communication

A PLAN FOR TEACHING

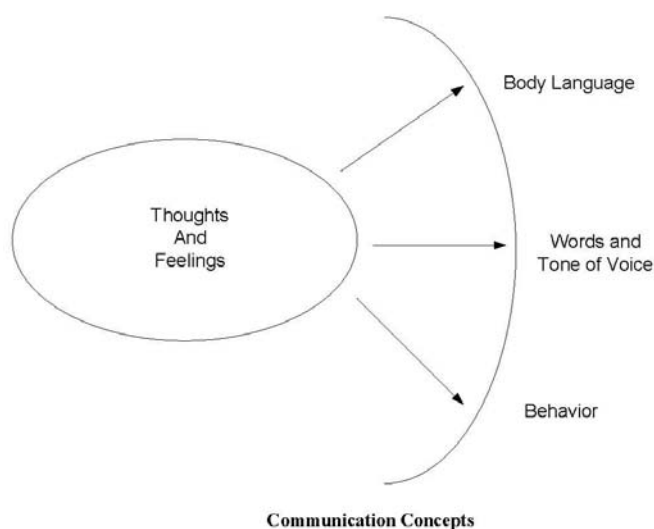
The most convenient way to teach this lesson is by giving a brief lecture on the background of each skill, demonstrating it on a volunteer, and allowing the students to practice the skill in triads. It will be best to repeat this procedure several times throughout the lesson as opposed to...teaching all the skills, demonstrating all the skills, and then having students practice all the skills...because, the students will have difficulties remembering all the new material.

Therefore, the plan for teaching constitutes the following steps:

- Step One: Give the TAs the motivation to learn listening skills.
- Step Two: Cover the *Summary of Skills* outline.
- Step Three: Demonstrate the skills on a volunteer student.
- Step Four: Practice each skill in triads.

Step One: Give the TAs the motivation to learn listening skills

- a. You can connect better with students by communicating with them. The first step in communicating is to listen.
 - i. Have you ever had a teacher who answered before you got your question out? That shows a lack of being patient enough to hear the student out.
 - ii. Effective listening skills are no substitute for caring, but these skills are essential tools that help us to express that caring.
- b. Give the example of a transmitter and a receiver for an *Engineering Connection!*



Step Two: Cover the *Summary of Skills* outline

The *Summary of Skills* can be covered thus:

1. Give an explanation of active listening posture (S.O.L.E.R.)

Cover the background of SOLER skills from *A summary of skills*. Demonstrate an example of bad SOLER and good SOLER.

2. Teach paraphrasing skills

Cover the background of the paraphrasing skill from *A summary of skills*. Paraphrasing can be connected again to the transmitter/receiver example. In communication theory, the receiver sends a signal back to the transmitter to verify that it has actually received the proper signal. If there is a mistake, there is the opportunity to correct it. Communication between people by using the skill of paraphrasing is quite similar.

3. Teach the perception check

Cover the background of the perception check skill from *A summary of skills*. For example, a good time to use this skill would be in helping a frustrated student to get unstuck. You should be sensitive to the level of trust in a relationship when using this skill.

4. Teach the expression of feelings and emotions

Cover the background of expression of feelings and emotions from *A summary of skills*. Example: Ask a TA how he/she is feeling today? Did he/she respond with 'I am feeling...' or 'I am thinking...?' Expressing emotions can be healthy and professional in the classroom. Express your emotions to better connect with the students. Read through role playing exercise in triads and discuss it.

Step Three: Demonstrate the skills on a volunteer student

For each of the skills in Step Two, ask for a volunteer from the class. Demonstrate the skill on the TA and give the TAs an opportunity to ask questions before practicing the skills in triads.

Step Four: Practice each skill in triads

For each of the skills in Step Two, give the TAs a short amount of time to practice on one another in triads. Make sure to keep the time moving so that each student has a chance to be the counselor, counselee and observer.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix F: Handouts for Chapter Six*.

- *A summary of skills*.
- *Role playing scenario*.
- **HW Assignment:** *Communicator's Log*.

REFERENCE MATERIALS

- "Listening and Caring Skills", by John Savage.

CHAPTER SEVEN

Diversity in the classroom

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Give a short lecture on the importance of identity.
- Step Two: Complete the *How ethnic am I?* Exercise in triads.
- Step Three: Conduct a large-group discussion on ethnicity.
- Step Four: Give a short lecture on gender issues.

Step One: Give a short lecture on the importance of identity

1. Give a short lecture on identity: what it is and why it is important. People answer the question, “Who am I?” by answering “Where do I come from?”
2. Brainstorm with the class about what factors affect our identity. If they get stuck, some examples are: race, gender, religion, ethnicity, socio-economic background, age, geographical region you were raised, etc.
3. The following are typical ground rules for such discussions:
 - Use active listening skills.
 - Show respect for other points of view
 - Have the attitude of a loyal learner when you don’t understand something.
 - Be an active participant.

Step Two: Complete the *How Ethnic am I?* Exercise in triads

Complete the *How Ethnic am I?* Exercise in triads.

Step Three: Conduct a large-group discussion on ethnicity

Engage the TAs in a large group discussion on race/ ethnicity. A person’s racial and ethnic identity affects how he or she approaches his or her engineering studies. How does your student’s ethnic and racial background affect them in the lab? For example, discuss why some cultures value team effort more and some others value individual innovation more.

Step Four: Give a short lecture on gender issues

Women are also typically a minority in the classroom. Give the students a short lecture on sexual harassment and gender harassment. Such behavior is unacceptable, but trying to avoid the issue by ignoring it is also a mistake. Be sensitive to the needs of all students by encouraging them.

1. Sexual harassment: Read through the list *Definition of Sexual Harassment* that appears at the end of this chapter. After reading that, consider this:
 - It is fairly obvious that these activities of sexual harassment are inappropriate.
 - They are especially inappropriate coming from a person in authority.

2. Gender harassment: This is less dramatic and more subtle. It should also be avoided because it makes women in engineering feel unwelcome. Discuss gender harassment thus:
 - Cover the example of gender harassment using: *You might be an Engineer If...*, a write-up that appears at the end of this chapter.
3. How do women prefer to learn?
 - Women are generally collaborative learners as opposed to competitive ones. This puts them at a disadvantage because the engineering culture is generally competitive.
 - They enjoy connecting relationally to other students, the TA and professor.
 - They enjoy gaining confidence through hands-on experience in lab.
4. Cover *Factors Affecting Female Persistence*, a write-up that appears at the end of this chapter. Which of these factors can you, as a TA, affect?

HANDOUTS

The following handout pertaining to this chapter can be found in *Appendix G: Handouts for Chapter Seven*.

- *Encouraging Women and Minorities in the Classroom*.

REFERENCE MATERIALS

- Center for Teaching and Learning. <http://oregonstate.edu/ctl/>
- “The Chicago Handbook for Teachers”, by Alan Brinkley, etc.
- “Sexual and Gender Harassment in the Academy”, by Phyllis Franklin, etc.
- “Removing Barriers: Women in Academic Science, Technology, Engineering, and Mathematics”, edited by Jill Bystydzienski, etc.
- “Women succeeding in the Sciences”, edited by Jody Bart.
- “Multicultural teaching in the University”, edited by David Schoem, etc.
- “Multicultural Education: A Teacher’s Guide to Content and Process”, by Hilda Hernandez.

Definition of Sexual Harassment

Sexual harassment includes activities such as:

- Verbal harassment or abuse.
- Subtle pressure for sexual activity.
- Sexist remarks about a person's clothing, body, or sexual activities.
- Unwarranted touching, patting, or pinching.
- Leering or ogling at a person's body.
- Demanding sexual favors accompanied by implied or overt threats concerning one's job, grades, letters of recommendation, and so forth.

Gender Harassment

The following is an email forward which is an example of gender harassment. Read through the email and try to see how it is gender harassment.

YOU MIGHT BE AN ENGINEER IF...

>

>Buying flowers for your girlfriend or spending the money to upgrade your RAM is a moral dilemma.

>

>You bought your wife a new CD ROM for her birthday.

>>

>You comment to your wife that her straight hair is nice and parallel.

>>

>You still own a slide rule and you know how to work it.

>

>>You're in the back seat of your car, she's looking wistfully at the moon, and you're trying to locate

>a geosynchronous satellite.

>>

>Your wife hasn't the foggiest idea what you do at work.

>>

>

Factors Affecting Female Persistence in Undergraduate Math, Engineering, and Science Majors

School Factors

- Positive association with professors.
- Role models.
- Curriculum plan – tracks, good labs, study groups.
- Lab research – related to area of interest, professor available, support, coordinators as mentors.
- Good teaching – good explanations, problem-centered, interesting.
- Special programs (Project Access, Minorities in Engineering, Undergraduate Research Opportunities Program).
- Support agencies (Women's Resource Center, career services, financial).
- Scholarships.
- On-campus living – roommates, positive association with others in the same major.
- High-school preparation – AP classes, honors, math foundation, science fairs, gifted program.
- Secondary education teachers – mentors, academic foundation, confidence building, advisors.

External Factors

- Family support – science and academics valued, financial assistance, similar background, encouragement.
- Work-related experience.
- Study groups – crucial for freshman year.
- Female friends – support network, emotional and academic.
- Role model – family, advisor, boss, career-day speaker, or friend.
- Multidimensional experience – well-rounded, balanced, good perspective, open-minded.

Personal Factors

- Inclination.
- Natural ability.
- Confidence.
- Determination.
- Career outcome.

Analyze: Which of the above factors can you, as a TA, affect?

CHAPTER EIGHT

Connecting by mentoring

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Cover *Why mentor? (A brief look at self-efficacy)*.
- Step Two: Do the exercise, *Reflections on Mentoring*.
- Step Three: Cover the handout *Expectations of a TA*.

Step One: Cover Why mentor? (A brief look at self-efficacy)

Following is a write-up on: Why mentor? (A brief look at self-efficacy).

Reference: Albert Bandura.

What is self-efficacy?

Perceived self-efficacy is defined as people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives.

BELIEF → ABILITY TO PERFORM → DESIRED RESULTS

People with high self-efficacy...

- Approach difficult tasks as challenges to be mastered, rather than threats to be avoided.
- Are intrinsically interested and deeply engrossed in their activities.
- Set for themselves challenging goals as well as maintain strong commitment to them.
- Heighten and sustain their efforts in the face of failure.
- Quickly recover their sense of efficacy after failures or setbacks.
- Attribute failure to insufficient effort or deficient knowledge and skills which are acquirable.
- Approach threatening situations with assurance that they can exercise control over them.
- Produce personal accomplishments, and have reduced stress as well as lower vulnerability to depression.

What are the sources of self-efficacy? (They are mentioned below in order of effectiveness).

- *Mastery Experiences* – A resilient sense of efficacy requires experiencing overcoming obstacles by persisting, not only easy successes.
- *Vicarious Experiences* – Seeing a social model, who is similar to oneself, raises the observers' beliefs that they too possess the capabilities to succeed.
- *Social Persuasion* – Verbal persuasion causes people to give greater effort and sustain it in the face of self-doubts and personal deficiencies when problems arise. Unfortunately, it is easier to undermine self-efficacy by negative persuasion than it is to boost self-efficacy by positive persuasion.
- *Emotional States* – People interpret stress and tension as signs of vulnerability to poor performance.

Tips for a Mentor/ TA

- Structure situations where a student may experience success (and avoid premature failure).
- Measure success in terms of self-improvement rather than by comparison.
- Connect with students so that they may see themselves as successful as you in the future.
- Give verbal encouragement to persist when solving problems and facing difficulties.
- Make lab and office hours a fun time!

Step Two: Do the exercise *Reflection on Mentoring*

Complete the exercise *Reflection on Mentoring*, which may be found in *Appendix H: Handouts for Chapter Eight*.

Step Three: Cover the handout, *Expectations of a TA*

See *Appendix H: Handouts for Chapter Eight* for the same.

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix H: Handouts for Chapter Eight*.

- Reflections on Mentoring.
- Expectations of a TA.

REFERENCE MATERIALS

- “Self-Efficacy”, by Albert Bandura.
- “Please Understand Me”, by David Keirsey and Marilyn Bates.

CHAPTER NINE

Boundaries and assertiveness for TAs

Chapter Nine: Boundaries and assertiveness for TAs

A PLAN FOR TEACHING

The plan for teaching constitutes the following steps:

- Step One: Cover the *Boundaries for the TA* outline.
- Step Two: Discuss boundaries/ assertiveness.

Step One: Cover the *Boundaries for the TA* outline

See *Appendix I: Handouts for Chapter Nine* for the same.

Step Two: Discuss boundaries/ assertiveness

Engage the TAs in a discussion about boundaries/assertiveness by asking the following questions:

1. Have you ever heard about boundaries or assertiveness before?
2. Do you agree or disagree with the principles of boundaries?
3. Does anyone have an example of applying a boundary with a student?
4. Does anyone have an example of when a boundary should have been applied, but wasn't? What was the outcome? How could boundaries have been applied?
5. How does your culture view boundaries?

HANDOUTS

The following handouts pertaining to this chapter can be found in *Appendix I: Handouts for Chapter Nine*.

- *Boundaries for the TA*.
- **HW Assignment:** *Final Reflection Assignment*.

REFERENCE MATERIALS

- Boundaries by Cloud and Townsend
- http://oregonstate.edu/dept/counsel/faculty_staff.php
- The Chicago Handbook for Teachers by Brinkley, etc.

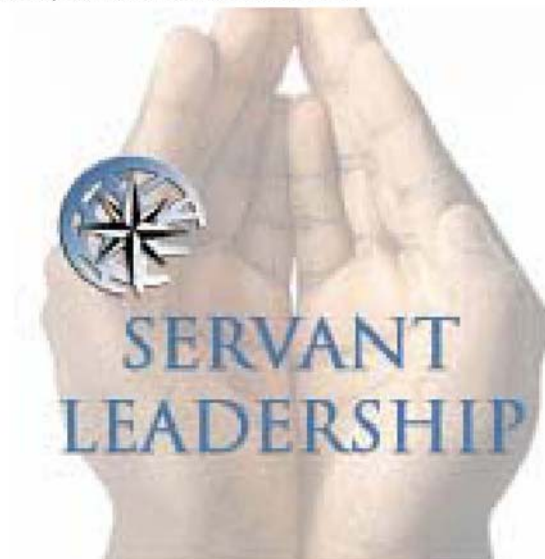
APPENDIX A

Handouts for Chapter One

KEY PRINCIPLES OF LEADERSHIP

Adapted from Edward White Benson, Archbishop of Canterbury, 1882-1896

- ✚ Eagerly start the day's main work.
- ✚ Do not complain at your busyness or lack of time, but make the most of the time you do have.
- ✚ Never grumble when you receive a letter or email.
- ✚ Never exaggerate duties by seeming to suffer under the load, but treat all your responsibilities as liberty and gladness.
- ✚ Never call attention to a crowded work situation or trivial experiences.
- ✚ Before confrontation, obtain a genuine concern for the one at fault. Know the facts; be generous in your judgment. Otherwise, how ineffective, how unintelligible or perhaps provocative your well-intentioned confrontation may be.
- ✚ Do not believe everything you hear; do not spread gossip.
- ✚ Do not seek praise, gratitude, respect, or regard for past service.
- ✚ Avoid complaining when your advice or opinion is not consulted, or having been consulted, set aside.
- ✚ Never allow yourself to be placed in favorable contrast with anyone.
- ✚ Do not turn a conversation to your own needs and concerns.
- ✚ Seek no favors, nor sympathies; do not ask for tenderness, but receive what comes.
- ✚ Bear the blame; do not share or transfer it.



GET TO KNOW YOUR NEIGHBOR!

HAS A PET	YOUNGEST IN FAMILY	IS A MUSICIAN	KNOWS SOME CONSTELLATIONS	ELVIS FAN
LEFT-HANDED	LOVES ROCK -N- ROLL	LIKES SEAFOOD	LIKES A GOOD JOKE	STARTED AN ACCIDENTAL FIRE AS A KID
LIKES SPICY FOOD	HAS HITCHHIKED	FREE	FAVORITE COLOR IS RED OR GREEN	SPEAKS MORE THAN 2 LANGUAGES
LIKES FISHING	BORN IN ANOTHER STATE	WANTS TO BECOME AN ENGINEER	HAS TRAVELED TO MORE THAN 2 CONTINENTS	HAS BEEN TO CHICAGO
LOVES DISCO MUSIC	FAVORITE SEASON IS FALL	HAS A SECRET TALENT	KNOWS HOW TO JUGGLE	ENJOYS PLAYING SPORTS

To play:

1. Find another person who matches the description in the box.
 2. Have them sign that box and answer one more question about it. For example, 'LIKES FISHING'... What was the biggest fish you ever caught?
 3. You may have no more than two signatures from the same person.
 4. When an entire row is filled, yell BINGO! Be prepared to share the answer to the extra question.
-

EXAMPLE SYLLABUS

ECE 272	Digital Logic Design Lab	Spring 2006																															
<p>Where to get labs: http://eeecs.oregonstate.edu/education/classes/ece272/index.html</p> <p>TA's: Marjorie Plisch plisch@engr.orst.edu Office hours by appointment. Ding Luo luod@onid.orst.edu</p> <p>Requirements:</p> <ul style="list-style-type: none"> • A working TekBot. • Printed labs and appendices. <p>If you do not have a TekBot, you can purchase and assemble it today. After today, you can get one from Don Heer heer@eeecs.oregonstate.edu at the TekBots lab in KEC 1110. The cost is \$80 and checks are payable to EECS.</p> <p>How to Get Help:</p> <ul style="list-style-type: none"> • First ask your lab partner. • Then ask other groups. • Then ask your TA. <p>The main idea here is that you are responsible for finding solutions to your questions. Rely first on your classmates and last on your TA.</p> <p>Attendance:</p> <ul style="list-style-type: none"> • Attendance is not taken. • You must be present to have your lab graded. <p>If you have an emergency or are sick and cannot be present, you should email me about your circumstances as early as possible. The measure of your courtesy of communication will be directly proportional to my flexibility in accommodating your circumstances.</p> <p>Grading:</p> <ul style="list-style-type: none"> • No late work accepted. • Show the completed lab. Turn in legible Study Questions and schematics. • Lab is due the week following its completion. <p>Schedule:</p> <table border="1"> <thead> <tr> <th>Week</th><th>Date</th><th>Schedule</th></tr> </thead> <tbody> <tr> <td>1</td><td>4/3-4/7</td><td>Introduction</td></tr> <tr> <td>2</td><td>4/10-4/14</td><td>Section 1</td></tr> <tr> <td>3</td><td>4/17-4/21</td><td>Section 2</td></tr> <tr> <td>4</td><td>4/24-4/28</td><td>Section 3 (first week requiring a Tekbot.)</td></tr> <tr> <td>5</td><td>5/1-5/5</td><td>Section 4</td></tr> <tr> <td>6</td><td>5/8-5/12</td><td>Section 5</td></tr> <tr> <td>7</td><td>5/15-5/19</td><td>Section 6. Tekbot Triathlon</td></tr> <tr> <td>8</td><td>5/22-5/26</td><td rowspan="3">Section 7 or Section 8</td></tr> <tr> <td>9</td><td>5/29-6/2</td></tr> <tr> <td>10</td><td>6/5-6/9</td></tr> </tbody> </table>			Week	Date	Schedule	1	4/3-4/7	Introduction	2	4/10-4/14	Section 1	3	4/17-4/21	Section 2	4	4/24-4/28	Section 3 (first week requiring a Tekbot.)	5	5/1-5/5	Section 4	6	5/8-5/12	Section 5	7	5/15-5/19	Section 6. Tekbot Triathlon	8	5/22-5/26	Section 7 or Section 8	9	5/29-6/2	10	6/5-6/9
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FIRST LAB SESSION: BASICS TO COVER

1. Create a syllabus which contains the information most relevant to the course. Examples of relevant materials may be found in the following list:
 - a. Class web page/where to download labs
 - b. TA's names and contact information
 - c. Your role in the lab/what students can expect from you
 - d. Office hours times and location
 - e. HW/Lab grading policy
 - f. Attendance policy
 - g. Required text/materials
 - h. Software used for course
 - i. Brief schedule.
2. Hand out/ sell lab kits.
3. Facilitate an activity which helps your students get to know one another. During the term, your students will be one another's best resources, so it is a great benefit to them to meet one another at the beginning.

Some example activities can be found below:

- a. *Get to know your Neighbor* activity
 - b. Community building exercise
 - i. Break students into groups of no more than 6-8 students
 - ii. Have students answer the following questions in each group:
 - ❖ What is my name?
 - ❖ Where do I come from?
 - ❖ Why am I at OSU?
 - ❖ Why am I in EECS?
 - ❖ What is something fun I did over the summer?
 - c. Make up a community building exercise of your own!
-

HW ASSIGNMENT: FOUNDATIONS OF LEADERSHIP

Choose at least **two** principles from *Key Principles of Leadership*, one of which is a personal area of strength and one an area for improvement. Write a **typed** reflection including answers to the following questions:

1. Which principle did you choose to reflect on and why?
 2. How is that principle a personal area of strength/weakness?
 3. If it is a strength, how have you employed it to be a better leader? Give an example.
 4. If it is a weakness, how is it a disadvantage to yourself and the people you lead? Give an example.
 5. What could you do to improve in that area?
-

APPENDIX B

Handouts for Chapter Two

CONFLICT RESOLUTION IN THE CLASSROOM

What is conflict?

Definition of conflict: A situation in which two or more human beings desire goals which they perceive as being attainable by one or the other but not by both.

What are the sources of conflict?

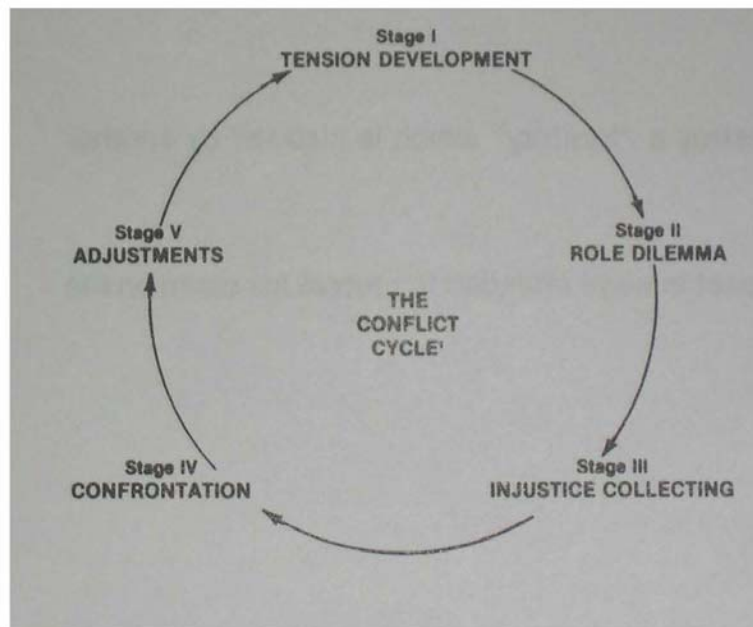
- Attitude – differences of feelings or perspectives about persons and issues.
- Substance – differences of opinion about facts, goals, ends or means.
- Emotional – when personal value is attached either to attitudinal or substantive conflict.
- Communicative – the by-product of a breakdown in healthy, open conversation about the sources of conflict.

What is the root cause of conflict?

Answer: *Stress!*

See the handout on *Social Readjustment Rating Scale*. Which of these stresses do you think may be affecting your students right now? Although most students are not experiencing the major stresses listed, they are experiencing many of the minor ones, which add up.

What is the cycle of conflict?

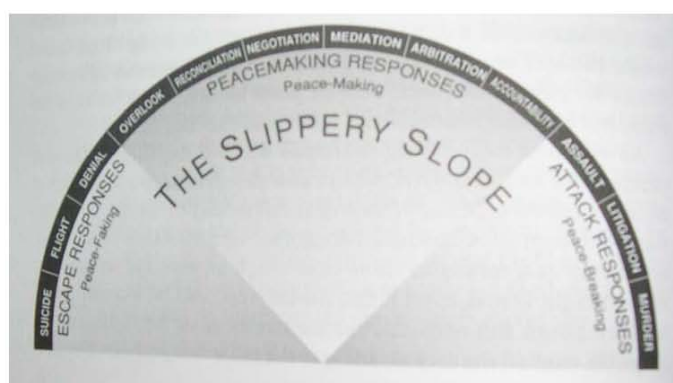


The Conflict Cycle by Norman Shawchuck

The Cycle of Conflict

- **Tension development** – Tension in the relationship develops as someone is experiencing a sense of loss of freedom.
- **Role dilemma** – Confusion develops as a result of the tension and leads to questions about the tension and who should be acting on it and how.
- **Injustice collecting** – The first dangerous stage in the cycle of conflict: People dig in and prepare for battle, collecting information and allies, for later use as “artillery.”
- **Confrontation** – This may range from “clearing the air” to outright violence as the parties confront the issue or each other.
- **Adjustments** – The changes people make to end the confrontation.

Responses to Conflict



The Slippery Slope of Responses to Conflict by Ken Sande

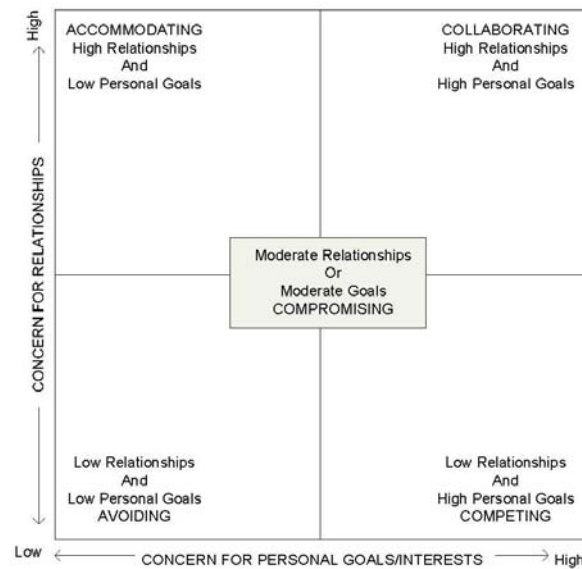
- **Escape responses (peace-faking)** – People resort to these responses when they are more interested in avoiding a conflict than resolving it.
- **Attack responses (peace-breaking)** – People resort to these responses when they are more interested in winning the argument than preserving relationships.
- **Peacemaking responses** – People engage in these responses when they are committed to finding just and mutually agreeable solutions to conflict.

Engaging Conflict as a Facilitator

The **PAUSE** principle of negotiating:

- **Prepare** – get the facts.
 - **Affirm relationships** – affirm the value of each person and the value of the relationship.
 - **Understand interests** – clarify the goal of each person involved.
 - **Search for creative solutions** – help brainstorm a just and mutually agreeable solution.
 - **Evaluate options** objectively and reasonably.
-

Engaging Conflict as a Participant



Conflict concerns resulting in conflict styles by N. Shawchuck

What is your primary conflict style?

- *Avoiding (the turtle)* – The intent of this style is to stay out of the conflict, to avoid being identified with either side.
 - *Accommodating (the teddy bear)* – The intent of this style is to preserve the relationship at all costs.
 - *Collaborating (the owl)* – The intent of this style is to get all the parties fully involved in defining the conflict and in carrying out mutually agreeable steps for managing the conflict.
 - *Compromising (the fox)* – The intent of this style is to provide each side with a little bit of winning in order to persuade each to accept a little bit of losing.
 - *Competing (the shark)* – The intent of this style is to win.
-

APPENDIX C

Handouts for Chapter Three

TEACHING TIPS FOR THE TA

Teaching in a Recitation section

- ❖ **Being prepared and organized** – The most important thing you can do to ensure success in your section is to come prepared. Make a plan or checklist of items to cover and stick to it. Being the teacher requires you to be a step ahead of your students, not just know the material.
- ❖ **Effective questioning** – Effective questioning can help to develop student learning by developing critical thinking skills, reinforcing student understanding, correcting student misunderstanding, providing feedback for students and enlivening class discussion. See some ideas below for effective questions:

LEVEL	STUDENT SKILLS	SAMPLE QUESTIONS
KNOWLEDGE	<ul style="list-style-type: none"> • Recalling facts or observations • Supplying Definitions 	1. Who? What? Where? When? 2. How would you define the term ...?
COMPREHENSION	<ul style="list-style-type: none"> • Describing • Stating main ideas • Comparing and contrasting 	1. Describe (what will happen when...) 2. What is the main idea? 3. How are the theories alike/different?
APPLICATION	<ul style="list-style-type: none"> • Applying techniques and rules to solve problems that have a single correct right answer 	1. If ..., then... ? 2. How does this rule apply to... 3. How would you interpret this graph/chart?
ANALYSIS	<ul style="list-style-type: none"> • Identifying motives or making inferences • Finding evidence to support generalizations 	1. What can we conclude about... ? 2. What does this tell us about... ? 3. What evidence can you find to support... ?
SYNTHESIS	<ul style="list-style-type: none"> • Developing solutions to problems • Making predictions 	1. How can this dilemma be solved? 2. How can we improve this? 3. What might happen if... ?
EVALUATION	<ul style="list-style-type: none"> • Judging truth, validity, worth, etc. • Making value judgments about a controversial issue 	1. What is your opinion (on this matter)? 2. Would it be better done another way? 3. Why do you agree with... ?

Effective Questioning Chart

- ❖ **Waiting** – Wait-time is the amount of time an instructor waits for students to respond before giving the answer or posing another question. At least 5 to 10 seconds are needed for students to think about and respond to the questions. Of course, questions at higher cognitive levels require more wait-time. Do not be afraid to wait. Waiting is a sign that you want thoughtful participation.
-

Teaching in the Lab: Troubleshooting

- ❖ **Modeling** - This involves an expert's carrying out a task so that students can observe and build a conceptual model of the processes that are required to accomplish the task. For example, the teacher may demonstrate a skill in lab, while verbalizing his thought processes.
- ❖ **Coaching** - This consists of observing students while they carry out a task and offering hints, scaffolding, feedback, modeling, reminders, and new tasks aimed at bringing their performance closer to expert performance. For example, compliment the student on something good she is doing and then offer advice for improvement on a technique.
- ❖ **Building Scaffolding** - Scaffolding refers to the supports the teacher provides to help the student carry out a task. The teacher must first infer an accurate diagnosis of the student's current skill level and the level of difficulty of the target activity and identify an intermediate step at an appropriate level of difficulty. The teacher gradually fades out the supports until the student is on his own.

Evaluation in Teaching

- ❖ **Evaluating the students**
 - ✓ Ask your professor first for his or her input.
 - ✓ Create grading guidelines: There are three main elements to any Grading Rubric: the grading criteria, the scale, and the descriptions of the criteria.
 - ✓ More information can be found at: <http://www.oic.id.ucsb.edu/TA/tips/rubric.html>
- ❖ **Plagiarism and cheating**
 - ✓ At Oregon State University academic dishonesty is defined by the Oregon Administrative Rules 576-015-0020.1.a-c as: *An intentional act of deception in which a student seeks to claim credit for the work or effort of another person or uses unauthorized materials or fabricated information in any academic work.* Academic dishonesty includes: cheating, fabrication, assisting, tampering, and plagiarism.
 - ✓ More information can be found at: <http://oregonstate.edu/admin/stucon/achon.htm>
- ❖ **Having your students evaluate you**

It is necessary to readjust the pace, direction and format of your class to maximize the effectiveness of your teaching. Take some time out after a few weeks of class to ask your students for some feedback. If they are reluctant to comment, you may have them write their comments down and turn them in anonymously.
- ❖ **Confidentiality**
 - ✓ Use of students' e-mail addresses is acceptable for academic and educational purposes; the students' ONID addresses are the only officially recognized OSU e-mail addresses.
 - ✓ You may post grades as long as only you and the individual student know who the grade is for. That is, you cannot use the students' names or their Student ID numbers. You can create a unique identifier (such as a number, or the last four digits of the Student ID number) for each of your students and post grades by that identifier.
 - ✓ Distributing students' exams and papers by putting them in a self-serve box violates their confidentiality by making confidential records available to the public. This is **not** an acceptable practice.
 - ✓ More information can be found at: <http://oregonstate.edu/registrar/GuidelinesforReleaseofStudentRecords.html>

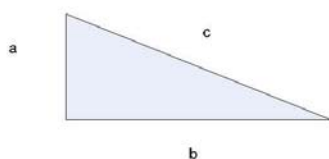
TEACHING EXAMPLES

1. Quadratic Equation

$$ax^2 + bx + c = 0$$

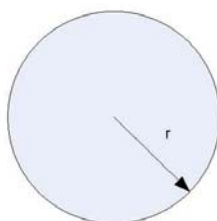
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

2. Pythagorean Theorem



$$a^2 + b^2 = c^2$$

3. Area of a Circle



$$A = \pi * r^2$$

APPENDIX D

Handouts for Chapter Four

SEVEN PRINCIPLES FOR GOOD PRACTICE IN UNDERGRADUATE EDUCATION

Good Practice means a teacher who...

1. Encourages contact between students and faculty.
(Especially contact focused on the academic agenda – in and out of class.)
2. Develops reciprocity and cooperation among students.
(Deepens understanding, improves thinking, and enhances communications.)
3. Encourages active learning.
(Writing, applying, doing, thinking, and thinking about what they're doing.)
4. Gives prompt feedback on performance...
(...so that the students can learn to self-assess.)
5. Emphasizes time on task.
(Practice improves learning because learning = time x effective energy.)
6. Communicates high expectations.
(Reward the positive and encourage students to learn high self-expectations.)
7. Respect diverse talents and ways of learning.
(And engenders respect for the many forms of genius.)

(Reference: Center for Teaching and Learning. <http://www.siue.edu/~deder/hamilton/index.html>)

HW ASSIGNMENT: STUDENT-FOCUSED TEACHING

Pick three of the *Seven Principles for Good Practice in Undergraduate Education*.

Write your answers to the following questions:

1. Describe the context of your teaching this term, i.e. lab, lecture, etc.
 2. Give a practical example of how you can apply each of the three principles you chose to your teaching setting.
-

APPENDIX E

Handouts for Chapter Five

TA TRAINING FUN LAB

Introduction

This lab is designed for you to have fun and ‘get your hands dirty’ with four of the most important pieces of equipment found in the Oregon State University labs: the oscilloscope (“o-scope”), multi-meter, signal generator, and power supply. There are no detailed instructions on how to run the equipment. This is your chance to play and just figure it out. Don’t worry if you don’t finish the lab; the main idea is gain experience fixing problems when you run into them. In this way, you will be better prepared to answer questions from your students. You may also learn something about the benefits and struggles of working in a lab group. Enjoy!

You will be building and testing the circuit found in Figure 1. It is an inverting amplifier with a gain of

$$A_v = \frac{R_2}{R_1 + 1}.$$

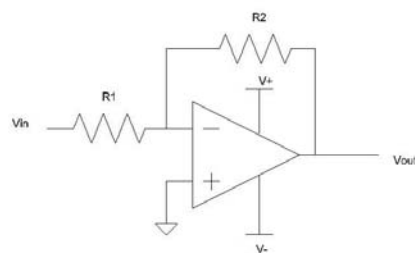


Figure 1: Simple amplifier configuration

Task 1: Setting up the Power Supply

Set up the dual power supply to provide +10V, 0V, and -10V. These power supplies can be set up in a master/slave mode so that the slave supply tracks the master supply. A dual power supply is shown in Figure 2.

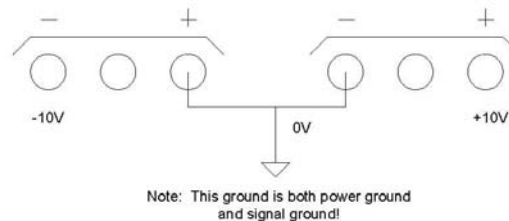


Figure 2: Power Supply Set-up

Verify that your power supply is correctly set up with the multi-meter:

- ☐ Dual power supply provides +10V.
 - ☐ Dual power supply provides -10V.
-

Task 2: Setting up the Function Generator

Set the function generator to create a sine wave of 1V_{pp} at 1 kHz. Check that the function generator is working by using the AC setting on the multi-meter. Note that the multi-meter may be reading an RMS value. Hook the oscilloscope scope probe directly up to the signal generator and verify that it is working. Use the 'Measure' function to verify the frequency and magnitude.

- ☐ Verify the correct signal from the function generator by using the multi-meter.
- ☐ What voltage does the multi-meter measure? _____ V
- ☐ Verify the correct signal from the function generator by using the oscilloscope.
- ☐ What voltage does the oscilloscope measure? _____ V
- ☐ What frequency does the oscilloscope measure? _____ V

Note (on oscilloscope probes):

Passive scope probes contain no active electronic parts, such as transistors, so they require no external power. The most common design inserts a 9 M Ω resistor in series with the probe tip. The signal is then transmitted from the probe head to the oscilloscope over a highly specialized coaxial cable that is designed to minimize capacitance and ringing. The resistor serves to minimize the loading that the cable capacitance would impose on the DUT. In series with the normal 1 M Ω input impedance of the oscilloscope, the 9 M Ω resistor creates a 10x voltage divider so such probes are normally known as either low capacitance probes or 10X probes.

Task 3: Building and verifying the circuit

Choose two resistors for your circuit. Any two will do, but make sure that $R_2 > R_1$. For best results, choose $R_2 = 10R_1$. Refer to Figure 1 for the amplifier. The pin connections can be found in Figure 3 below.

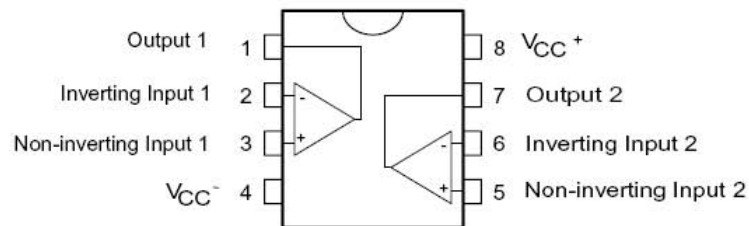


Figure 3: Pin-connections for TS912

- From the oscilloscope, what is the peak-to-peak amplitude of V_{in} ? ▶ _____ V.
- From the oscilloscope, what is the peak-to-peak amplitude of V_{out} ? ▶ _____ V.
- Does $V_{out}/V_{in} = R_2/R_1 + 1$? ▶ _____.

1. What problems did you encounter while doing the lab?
2. How did you approach solving them?
3. What qualities do you need in a Teaching Assistant to help you solve problems?
4. What were some of the advantages and disadvantages you experienced of working together with others in a lab group?

CONNECTOR REFERENCE SHEET

BNC connector



Oscilloscope probe (scope probe)



Banana plug (single and dual)



Mini-test clip lead



RCA jack and plug



Alligator clips



SUMMARY OF LABS AND EQUIPMENT IN DEARBORN

<u>Lab Room</u>	<u>Engineering Courses</u>	<u>Equipment</u>
DB 120	ENGR 201	FLUKE 45 DUAL DISPLAY MULTIMETER
	ENGR 202	TEKTRONIX CPS250 TRIPLE OUTPUT POWER SUPPLY
	ENGR 203	TEKTRONIX CFG253 3MHZ FUNCTION GENERATOR
		TEKTRONIX TDS210 TWO CHANNEL DIGITAL REAL-TIME OSCILLOSCOPE

DB 203	ECE 272	TEKTRONIX CFG253 3MHZ FUNCTION GENERATOR
	ECE 375	TEKTRONIX CPS250 TRIPLE OUTPUT POWER SUPPLY
		TEKTRONIX TDS210 TWO CHANNEL DIGITAL REAL-TIME OSCILLOSCOPE
		TEKTRONIX CDM250 DIGITAL MULTIMETER

DB 208	ECE 111	DRILLPRESS
	ECE 322	TEKTRONIX 571 CURVE TRACER
	ECE 323	TEKTRONIX 2012 TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE 100MHZ
		TEKTRONIX CDM250 DIGITAL MULTIMETER
		TEKTRONIX CFG253 3MHZ FUNCTION GENERATOR
		TEKTRONIX PS2520G PROGRAMMABLE POWER SUPPLY
		TEKTRONIX PS280 DC POWER SUPPLY
		SONY/TEKTRONIX AFG320 ARBITRARY FUNCTION GENERATOR

DB 211	SENIOR DESIGN	TEKTRONIX 2012 TWO CHANNEL DIGITAL STORAGE OSCILLOSCOPE 100MHZ
		TEKTRONIX PS2520G PROGRAMMABLE POWER SUPPLY
		TEKTRONIX CDM250 DIGITAL MULTIMETER
		SONY/TEKTRONIX AFG320 ARBITRARY FUNCTION GENERATOR
		TEKTRONIX TDS3014 FOUR CHANNEL COLOR DIGITAL PHOSPHOR OSCILLOSCOPE
		TEKTRONIX 611 LOGIC ANALYZER

DB 302	ECE 112	CENTRAL MACHINERY 8" DRILL PRESS
		TEKTRONIX 2225 50MHZ OSCILLOSCOPE
		RSR MA5830 DIGITAL MULTIMETER

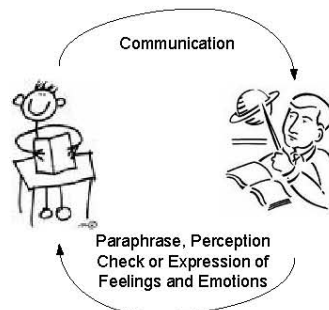
APPENDIX F

Handouts for Chapter Six

A SUMMARY OF SKILLS

Active Listening Posture (S.O.L.E.R.)

- ✓ **S**quarely face the other person.
- ✓ **O**pen your posture.
- ✓ **L**ean towards the speaker.
- ✓ **E**ye contact maintained.
- ✓ **R**elax while listening.



Paraphrasing

1. There are two main ways to do a paraphrase:
 - ✓ Paraphrase of content - checking out whether the words you heard are the words that were sent.
 - ✓ Paraphrase of meaning - checking out what you think the speaker meant by the comments.
2. Examples of the structure of a paraphrase:
 - ✓ “You are saying that...”
 - ✓ “What I hear you saying is that...”
 - ✓ “If I am hearing you right, you are...”
 - ✓ “Let me say what I am hearing...”

Perception Check

A perception check is making a guess at the inner emotional state of another person. The check is accomplished thus:

1. First observe the body language, tone of voice, and verbal communication being sent to you.
2. From those behavioral clues, you make a guess at what you believe the speaker is feeling.
3. After naming the feeling in your head, you may want to soften it, according to the trust level you have with the speaker.
4. You then place the feeling word into the context of the perception check, which has the following components: STEM + FEELING WORD(S) + CONTEXT + QUESTION.

Some examples of STEM statements are:

- ✓ I wonder if...
- ✓ It seems to me that you might be feeling...
- ✓ I get the impression that...
- ✓ Is it possible that you might be feeling...

Expression of Feelings and Emotions

1. Definition: The skill of direct expression of emotion is naming, in first person singular, an emotion or feeling that you have experienced or are now experiencing.
 2. Purpose: The purpose of direct expression is to identify your emotional state, and name that emotion to the persona with whom you are communicating.
 3. Example: I feel very irritated by the committee's actions.
 4. Expressions: acting out, acting in, direct verbalization and indirect verbalization
-

USING EXPRESSION OF FEELINGS TO DIFFUSE CONFLICT

The players: TA, angry student (John/Jill), observer.

John/ Jill:	Do you have a moment to talk with me?
TA:	Oh hi, John... Sure, sit down.
John/Jill:	It has become obvious to me today that you are trying to fail me in this class. I need to find out what is going on.
TA:	John, I'd like to hear what I did that gives you the impression that I am trying to fail you. I'm feeling unsure about what you might want to say.
John/Jill:	You just took all these points off and didn't explain why. The grading in this class is so ridiculous.
TA:	I'm really disturbed to hear that. The professor decided to make the homework assignment worth only half as much as usual this week. I'm really confused when you tell me you that I took a lot of points off.
John/Jill:	You're saying that this week's homework assignment was only worth half the points? Why didn't the professor tell me?
TA:	I don't know, John. You'll have to ask him yourself.
John/Jill:	I'm sorry for accusing you. I had the wrong impression.

Answer the question in your triad: How did the TA effectively use the expression of feelings to diffuse the conflict with the student?

HW ASSIGNMENT: COMMUNICATOR'S LOG

Complete the *Communicator's Log* by trying out the communication skills (paraphrase, perception check and description of feelings) on your students, roommate, and friends. First describe the person and situation in which you tried the skill. Then, record that person's reaction to the skill used.

I. Today I used PARAPHRASE with...

#	<u>Person/Situation</u>	<u>Person's reaction</u>
1.		
2.		
3.		
4.		
5.		

II. Today I used PERCEPTION CHECK with...

#	<u>Person/Situation</u>	<u>Person's reaction</u>
1.		
2.		
3.		
4.		
5.		

III. Today I used DESCRIPTION OF FEELINGS with...

#	<u>Person/Situation</u>	<u>Person's reaction</u>
1.		
2.		
3.		
4.		
5.		

APPENDIX G

Handouts for Chapter Seven

HOW ETHNIC AM I?

Spend some time considering the following question and write your answers in the space provided below:

1. What is (are) your ethnic background(s)?

 2. Name a minimum of 5 values which at least one member of your parents, grandparents or great-grandparents held.

 3. Name at least 5 of your values.

 4. How did social, historical, or political forces shape the experiences of your family and their values?
How did they shape your values?

 5. How do your values affect how I approach my engineering studies? (For example: class work, thesis work, working with other students, working with professors, etc.)

 6. How do your values affect your expectations of others?
-

ENCOURAGING WOMEN AND MINORITIES IN THE CLASSROOM

To-Do-List:

- ✓ Use active listening skills.
 - ✓ Show respect for other points of view.
 - ✓ Take the attitude of the loyal learner when you don't understand something.
 - ✓ Connect with the students.
 - ✓ Help the students to connect with one another.
 - ✓ Provide a collaborative learning experience whenever possible.
 - ✓ Be a great role model.
 - ✓ Practice good teaching.
 - ✓ Encourage students getting involved in special programs.
 - ✓ Encourage work-related experience such as MECOP.
 - ✓ Encourage study groups, especially for freshman.
-

APPENDIX H

Handouts for Chapter Eight

HW ASSIGNMENT: REFLECTIONS ON MENTORING

1. **Write your response to the following question in the space below:**

Think about a person who was or is your mentor who had a significant and positive impact on your life. Who was (or is) your mentor? How did the relationship form? Why did (or does) your mentor have such a positive effect on you? What qualities about your mentor and the relationship made it so effective?

2. **For discussion within your triad:** Share your experience with the other members in your triad. What quality about your mentors and the relationships is common to all?

✓ Common quality of mentors:

✓ Common quality of relationships:

3. **For large group discussion:** Be prepared to share your triad's answer to the previous question.
-

EXPECTATIONS OF A TA

(Compiled using information gathered from OSU students.)

- ✓ **Punctuality:** Show up on time, or preferably 5 minutes early to lab – it shows you care. Return students' graded papers and labs promptly.
 - ✓ **Behavior:** Be actively involved with helping students. For example, save grading, doing your homework, snacking, talking on the phone, socializing or just sitting back for another time.
 - ✓ **Communication:** Be ready to communicate ideas and information clearly. If you have a language barrier or are not skilled at communicating your thoughts, be working to improve in that area.
 - ✓ **Leadership:** Be prepared to present information and concerns at the beginning of the lab time. You are responsible to look out for your class, answer their questions and so on.
 - ✓ **Attitude:** Have a kind attitude towards your students. Even though you do not know all the answers, they will still feel cared for as students if you are fair, patient, helpful, kind and show that you are on their side.
 - ✓ **Class material:** Know the class material generally so that you can field questions which arise out of the lecture time. Students don't always have the opportunity to ask the professor questions or sometimes feel intimidated to approach him or her. You are in a unique place of having technical knowledge while still being more accessible than a professor. Be intentional about being approachable.
 - ✓ **Lab material:** At the very least, be familiar with the lab. At the very best, work through it yourself beforehand. You should be able to help guide a student through the problem solving process. While a response of 'I don't know' shows you don't care, an answer too quickly or easily given shows you don't care about the student's learning.
-

APPENDIX I

Handouts for Chapter Nine

BOUNDARIES FOR THE TA

❖ What are boundaries?

- ✓ A *boundary* is where “me” ends and “not me” begins.
- ✓ *Good boundaries* are designed to let the good in and keep the bad out.
- ✓ Some *examples* of boundaries include skin (physical), “no” (words), distance (geographical and emotional) and time.

❖ Boundaries and interacting with others:

- ✓ The *goal* of a boundary is for the consequences of your actions to come to you and the consequences of my actions to come to me.
- ✓ We are responsible *for* ourselves and *to* others.
- ✓ When another crosses your boundary, you feel *hurt*. What you feel when you want to restore the boundary to its appropriate location is *anger*.

❖ Some practical principles of boundaries:

- ✓ Sowing and reaping: Let the consequences for a person’s actions cleanly fall on him.
- ✓ Responsibility: Do *care* for one another, do not try to *be* one another.
- ✓ Reciprocity: Respect the boundaries of others so that they may respect yours.
- ✓ Evaluation: Evaluate the effects of setting boundaries and be responsible to the other person.

❖ Examples of boundaries for the TA:

- ✓ If the TA, the student, or someone else is in danger, the TA is not responsible to directly deal with the situation, but should call Public Safety to protect the students and him/ herself.
- ✓ Call Public Safety/ OSP for Immediate Assistance at 541-737-7000.
- ✓ If the student is in need of counseling and psychological services, the TA is not responsible to counsel the student, but may refer him or her to Counseling and Psychological Services.
- ✓ More information can be found at: http://oregonstate.edu/dept/counsel/faculty_staff.php.
- ✓ The TA should not engage in romantic relationships with students.

Recommendation for further reading:

Boundaries, by Dr. Henry Cloud and Dr. John Townsend, (ISBN #0-310-24745-4).

HW ASSIGNMENT: FINAL REFLECTION

In summary, the class topics were:

- ❖ Leadership (basic foundations and conflict resolution),
- ❖ Teaching (skills for the teacher and student learning),
- ❖ Communicating (listening skills and topics of gender and ethnicity), and
- ❖ Mentoring (connecting and boundaries.)

Bearing that in mind, answer the following questions (typed) on a separate sheet of paper.

1. What leadership position(s) are you in this term?
 2. Which of the leadership skills, that this course covered, did you find most useful in that leadership position and why?
 3. Which of the leadership skills, that this course covered, did you find least useful in that leadership position and why?
 4. Were there any skills and topics that you would like to see covered in the future?
 5. Which skill(s) did you experience the most growth in this term? Describe the circumstances of that growth.
 6. What area(s) do you most need to grow in? How did that area(s) of weakness affect your leadership this term?
-

APPENDIX B – TEACHING SELF-EFFICACY SURVEY

This section contains the teaching self-efficacy survey which was given to graduate and undergraduate TAs. It was adapted from a teaching self-efficacy survey designed by Albert Bandura.

Last 4 digits of Student ID _____

Engineering Lab Teaching Assistant Self-Efficacy Scale

This questionnaire is designed to help us gain a better understanding of the kinds of things that create difficulties for engineering lab TA's in their university activities by measuring self-efficacy. Self-efficacy is "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations." Please rate how certain you are that you can do the things discussed below by writing the appropriate number. Your answers will be kept strictly confidential and will not be identified by name.

Rate your degree of confidence by recording a number from 0 to 100 using the scale given below:

0	10	20	30	40	50	60	70	80	90	100
Cannot					Moderately			Highly		
do at all					certain can do			certain can do		

Efficacy to Influence Decision Making

Influence the decisions that are made in the engineering course..... _____

Express my views freely on important course matters..... _____

Get the instructional materials and equipment I need..... _____

Instructional Self-Efficacy

Get through to the most difficult students..... _____

Get students to learn when they have a weak support structure..... _____

Keep students on task on difficult assignments/labs..... _____

Increase students' memory of what they have been taught
in previous lessons/labs..... _____

Disciplinary Self-Efficacy

Get students to follow lab rules..... _____

Control inappropriate behavior in the lab..... _____

Prevent problem behavior in other engineering settings..... _____

Efficacy to Create a Positive University Climate

Make the lab a safe place..... _____

Make students enjoy coming to lab..... _____

Get students to trust TA's..... _____

Help other TA's with their teaching skills..... _____

Increase collaboration between TA's and professors
to make the university run effectively..... _____

Reduce students dropping out of engineering..... _____

Reduce students cutting class..... _____

Get students to believe they can do well in engineering..... _____

**APPENDIX C – SURVEY AND RESULTS FOR OLD ECE 323,
SPRING 2006**

ECE 323 Class Survey – Spring 2006

Section 1 – Circle the best response for each of the following items.

1. Gender

- a. Female
- b. Male

2. Race/Ethnicity (You may choose not to answer)

- a. African American or Black
- b. American Indian or Alaskan Native
- c. Asian
- d. Hispanic or Latino
- e. Native Hawaiian or other Pacific Islander
- f. White
- g. Other _____

3. I think the grade I will receive in this course is...

- a. A
- b. B
- c. C
- d. D
- e. Don't think I will pass
- f. I have no idea.

Section 2 – Please answer the following by circling only one of the possible choices for each question.

- | | | | |
|--|--------|------------------|-----------|
| 1. I attended class. | Always | Most of the time | Sometimes |
| 2. I sought help from the professor. | Often | Occasionally | Never |
| 3. I sought help from the TAs. | Often | Occasionally | Never |
| 4. I attended scheduled TA help session. | Often | Occasionally | Never |
| 5. I worked out the homework problems. | Always | Most of the time | Sometimes |

Section 3 – For each element below, please identify how much it either helped or hurt your understanding of course materials.

A. Teaching Assistants:

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

B. Prelabs:

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

C. Homework:

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

D. Lab Reports

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

E. Lecture Professor

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

F. Lab Professor

Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
-----------------	--------	---------	------	---------------

Section 4 – Please answer the following by circling only one of the possible choices for each question.

- Overall I think the lecture and the lab for this course are connected.

Strongly Agree	Agree	Neutral	DisagreeStrongly	Disagree
----------------	-------	---------	------------------	----------

- I understand frequency dependence in transistor circuits.

Strongly Agree	Agree	Neutral	DisagreeStrongly	Disagree
----------------	-------	---------	------------------	----------

- I understand ways a logic gat can be constructed.

Strongly Agree	Agree	Neutral	DisagreeStrongly	Disagree
----------------	-------	---------	------------------	----------

- My project management skills are improved because of this course.

Strongly Agree	Agree	Neutral	DisagreeStrongly	Disagree
----------------	-------	---------	------------------	----------

- I think I am better prepared for my senior design project because of this course.

Strongly Agree	Agree	Neutral	DisagreeStrongly	Disagree
----------------	-------	---------	------------------	----------

ECE 323 Class Survey Results – Spring 2006

Section 1							
Gender	Female	Male					
	8	32					
Race/Ethnicity	African American or Black	American Indian or Alaskan Native	Asian	Hispanic or Latino	Native Hawaiian or other Pacific Islander	White	Other
	0	0	6	3	0	28	3
Expected Grade	A	B	C	D	Don't think I will pass.	I have no idea.	
	14	21	0	0	1	4	

Section 2			
I attended class.	Always	Most of the time	Sometimes
	29	10	1
I sought help from the professor.	Often	Occasionally	Never
	1	16	22
I sought help from the TAs.	Often	Occasionally	Never
	2	16	21
I attended scheduled TA help sessions.	Often	Occasionally	Never
	2	11	25
I worked out the homework problems.	Always	Most of the time	Sometimes
	11	16	12

Section 3					
	Strongly Helped	Helped	Neutral	Hurt	Strongly Hurt
Teaching Assistants	3	14	17	3	0
Prelabs	1	8	16	10	4
Homework	3	19	15	0	2
Lab Reports	1	7	19	11	1
Lecture Professor	17	17	4	1	0
Lab Professor	0	3	8	11	16

Section 4					
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Lecture and lab connected	0	11	7	15	6
Understand frequency dependence	7	22	9	0	0
Construct a logic gate	18	16	2	1	1
Project management skills	3	10	14	7	3
Senior design project	1	21	9	2	3

APPENDIX D – ECE 323 LAB MANUAL

This appendix contains in entirety the newly developed ECE 323 lab manual. The format and content of this document are explained at the beginning of the text. The lab manual is designed to be printed in the landscape format which may then be cropped by several inches on one side and bound. As such, the placement of the text alternates between right and left justified and appears to be slightly awkward in its format in this appendix.

The lab chapters are as follows:

1. Introduction to PSPICE and Bode plots
2. Frequency generator, summing circuit, and low pass filter
3. Single-stage amplifiers and active filters
4. Output stages
5. Peak detector and Schmitt trigger
6. Microphone and class project
7. Building the receiver

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PREFACE

Preface

HOW TO USE THIS MANUAL

During this course, various tasks will be performed from the assembly of electronic devices, and through the development process of digital logic controllers and systems. These tasks are divided into individual lab documents that correspond to what is being taught in the Digital Logic Design lecture.

Everything learned in lecture is relevant and useful in later (related) courses and in your future career. As various tasks are performed in these labs, try to pay attention to how the lecture material relates to these tasks. Understanding how the lecture material is used and applied will greatly improve your understanding of the topics as well.

IMPORTANT SYMBOLS

During this lab and other TekBots labs, you will encounter the following symbols. So, review or acquaint yourself with these symbols, as they are widely used in this lab manual.



This symbol indicates an **important note** that should be remembered/ memorized. Paying attention to notes like these will make tasks easier and more efficient.



This symbol designates **caution**, and the information in this caution-table should be read thoroughly, and adhered to, before moving ahead. If the caution warning is ignored, the task may appear impossible and/ or can lead to damaged TekBots and systems.



This symbol represents something that helps you make your task easier by reminding you to perform a particular task before the next step. These **reminder** symbols are not normally critical things to complete, but can make things easier.



The **innovation** symbol will give information to enrich your experience. These sections will give more insight into the what, why, and how of the task being done. Use these to learn more, or to get ideas for cool innovations.

LAB STRUCTURE

The entire lab is divided into various sections, in order to break up the tasks. Typically, each section will have the Section Overview as the introductory paragraphs and information detailing the task in the Procedure paragraphs. Towards the end, we have Study Questions/ Turn-Ins (which will be your homework from this lab), and/ or Challenges.

Section Overview

The section overview briefly describes what will be learned in the section, and what will be done.

Procedure

The procedure portion of each section contains all of the tasks to be completed and relates to the corresponding lecture. Keeping this in mind will help to better understand the lecture as well as the lab material.

Study Questions

The study questions are intended to give more practice and insight into what has been learned in lab and lecture. Some of the study questions will be due in lab.

Challenges

The challenge sections of labs are for extra credit. Performing the tasks in the challenge sections will improve understanding of what is being learned and will result in some cool TekBots and innovations.

LAB SAFETY

Safety is always important when working with electricity and electronics. This includes both the safety for you as well as safety for the circuit components you are working with. Concerns such as high voltage or currents can affect the human body, while static safety and proper component use can affect the life of your circuits.

Personal safety

When working with high voltage s and currents, it is important that you remember that you can be hurt, if your body becomes the 'circuit', since the human body is a conductor of electricity.. This issue has long been combated by using the 'one hand rule.' Whenever you are working with a potentially dangerous circuit, turn it off, but if it cannot be turned off, use only one hand when working on it. This will prevent a circuit from being made through your heart, which could be potentially fatal.

Component safety

Many electrical components are likely to be damaged by static electricity. Static charge can build up to many thousands of volts, but with little energy. This cannot harm humans, but it can easily damage electronic components. To ensure static-safe handling, the best practice is to wear an anti-static strap and connect it to an earth ground such as a computer case or a water pipe. If you do not have an anti-static wristband, you can instead touch a ground every few minutes to discharge your static build up.

SECTION ONE

Introduction to PSPICE and Bode plots (One Week)

SECTION OVERVIEW

This section will provide you an introduction to PSPICE and Bode plots. Following are the objectives and a description of the system that you will be designing in this lab.

Objectives

Following are the objectives for this lab:

- Become more familiar with PSPICE.
- Learn how to create Bode plots.

System description

During the course of this lab, you will be constructing an audio remote control for your TekBot. Using this project, you will explore the principles of amplification, the frequency response, and system design. Figure 1 is an illustration of this system.

The system you will be designing is composed of two pieces, a transmitter and a receiver. The transmitter can generate two different tones (or three if you want a challenge), and combine them to be transmitted using a speaker. The receiver can receive any number of different tones, but filters out the frequencies of interest. It converts these signals into logic signals that control your TekBot. This type of system is still used in modern telephones; it is called DTMF (dual-tone multi-frequency). Have you ever wondered why pressing each button on a telephone makes a different sound?

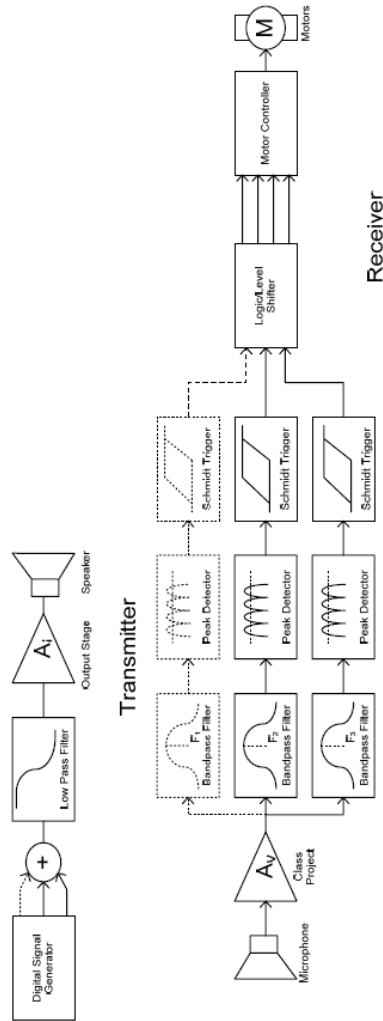


Figure 1: Description of the Audio Remote Control System

INTRODUCTION

We begin the lab by giving you a brief introduction to PSpice and Bode plots.

About PSpice

As you probably remember from previous courses, the engineering method begins by first creating a design. However, the design needs to be tested. This can be performed through conceptual tests, or in the case of a circuit, through simulation results. Properly and thoroughly simulating a circuit is more important than many people realize. One of the most popular circuit simulation tools is **SPICE**, which stands for Simulation Program with Integrated Circuit Emphasis.

SPICE was developed at the Department of Electrical and Computer Engineering at the University of California at Berkeley in the 1970s. PSpice, one of almost twenty versions, was developed for personal computers in 1984 by MicroSim Corporation in California. The software is not only very popular with students but is also available free for their usage. The following block diagram in Figure 2 gives an overview of how the simulation program operates.

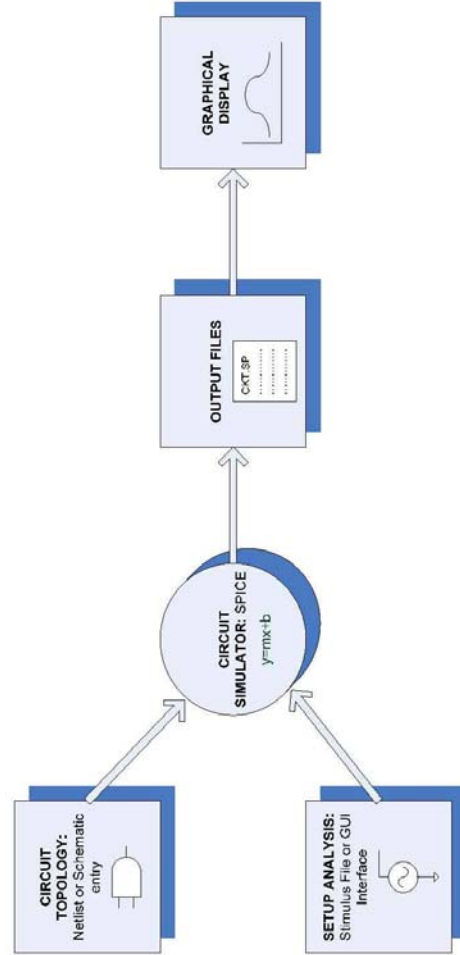


Figure 2: Block diagram of the simulation process

Bode plots

Bode plots are industry-standard tools that are used while inspecting circuits that have varied responses at different frequencies. A Bode plot, named after Hendrik Wade Bode (1905-1982), is a combination of a Bode **magnitude plot** and a Bode **phase plot**.

Bode magnitude plot

A **Bode magnitude plot** is a log-log plot of magnitude versus frequency, which shows the transfer function of a linear time-invariant system. Figure 3 illustrates an example of a Bode magnitude plot.

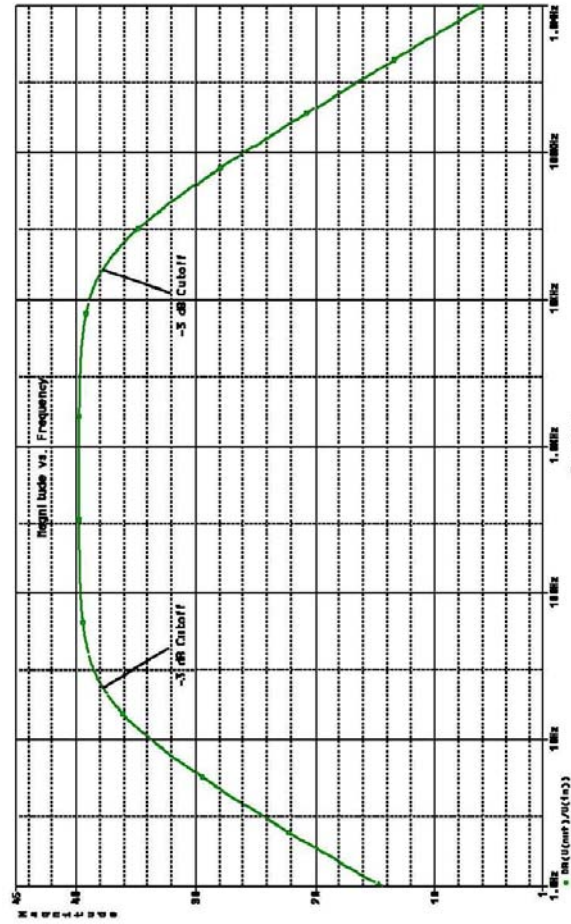


Figure 3: Bode Magnitude Plot of a Bandpass Filter

Bode phase plot

A **Bode phase plot** is a graph of phase versus log frequency. It is used to show how much the phase of the output signal will be shifted from the input signal. Figure 4 illustrates an example of a Bode phase plot.

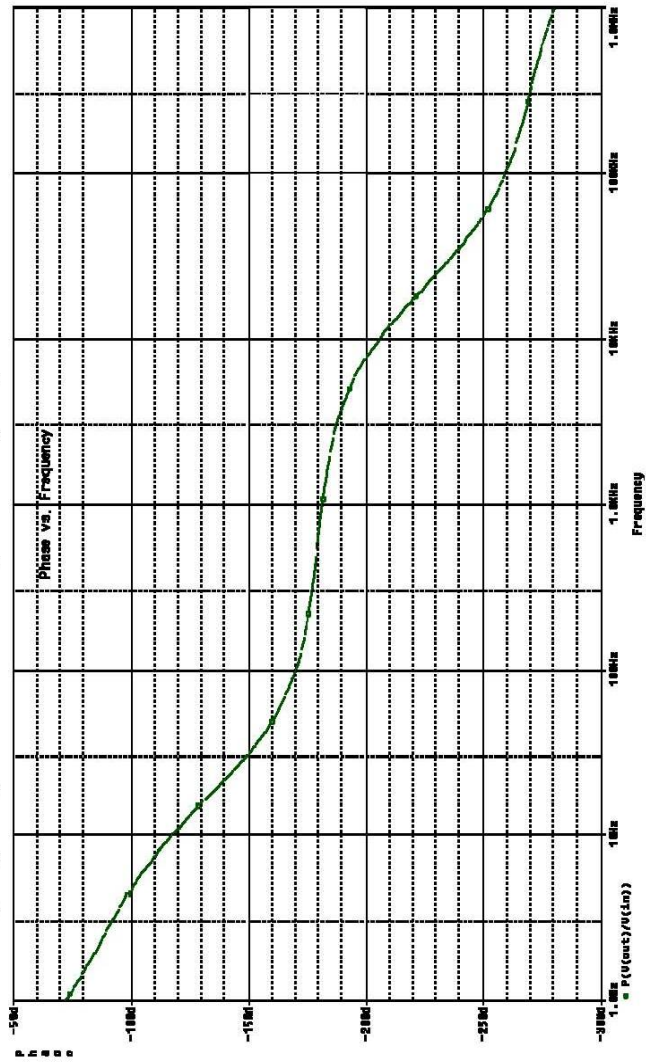


Figure 4: Bode Phase Plot of the same Bandpass Filter

PROCEDURE

The procedure for this lab has been divided into three tasks: (a) briefly refresh using the PSPICE circuit simulator, (b) create Bode plots for a circuit, and (c) simulate the circuit in PSPICE.

Task One: Briefly refresh using the PSPICE simulator

The PSPICE software can be found under:

- Start → Programs → PSPICE Student → Schematics.
- Open a new schematic in PSPICE.

In order to successfully simulate a circuit in PSPICE, you must first choose an analysis type. There are three main types of analyses commonly used in PSPICE. They are: AC, DC, and Transient analysis.

There are also two ways to learn about these different types of analyses.

- (a) The first is via the PSPICE manual located at:
<http://eeecs.oregonstate.edu/education/classes/ece322/docs/PSpiceRef.pdf>.
- (b) Another useful source of information is the **Help file** found on the menu bar of the Schematics window in PSPICE. Select Help topics and search the index for the different types of analysis.

Task Two: Create Bode plots for a circuit

For this task, you will create Bode plots for a circuit that will be built and simulated using PSPICE. However, before you begin building the circuit, read the sections on Cutoff Frequency and Tips thoroughly.

Cutoff frequency

In analyzing the response of filters, it is important to know about the **-3 dB cutoff frequency**, $f_c [Hz]$. The -3 dB point corresponds to the frequency at which the filter passes only half of the input power. This is equivalent to a voltage reduction of $\frac{1}{\sqrt{2}}$ of the passband. This point also corresponds to a value of 1τ .

Figures 5 and 6 (appearing later in this section) are illustrations of two circuits that you need to build in PSPICE, and simulate as well. Find the frequency where the magnitude is decreased by 3 dB.



While analyzing these two circuits, read and use the helpful information provided for the same under *Tips*.

Tips

Remember and use the following tips for Circuits (a) and (b), under Figures 5 and 6 respectively:

1. To determine the start and stop frequencies for the AC sweep.

$$\tau [s] = RC, \text{ and } \omega [rad/s] = \frac{1}{RC} = 2\pi f_c.$$

For example, let $R = 20k\Omega$ and $C = 1\mu F$. For this filter, $\tau = RC = (20k\Omega)(1\mu F) = 20ms$, and the corner frequency is $f_c = 7.96Hz$. Remember that, at 5τ , the magnitude of the transfer function will have reached over 99% of its maximum value.

Therefore, a good start frequency would be 1 Hz, and a good stop frequency would be:

$$f_{stop} = (5) \left(\frac{1}{\tau} \right) = (5) \left(\frac{1}{20ms} \right) = 250Hz \text{ or more.}$$

Tips (Contd.)**2. To trace the Bode plot.**

- In the **Trace** menu → use the **DBO function**, or remember that the -3 dB point occurs at 70.7% of the magnitude of the transfer function.
- To view the data points, from the tool bar in the **Graphical Display** window → select the **Toggle Cursor** button. A **Probe Cursor** window will appear, and you will be able to trace the plot.

3. Choosing the correct voltage source.

When doing an AC analysis, use the VAC source. For a transient analysis, use the VSIN source.



Refer to Appendix A, located on the lab Web-page, for a tutorial on how to perform a frequency analysis in PSPICE.

Create Bode magnitude and phase plots

After thoroughly reading the information on cutoff frequency and the tips provided in the previous sections, you can use them to create Bode plots for both the magnitude and phase for each filter.

- **For the magnitude plot:** In the **OrCAD** display window → **Add Traces** menu → use the **DBO function**.
- **For the phase plot:** In the **OrCAD** display window → **Add Traces** menu → use the **PQ function**.
- Also, be sure that the sweep type is set to 'decade'. This will produce a log-log plot of the transfer function.
- It is possible to create a plot window which includes both graphs. In order to do this: in the **OrCAD** window → **Plot** menu → choose **Add Y-Axis**, and then add the **PQ trace**.

Analyze the circuits

This last sub-section in Task Two requires you to analyze the circuits in Figures 5 and 6, using all the information provided to you in the earlier sub-sections.

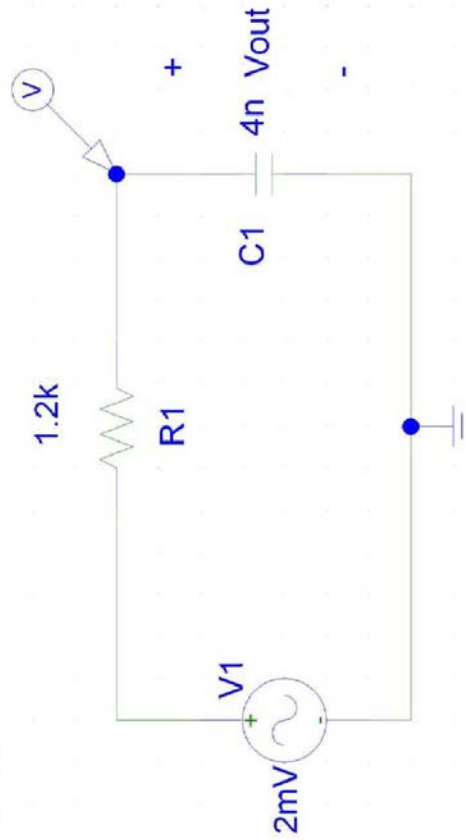


Figure 5: Circuit (a).

With reference to Circuit (a) in Figure 5, answer the following questions and record your calculations/ inferences below in the space provided:

- 2.1) What function does this circuit perform? ▲ _____
- 2.2) What is the -3 dB Cutoff Frequency? ▲ _____
- 2.3) What is the amplitude of V_{out} at the cutoff frequency? ▲ _____

Analyze the circuits (Contd.)

With reference to Circuit (b) in Figure 6, answer the following questions and record your calculations/ inferences below in the space provided:

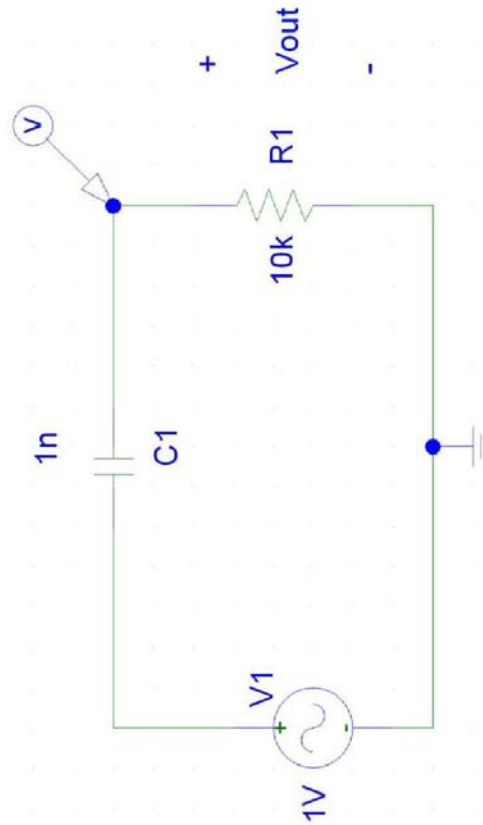


Figure 6: Circuit (b)

- 2.4) What function does this circuit perform? ▶ _____
- 2.5) What is the -3 dB Cutoff Frequency? ▶ _____
- 2.6) What is the amplitude of V_{out} at the cutoff frequency? ▶ _____

Task Three: Simulate the circuit in PSPICE

In this task, you will perform the following:

- Build and simulate the following circuit in PSPICE.
- Sweep the frequency from 1 Hz to 1 GHz.
- Create Bode plots for the amplifier.

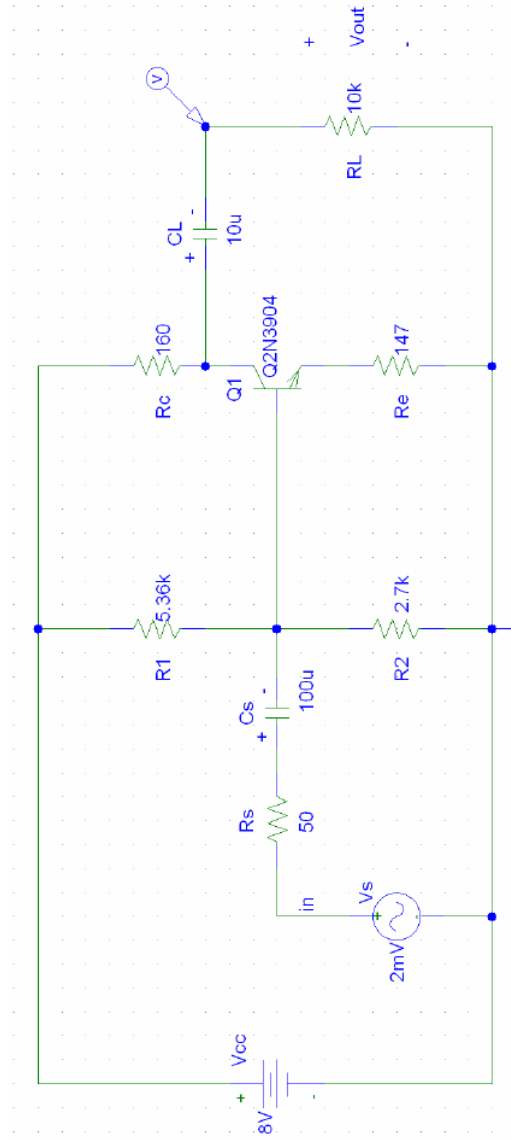


Figure 7: Circuit (c)

With reference to Circuit (c) in Figure 7, answer the following question:

- 3.1) What happens to the magnitude at high frequencies? ►

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the beginning of the next lab (Section Two):

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section One.
- ☐ Bode plots for Circuits (a), (b), and (c).
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to following Study Questions.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Two.
- ☐ Bring your ECE 272 Digital Logic Board.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.
 - a) What is the difference between DC, AC, and transient analysis in PSPICE? What information would each type of analysis give you about the circuit in Figure 4?
 - b) What is the benefit of using a log-log plot compared to using a linear plot?
 - c) Why do we use the -3 dB point when determining the cutoff frequencies?
 - d) What other options are there besides 'Decade' on the AC Sweep? How do these options affect the simulation?

APPENDIX A: QUICK-START TO SIMULATE A CIRCUIT USING PSPICE

1. **To open PSPICE:** Go to **Start** → **Programs** → **Class Applications** → **PSPICE Student**, and click on **Schematics**.
 2. **To add components:** Go to the component library by clicking on the **Draw** menu and choosing **Get New Part** (or press CTRL+G).
 - **To add a resistor:** Enter the letter **R** and click **Place**.
 - **To add a capacitor:** Enter the letter **C** and click **Place**.
 - **To add a voltage source:** Enter the letter **V** and choose **VAC** from the menu.
 - **To add a ground:** Enter the letter **G** and choose **GND_EARTH** from the menu.
 3. **Place each component** on the board and connect them by clicking on the 'pencil' icon in the toolbar or by typing CTRL+W.
 3. **Change the values** of the components by double clicking on their current value.
 4. **To perform an AC analysis:** From the **Analysis** menu → choose **Setup**. Click on **AC sweep** → choose **Decade** as the AC Sweep Type → and select the appropriate **Sweep Parameters**.
 5. **Simulate the circuit:** From the **Analysis** menu → select **Simulate** (or press F11). In the **OrCAD** window → from the **Trace** menu → select **Add Trace**.
 6. **For viewing the magnitude:** In the **Trace Expression** line → select the appropriate output voltage node and divide it by the appropriate input voltage node.
 7. **To change the vertical scale to decibels:** From the **Function** menu → select **DBQ** (i.e. DB(Vout/Vin)). Click **Ok**.
- Hint:* To more easily distinguish between the voltage nodes, it is possible to label the wire connecting the nodes. In the **Schematics** window, simply double click on the wires which are connected to either the input node or the output node, and name them. (However, the circuit will need to be simulated again).

SECTION TWO

Frequency Generator, Summing Circuit, and Low Pass Filter (One Week)

SECTION OVERVIEW

This section (Section Two) has been primarily divided into two parts: Pre-Lab and Lab. You will be showing all the Pre-Lab work from this lab as well as turning in the rest of the work from the previous lab (Section One).

Figure 8 has an illustration of the transmitter system that you will design in this lab.

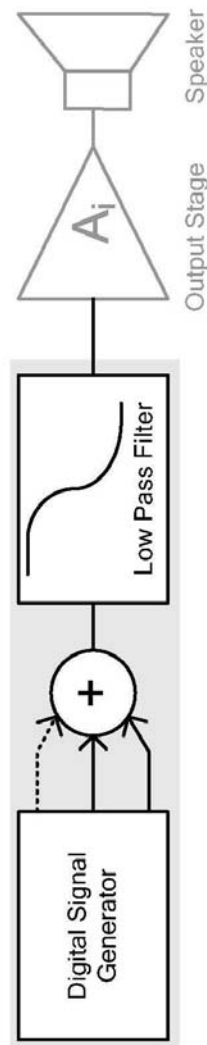


Figure 8: Description of the transmitter system

PRE-LAB

The pre-Lab has four main sub-sections: all about frequencies, superposition, physical summing circuit, low pass filter, and choosing a DC bias point for V^+ .

All about frequencies

This sub-section has information about frequencies in the following categories: frequency domains, frequency and the `d_logic` board, and frequency and the clock-counter.

Frequency domains

When working with a communication system, it is often beneficial to transmit only a single tone (one channel) rather than multiple channels. Figures 9(a) and 9(b), on the next page, show what this might look like in the frequency domain.

For this transmitter system, you will transmit two or three single tones. The receiver will receive these tones and decode them into four or eight movements of the TekBot.

As you can see from Figure 9(a), a noisy signal has many unwanted signals in addition to the desired tone, F_c . Figure 9(b) on the other hand, has only one pure tone at the desired frequency. You should remember from your signals and system coursework that a single frequency is a sine wave in the time domain.



Figure 9(a): Frequency Domain of a Noisy Signal

Figure 9(b): Frequency Domain of a Pure Sine Wave

Frequency and the d_logic board

You were told to bring your ECE 272 digital logic board this week. You will be using your d_logic board from ECE272 to generate at least two different square-wave frequencies. Then, you will add them up using a summing circuit and finally, smooth the square-wave to be as close to a sine wave as possible, using a low-pass filter.

Frequency and the clock-counter

The cPLD receives an external clock signal, which can be set to many different values. The 100 kHz external clock is used as the clock-counter in this schematic. For this lab, a circuit which generates eight different frequencies based off that clock, has already been created for you to use.

The frequencies generated are: 400 Hz, 800 Hz, 1.67 kHz, 3.33 kHz, 6.67 kHz, 13.2 kHz, 26.3 kHz, and 52.5 kHz. You may choose any two of these frequencies within the audio range of 20 Hz – 20 kHz. (You may also choose a third frequency for extra credit.) Keep in mind that some of the higher frequencies are quite annoying, so those should be avoided. You will have the opportunity to explore these frequencies in the lab.

Additionally, you will be transmitting these signals using a speaker and a microphone provided for you. The components have their own frequency responses, and that information can be found on their respective datasheets. You may want to be sure the frequencies you use are within the dynamic range of their components!

Figure 10 describes the schematic for the 100 kHz clock that is used as the clock-counter.

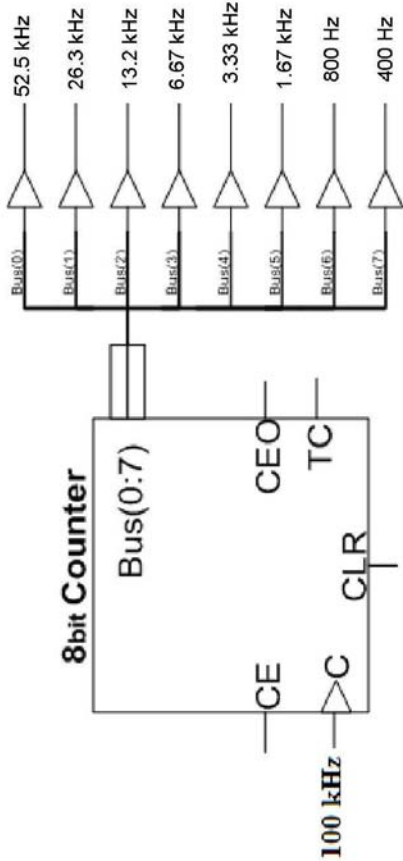


Figure 10: Xilinx schematic for generating frequencies

Note: When CLR is high all other inputs are ignored; CE = clock enable, C = clock speed, TC = terminal count, and CEO = clock enable out.

The counter, which is currently provided to you in the lab, is set up to output frequencies of 400 Hz and 800 Hz which are Bus(7) and Bus(6), respectively. If you want to select different frequencies, you should simply change the Bus number of the wire to the desired Bus number's frequency, such as: i.e. Bus(7) → Bus(4). A particular frequency is generated when its switch S₁ (or S₂) is held down. When S₁ or S₂ is not being pressed, that output is held at high impedance.

Note: This circuit generates square waves, not sine waves. You will also have a chance to explore in the lab how different types of signals sound.

Superposition

Any number of individual signals may be added together into one signal through **superposition**. The superposition theory states that the total current or voltage in any branch of a linear circuit equals the algebraic sum of the currents or voltages produced by each source acting separately throughout the circuit. This new signal can then be sent to the output stage and used to drive the speaker. The block diagram for this is shown in Figure 11.

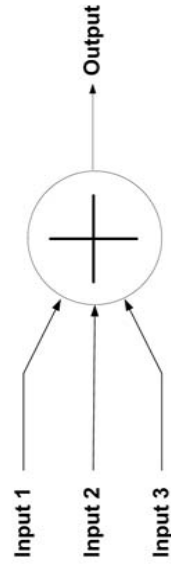


Figure 11: Summing Circuit Block Diagram

Section Two: Frequency Generator, Summing Circuit, and Low Pass Filter

Figure 12 shows three different input voltages. If these three inputs were fed into the summing circuit in Figure 11, draw the expected output at the bottom of Figure 12.

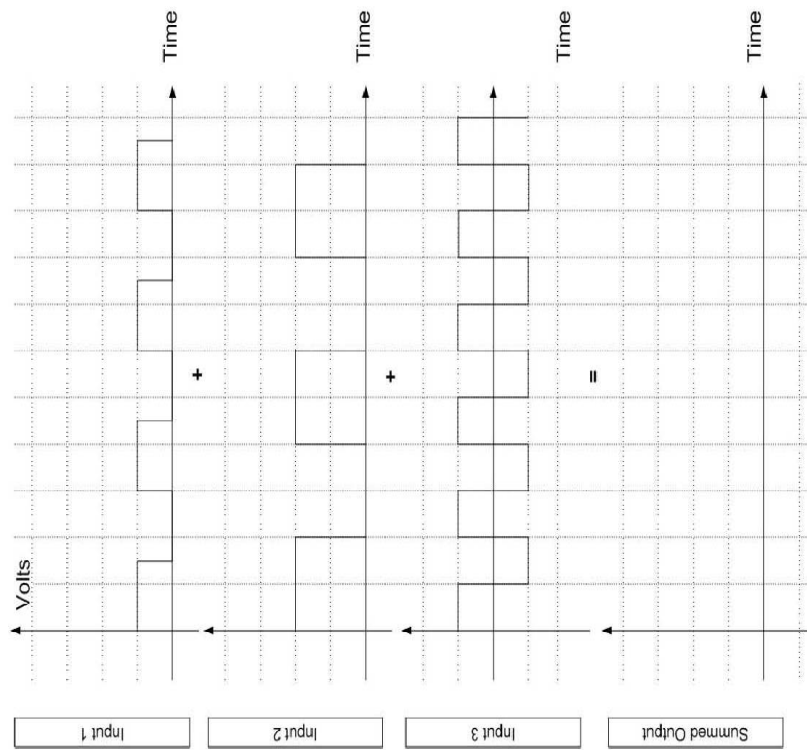


Figure 12: Superposition exercise

Physical summing circuit

The signals can be easily added together using a summing circuit. An example of one is shown in Figure 13.



Refer to Page 76 in Sedra/ Smith for a complete explanation of a summing circuit.

Because each signal from the cPLD should be weighted equally, you should make sure $R_1 = R_2$, when choosing resistor values for your circuit. **You may use this circuit as a basic framework for the topology of your summing circuit.**

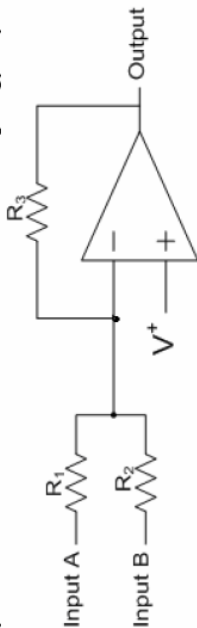


Figure 13: Physical summing circuit

Low-pass filter

After summing the two frequencies, f_1 and f_2 , from the cPLD, the signal is a superposition of square waves. Running the resultant signal through a low-pass filter, as shown in Figure 14(a), will cut out high-frequency components, making the signal more sinusoidal. It is also possible to not include this filter in the system and simply transmit square waves. Figure 14(b) shows how the desired frequencies are selected using a low pass filter.

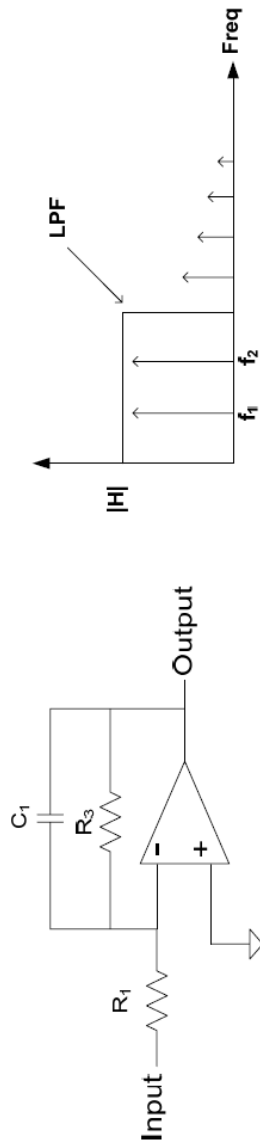


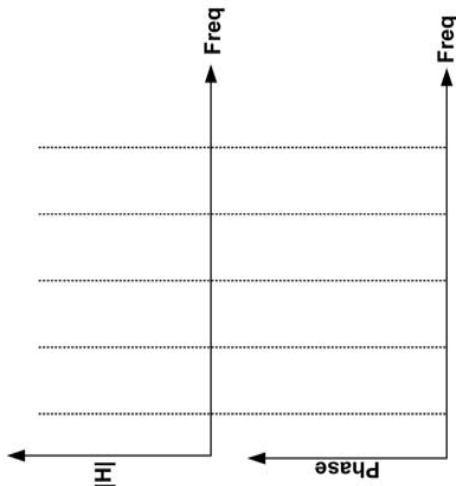
Figure 14(a): Low pass filter

Figure 14(b): Frequency response of LPF

Section Two: Frequency Generator, Summing Circuit, and Low Pass Filter

With reference to Figure 14(a), answer the following questions. Record your answers in the spaces provided.

- 3.1) Calculate the transfer function, $H(s) = \frac{V_{out}(s)}{V_{in}(s)}$ for the circuit in Figure 14(a). $H(s)$ ▶ _____
- 3.2) What is the magnitude of the gain at DC? A_v ▶ _____
- 3.3) Why is $H(s)$ negative? ▶ _____
- 3.4) How many poles does this circuit have? ▶ _____
- 3.5) What frequency is (are) the pole(s) at? ▶ _____
- 3.6) Sketch the Bode plots for this circuit in the graph below. Label all points of interest in terms of R and C.



Choosing a DC bias point for V^+

Solve these questions using the circuit in Figure 15 below.

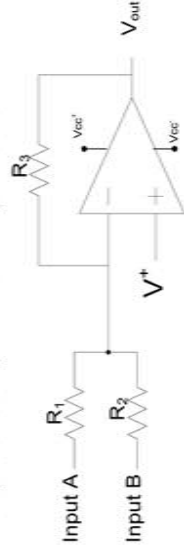
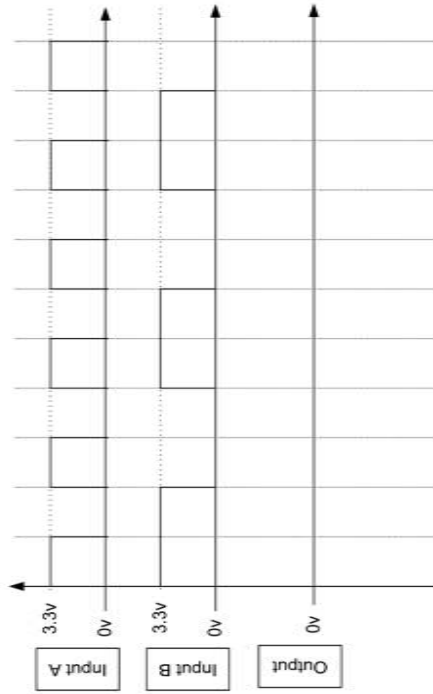


Figure 15: Physical summing circuit

4.1) Assuming Input B is high impedance, $R_1 = R_2 = R_3 = 10\text{k}\Omega$ and $V^+ = 0\text{V}$, when Input A = 3.3V, solve for V_{out} .

4.2) For the following plot of Inputs A and B, with $R_1 = R_2 = R_3 = 10\text{k}\Omega$, sketch V_{out} for at least one cycle in the graph below:



Choosing a DC bias point for V^+ (Contd.)

- 4.3) In reality, the op amp can only generate voltages at its output, between its positive and negative supply rails. For this system, the op amp will be supplied by a 9V battery, so $V_{cc}^+ = 9V$ and $V_{cc}^- = 0V$. Between what range of values could the DC bias point V^+ be set at, so that the op amp never tries to drive negative voltages at the output?

Range of V^+ ► _____

- 4.4) Design a circuit to generate the voltage V^+ . Draw it below in the space provided.
(Hint: You might use diodes or a voltage divider.)

- 4.5) Draw your overall design for the summing circuit and low pass filter. Include component values and label the bias voltage V^+ . (If you need more space than that provided below, draw your design on a separate sheet of paper and attach it to this).



TA Signature : _____

- ☐ Pre-lab completed before beginning of Section Two lab time.
☐ Student brought digital logic board to class. (0.5 point)

LAB

Now that you have done some preparation on the different blocks of your transmitter, you need to try them out in the lab. We begin the lab by outlining the objectives, which are nothing but the three primary tasks for this lab.

Objectives

Following are the objectives for this lab:

- Choose two frequencies for the transmitter.
- Program the cPLD.
- Build, test, and solder a summing circuit and LPF.

System description

During the course of this lab, you will be constructing a summing circuit and a low pass filter for your TekBot. Figure 16 is an illustration of the entire transmitter system. The blocks which you will construct during this lab section have been highlighted in boldface and a grey background.

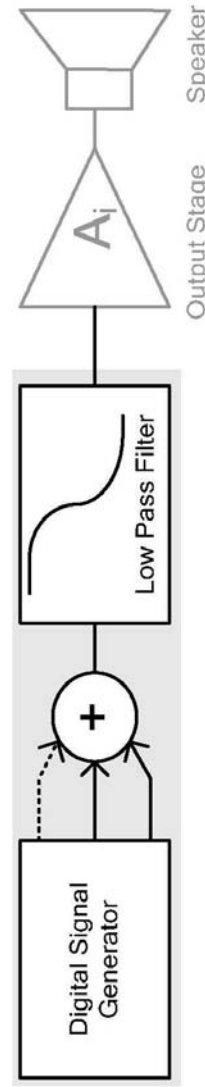


Figure 16: Description of the transmitter system

Task One: Choose two frequencies for the transmitter

The frequencies available for use were already explained in the pre-lab. This exercise is designed for you to get a feel for what different frequencies and waveforms sound like. Once you have accomplished this, you may select any **two** available frequencies to use, for the rest of the term. If you choose, you may also select a third frequency which will count as extra credit throughout the term.

You may do Task One in teams of two.

- Choose a partner for this task.
- Hook a speaker up to the frequency generator.
- Observe and record your answers to the following questions:

1.1) How do the different waveforms sound? Describe the sound as appropriately as you can, in your own words.

Sine wave ▶ _____

Square wave ▶ _____

Triangle wave ▶ _____

1.2) Using the pre-defined digital design above, you will only be able to select frequencies from those listed below. If you want to use the default design, circle the two (or three) frequencies below that you plan to use.

400 Hz	800 Hz	1.67 kHz	3.33 kHz	6.67 kHz	13.2 kHz
--------	--------	----------	----------	----------	----------

If you would like to make your own digital circuit, you might be able to get even better performance. If you would like to do this, write in the two frequencies you plan to design for.

Frequency 1 ▶ _____ Frequency 2 ▶ _____ Frequency 3 (optional) ▶ _____

1.3) Set the frequency generator to output a square wave. You should double-check the frequency responses of your microphone and speaker to verify that the frequencies that you selected are within the dynamic range of your parts. **If any of the frequencies that you selected does not emit sound or is too high-pitched and annoying to work with all term, you should re-think your choices.**


Task Two: Program the cPLD

ECE 272 used a digital logic board or cPLD to program re-configurable digital logic. These cPLDs will be used as part of the transmitter. To accomplish this, you will need to re-visit Xilinx, the software for the digital logic board. For the default design, Xilinx project files and design files are provided on the Web-page. All you need to do is to download this logic onto your chip.

Download the file and open it in Xilinx

Follow these steps to download the file:

- 1. Download the file [FrequencyGenerator.html](#), and open it using the Xilinx software.
- 2. Xilinx can be found via: **Start** → **Programs** → **Xilinx ISE 7.1i** → **Project Navigator**.
- 3. In Xilinx, to open the project, click: **File** → **Open Project** → (File Name) → **FrequencyGenerator.ise**.

 Notice that the two frequencies which are currently selected are 400 Hz and 800 Hz. If you chose different frequencies, alter the schematic before downloading it to your cPLD.

Download logic for the transmitter to the cPLD

To download the logic onto your cPLD, follow these steps:

Make the connections:

1. Connect the programming cable to the parallel port on your computer.
2. Connect the ribbon cable to the programming header on your d_logic board.
3. Connect power to the d_logic board using either your TekBot, a wall adapter, or the bench top power supply.

Configure the device:

4. Select your Schematic file in the **Sources in Project** window.
5. Double-click **Configure Device (iMPACT)** under the **Generate Programming File** section.
6. iMPACT will launch with a dialog asking you how to configure the device. If asked, select **Boundary-Scan Mode** (default), and click **Next**.

Download logic for the transmitter to the cPLD (Contd.)

7. In the **Boundary-Scan Mode Selection** dialog, select **Automatically connect to cable** (default), and then click **Finish**.
8. The program should identify your device automatically. Select the '**FrequencyGenerator.jed**' file when prompted for the configuration file, and click **Open**. Right-click on the chip and choose **Program**.

 If this fails, confirm again that your device is connected to the computer and that it is powered as well, (i.e. the 3.3V power LED should be on).

Note: If you need to re-acquaint yourself with the basics of navigating and programming a cPLD, refer to the walkthrough that was given in the second lab of ECE 272, which is also found at the link below.

If you are using the default design, you will need to configure your d_logic board to produce a 100kHz clock. You can find information about this in *Appendix A* for the d_logic board, also found at the link below.

ECE 272 link: <http://eeecs.oregonstate.edu/education/classes/ece272/index.html>

Task Three: Build the summing circuit and low pass filter

This task has been divided into the following sub-tasks: Verify the functionality of the summing circuit, verify the functionality of the low-pass filter (LPF), and tips for building the summing circuit and LPF.

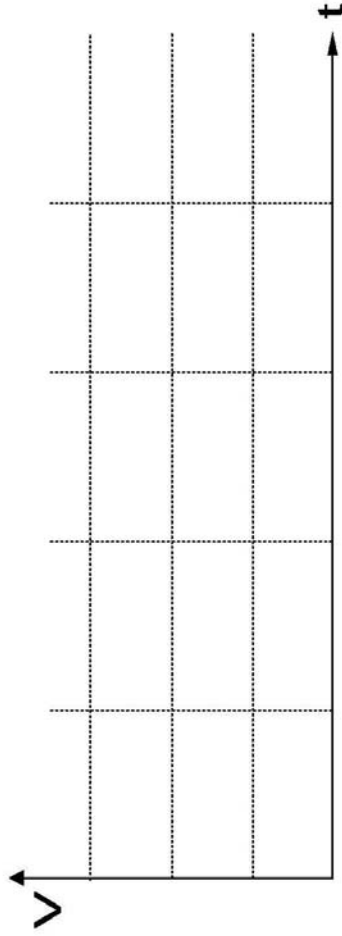
Verify the functionality of the summing circuit

Breadboard your summing circuit (without the capacitor) and verify the following functionalities:

- ☐ Outputs of cPLD generate correct signals.
 - ☐ S1 generates f_1 .
 - ☐ S2 generates f_2 .
- ☐ Summing circuit adds up signals correctly.

Verify the functionality of the summing circuit (Contd.)

- 2.1) Sketch the output of the summing circuit when both frequencies are selected in the graph below. Is it what you expected, based on the Superposition Exercise in the Pre-Lab? You only need to sketch one or two cycles. Be sure to label the time when the rising and falling edges occur.



Verify the functionality of the low-pass filter (LPF)

Add the capacitor in parallel with the feedback resistor of your summing circuit. This will also make the summing circuit function as a low pass filter.

How does the waveform change? Record your observations, by answering the Study Questions at the end of this task.

When your summing circuit and LPF are both functioning correctly, you will need to solder them onto a protoboard. Read the next sub-section on 'tips' to verify that the circuit you built complies with them.

Tips for building the summing circuit and LPF

Before soldering, here are a few tips that you should read, while building the summing circuit and LPF:

- Designate a horizontal row for V^+ at the top and GND at the bottom, as shown in Figure 17.
- Build your layout to look like the schematic. See Figure 18 for an example.
- Avoid using the areas too close to the through-holes.
- Do not solder your op amp directly onto the protoboard. Instead, solder the 8-pin socket onto the protoboard, and insert the op amp into that.

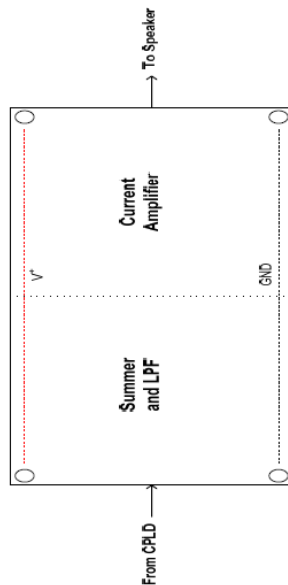


Figure 17: Suggested circuit layout

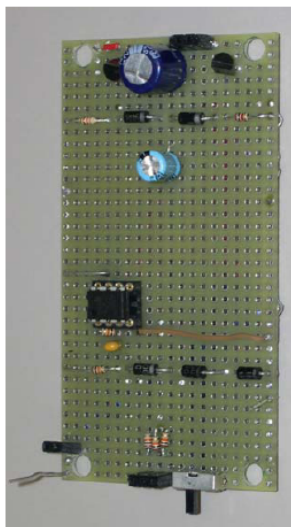


Figure 18: Example of summing circuit and current amplifier

Note: The current amplifier has not yet been discussed so far, and will be covered in a later lab. For now, you only need to be aware that additional room needs to be allowed on the protoboard, for the current amplifier circuit to be added later.

✓ TA Signature :

- | | |
|--|--------------|
| <input type="checkbox"/> Summing circuit (and LPF) function as expected. | (1.5 points) |
| <input type="checkbox"/> Circuit is soldered onto protoboard. | (0.5 point) |
| <input type="checkbox"/> Extra credit. | (0.5 point) |

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the **beginning of the next lab (Section Three)**:

1. Turn in **this lab sheet**, with all of your work written on it, to your T.A. Please make sure that your T.A can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Two.
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the Study Questions below.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Three.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.

- a) What is the mathematical expression for the infinite series of a square wave?
- b) Write out the first four terms of that series.
- c) Show a square wave on a magnitude vs. frequency plot.
- d) If you wanted to filter out just the fundamental sine wave from a square wave, how would you do it? Show this on the plot derived from Question 2(c).
- e) What effect does increasing R_3 have on the gain of the circuit from Figure 14?
- f) What effect does increasing the value of the feedback capacitor have on the waveform?

SECTION THREE

Single-Stage Amplifiers and Active Filters (Two Weeks)

SECTION OVERVIEW

This lab, which lasts two weeks, is intended to give you the opportunity to explore several different single-stage amplifier configurations. Gaining familiarity with the different aspects of an amplifier, such as biasing, decoupling issues, and gain will help prepare you for designing the class project, (which comes later in this term): a multi-stage amplifier.

A single-stage amplifier is also what provides the basis for the bandpass filter that will be used in this project, (as shown in Figure 19.) The microphone will receive some signals from the transmitter. It must first determine which signals are present or absent in the transmission. The bandpass filter is used to check for whether a particular frequency has been transmitted or not.

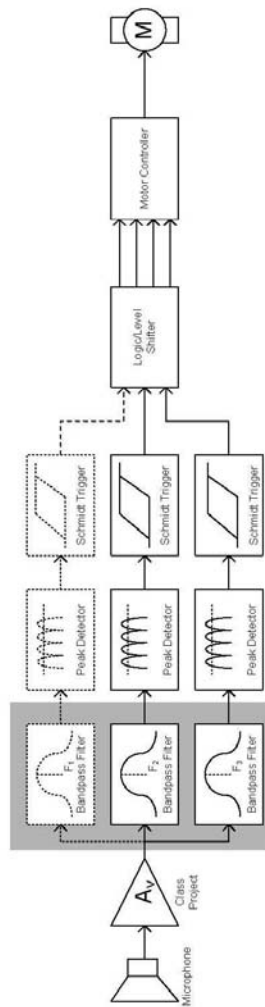


Figure 19: The Receiver Block Diagram

PRE-LAB

The pre-lab assignment for Section Three is also broken up into two weeks. However, it is a good idea to come to the lab with both pre-lab assignments completed, so you may get an early start on the next week's lab, (which is lengthier than the first).

Refer to the pre-lab for each week respectively. The Pre-lab has been divided into the following two sub-sections:

- Pre-lab Assignment for Week One, (due at the **beginning** of Week One of Section Three).
- Pre-lab Assignment for Week Two, (due at the **beginning** of Week Two of Section Three).

Pre-lab assignment for Week One

Calculate element values for the following single-stage amplifiers.



See the data sheets found on the ECE323 lab Web-page for extra information. You may calculate k_n and W/L from I_D . Look at Page 484 in your Sedra/ Smith textbook for additional help.

Single-stage NMOS amplifier

1. Record your values below for the NMOS single-stage amplifier shown in Figure 20.

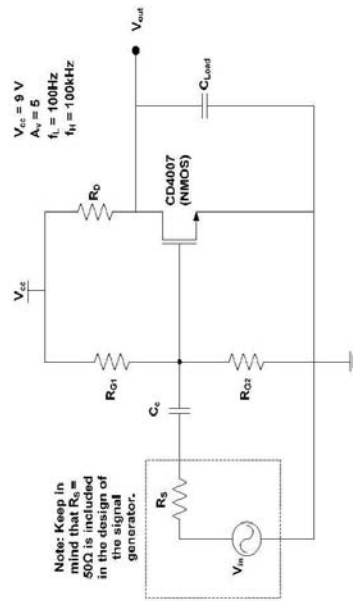
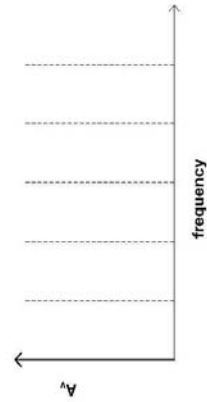


Figure 20: Single-stage Common Source Amplifier (NMOS)

2. Sketch the magnitude response in the graph below:



ENTER THE VALUES:

R_{G1}

R_{G2}

R_D

C_C

C_{Load}

What is the purpose of using C_C in this circuit?

Single-stage common collector BJT amplifier

1. Record your values below for the BJT single-stage amplifier shown in Figure 21.

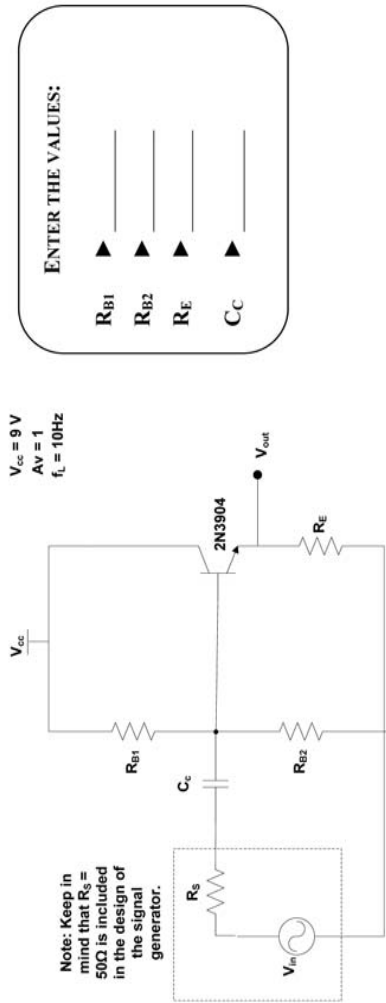
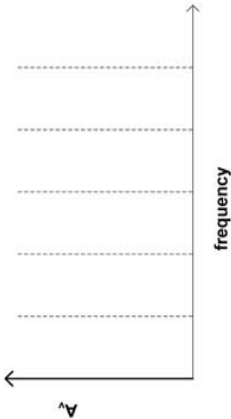


Figure 21: Single-Stage Common Collector Amplifier (BJT)

2. Sketch the magnitude response in the graph below:



Single-stage common collector BJT amplifier

1. Record your values below for the BJT single-stage amplifier shown in Figure 22.

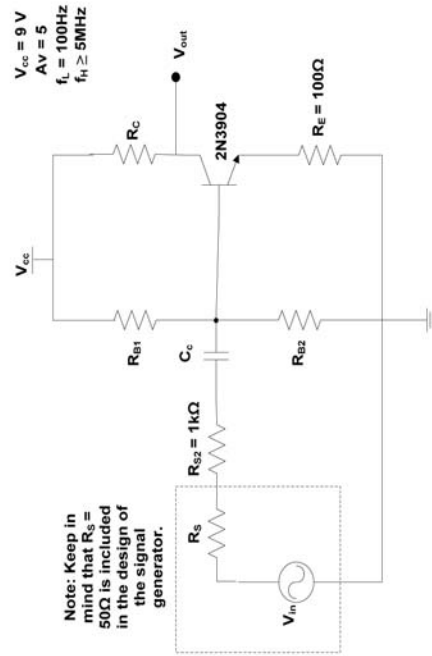


Figure 22: Single-stage Common-Emitter Amplifier with Emitter Degeneration (BJT)

2. Sketch the magnitude response in the graph below:



✓ TA Signature: _____

(Pre-lab completed before beginning of Week One of Section Three lab time).

Pre-lab assignment for Week Two

Resistors, capacitors, and inductors show non-ideal responses when subjected to AC voltages. All physical parts display some sort of frequency-dependent parasitic losses. These losses are due to non-ideal elements, which are introduced via packaging in the physical components. For example, the metal leads of a resistor introduce some series inductance as well as a parallel capacitance. Although small and generally not significant at low frequencies, these parasitic elements can have a significant effect on circuit performance at higher frequencies.

The equivalent high frequency models for a resistor, electrolytic capacitor, and inductor can be viewed in Figure 23.

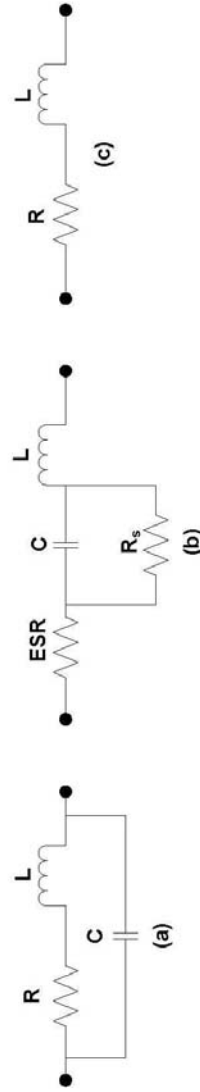


Figure 23: Parasitic Models for (a) Resistor (b) Electrolytic capacitor and (c) Inductor

In Figure 23, circuit (a) shows a resistor with its corresponding reactive components. Circuit (b) shows an electrolytic capacitor where ESR is the equivalent series resistance, R_s accounts for the DC leakage current, and L is the self-inductance. Circuit (c) shows the parasitic model for an inductor. For each case, the models will vary depending on package type.

During the course of the lab, you will design, test and build a filter by replacing the collector resistor of a common-collector amplifier with emitter degeneration by a parallel LC circuit. Look ahead in the lab to Figure 29 to see this. In an ideal world, the impedance of the parallel LC circuit will approach infinity, also causing the gain of this circuit to also approach infinity. However, because the LC circuit is not ideal, its impedance at its resonant frequency is not infinity. One way to test for the real impedance is to set the LC circuit up in the following circuit (as shown in Figure 24), and measure the input and output voltages at the frequency of interest. By choosing the value of R and using the principle of a voltage divider, you may calculate the impedance of the LC circuit.

Answer the questions using the following circuit and considering L and C to be ideal components:

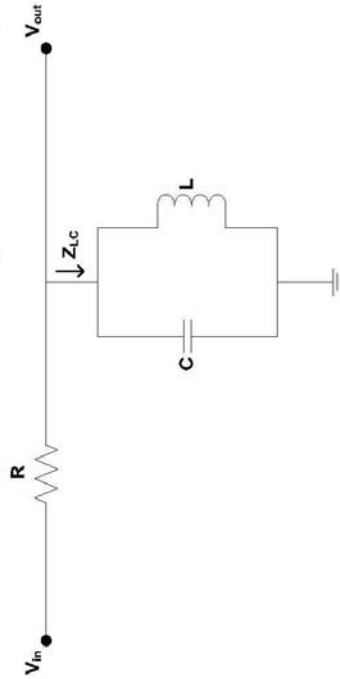


Figure 24: LC filter

1. What is $H(s)$ for the circuit in Figure 24? ▶ _____
2. What is the **resonant frequency** for this circuit, in terms of L and C ? ▶ _____
3. What is Z_{LC} at the resonant frequency? ▶ _____
4. Calculate L and C for the two (or three) frequencies you selected in Section Two. Choose values from among the parts you actually have.

ENTER THE VALUES:

For f_1 (required) ▶ _____, L_1 ▶ _____ and C_1 ▶ _____.

For f_2 (required) ▶ _____, L_2 ▶ _____ and C_2 ▶ _____.

For f_3 (optional) ▶ _____, L_3 ▶ _____ and C_3 ▶ _____.

✓ TA Signature: _____

(Pre-lab completed before beginning of Week Two of Section Three lab time).

LAB

Now that you have done the calculations for the single-stage amplifiers, you need to try them out in the lab.

Objectives

Following are the objectives for this lab:

- Task One: Test the amplifiers.
- Task Two: Find Z_{LC} of non-ideal components.
- Task Three: Create and build two active filters.

Task One: Test the amplifiers

Breadboard and test each of the amplifiers.

CMOS Single-Stage Amplifier

Record the DC bias points, f_L , f_H and A_V of the circuit. The original circuit is re-drawn for convenience, in Figure 25.

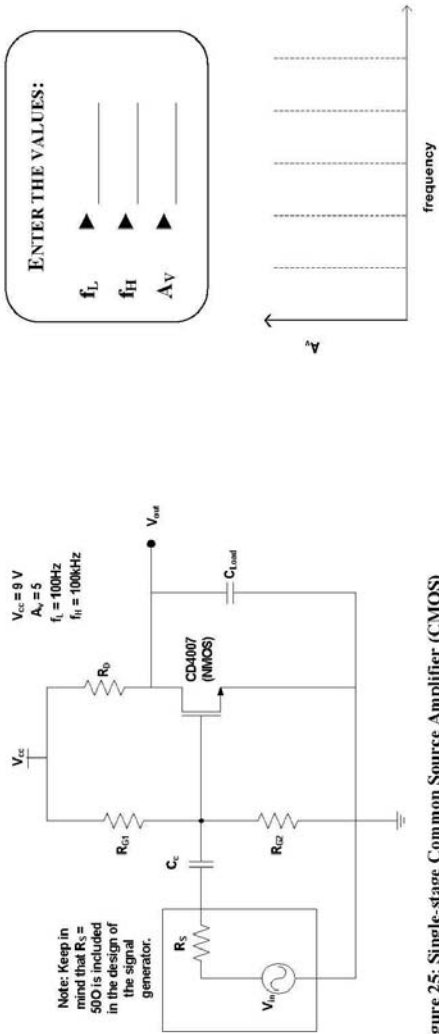


Figure 25: Single-stage Common Source Amplifier (CMOS)

BJT single-stage common collector amplifier

Record the DC bias points, f_L , f_H and A_V of the circuit. The original circuit is re-drawn for convenience, in Figure 26.

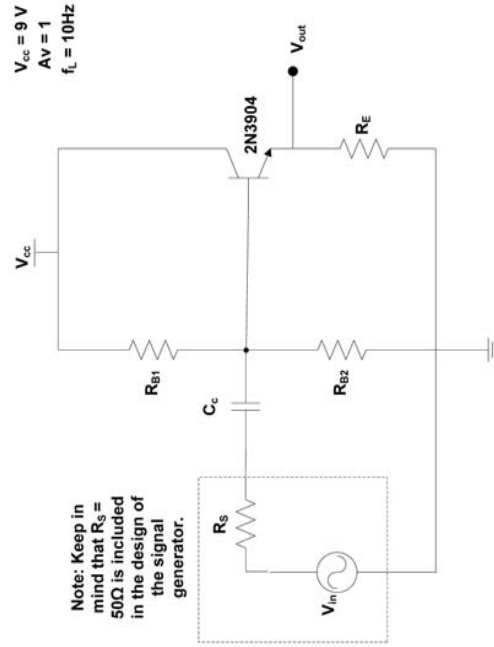
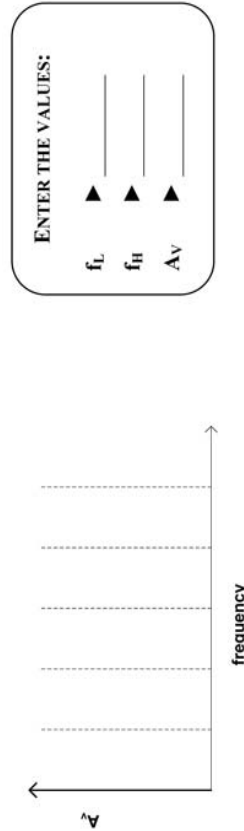


Figure 26: Single-stage Common Collector Amplifier (BJT)



BJT single-stage common emitter amplifier

Record the DC bias points, f_L , f_H and A_v of the circuit. The original circuit is re-drawn for convenience, in Figure 27.

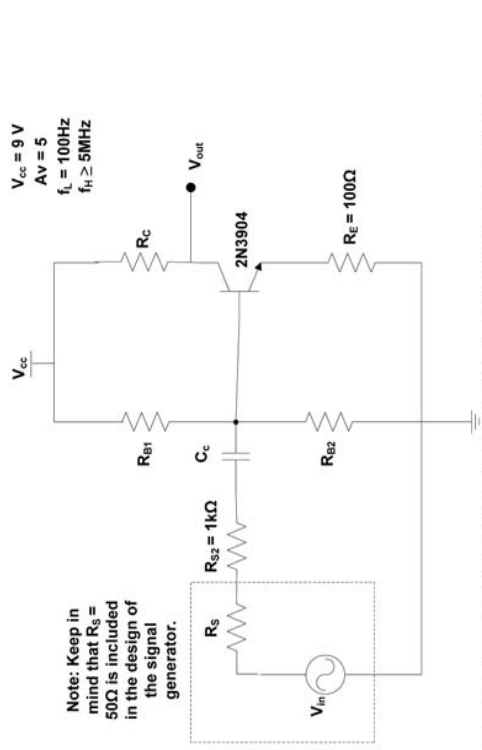


Figure 27: Single-stage Common Emitter Amplifier with Emitter Degeneration (BJT)



Task Two: Finding Z_{LC} of non-ideal components

Breadboard and test each LC resonant circuit and test it at its resonant frequency. Measure the voltage at V_{out} and use the concept of a voltage divider to calculate the non-ideal impedance of the LC circuit in Figure 28.

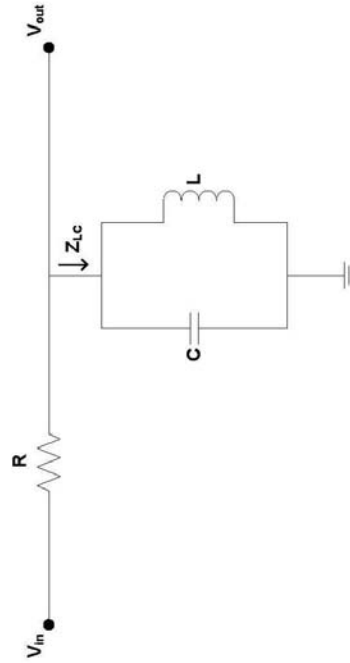


Figure 28: The LC Filter in a Voltage Divider

ENTER THE VALUES:

Z_{LC} at f_1 (required) ▶

Z_{LC} at f_2 (required) ▶

Z_{LC} at f_3 (optional) ▶

Task Three: Create and build two active filters

One way to design an active filter is to use the single-stage common emitter amplifier with emitter degeneration as a base topology. The gain of this circuit is approximately the impedance which the collector 'sees', divided by the impedance which the emitter 'sees.' After replacing R_C with a parallel LC circuit, (as shown in Figure 29), the gain of the amplifier will be greatest at the resonant frequency of the LC circuit.

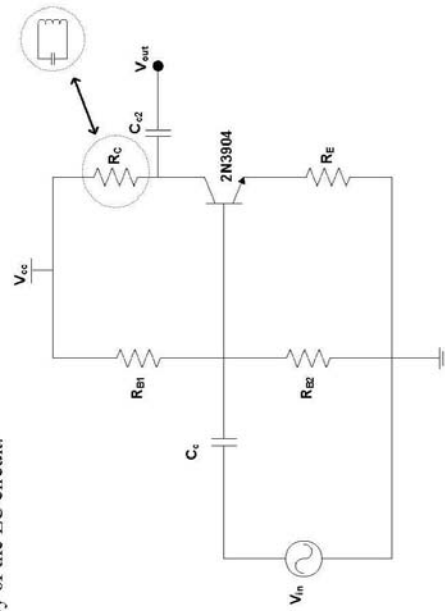


Figure 29: Active Filter

Later in the lab, it will be important that each filter passes its frequency of interest at approximately the same voltage level. Check the level of each signal to make sure the gain of each filter is about the same.

ENTER THE VALUES:

BPF ₁ :	f ₁	▶	A _{v1}	▶	
BPF ₂ :	f ₂	▶	A _{v2}	▶	

When each filter is functioning properly, solder it onto the protoboard. Figure 30 is an illustration of the suggested board layout.



Read the following tips before soldering the filters.

Tips for building the bandpass filters:

- Build your layout to look like the schematic.
- Designate a horizontal row for V^+ at the top, and for the GND at the bottom.
- Avoid using the areas close to the through-holes.

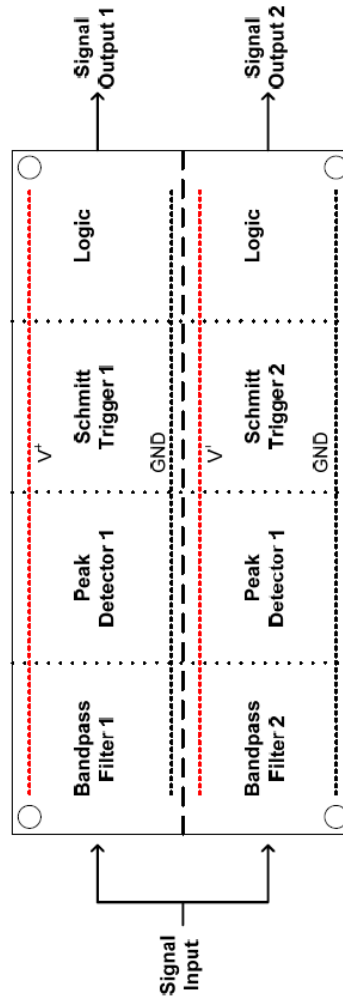


Figure 30: Suggested board layout

✓ TA Signature : _____

- ☐ Bandpass filters are centered around correct frequency. (2.0 points)
- ☐ Filters are soldered onto board. (1.0 point)
- ☐ Filters have approximately same gain. (1.0 point)
- ☐ Extra credit. (1.5 points)

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the beginning of the next lab (Section Four):

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Three.
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the Study Questions below.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Four.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.
 - a) What was the most difficult part of this lab?
 - b) How did exchanging the collector resistor for the LC circuit affect the gain of the amplifier at the frequency of interest?
 - c) What would you do differently for next time?

SECTION FOUR

Output Stages (One Week)

SECTION OVERVIEW

In the **Pre-lab**, the objectives are:

- Learn how to find and adapt designs.
- Design two output stages.

In the **Lab** part of this section, the objectives are:

- Build, test, and characterize the designs.
- Select and solder the best design for the system.

Figure 31 is an illustration of the entire transmitter block diagram. During the pre-lab and lab for this section, you will be designing the output stage (which has been highlighted in boldface). After completing Section Two, you probably noticed that your speaker was not putting out a very loud signal. After building the output stage, which is capable of driving more current, your transmitter will output the same signal, but with more power.

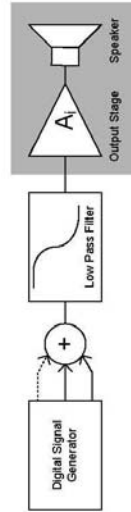


Figure 31: Transmitter Block Diagram

PRE-LAB

This lab is designed, in part, to help you learn how to research and adapt designs. This will help prepare you for Senior Design. In Senior Design, you must design and build an entire system. Freshman and sophomore level labs are quite structured. This lab is at an in-between level. You have complete freedom for the design of the output stage; yet it is just one block of the system, not the entire system.

For this lab, you will design, test, and build an output stage for the speaker of your transmitter. The purpose of the output stage is to be able to drive the load (in this case, the 8Ω speaker) with sufficient current. 8Ω is actually a “large” load compared to a “smaller” $1K\Omega$ load, because it requires more current and, consequently more power, to drive it for the same supply voltage. The sub-sections in the pre-lab are: design the output stage, tips for the output stage design, and amplifier specifications and requirements.

Figure 32 illustrates a closer view of the output stage. It shows detailed specifications for the block.

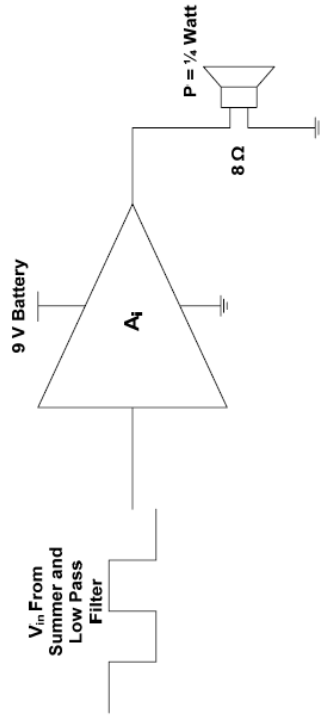


Figure 32: Output Stage

Design the output stage

To implement the output stage, follow these steps:

1. Find two different topologies for current amplifier output stages using BJTs.



Read the 'tips' sub-section before beginning your design.

(Hint: The two high current transistors, 2N4401 and 2N4403, as well as the audio transformer were included with your selection of parts for this section. A common output stage for this type of application is a Class-AB push-pull output stage.)

2. Calculate the component values for these topologies based on the requirements of your system. You may want to check your textbook, look On-line, or ask other professors for ideas for topologies. Also, there are a large number of schematic "cookbooks" with example circuits in them.
3. Calculate the power conversion efficiency, η , for each design. See Chapter 14 in the Sedra/ Smith text for a helpful discussion of output stages.



Come to lab prepared to physically build those circuits.

Tips for the output stage design

A few tips to consider when designing an output stage are listed below:

- No DC current may flow through the speaker. Two ways to achieve this are by using an AC coupling capacitor or an audio transformer.
- Check that the quiescent current flowing through the BJT is appropriate for the rated values of that component.
- Some topologies are prone to self-destruct. As a BJT heats up, its β -factor increases, drawing even more current and heating it up even more. This is a positive feedback loop which will quickly burn up a transistor. This is also known as *thermal runaway*.

Amplifier specifications and requirements

Use the following **amplifier specifications** for designing your circuits:



Be sure that the components that you choose meet these minimum requirements.

- Drive an 8Ω load at a minimum of 0.25 Watts.
- Design for an input impedance that matches the output impedance of your previous stages to allow for maximum power transfer.
- Power your system from only 9V.

Check that your pre-lab work meets the following **requirements**:

- ☐ Found two topologies for an output stage.
- ☐ Calculated component values for each topology.
- ☐ Calculated the power conversion efficiency, η , for each topology.
- ☐ Acquired the necessary parts to build each topology.

LAB

The three primary tasks in this lab are: to breadboard and test output stages, to build the output stage, and to assemble the transmitter.

Task One: Breadboard and test output stages

Build each of the two output stages on your breadboard, and measure its efficiency (η). Record this value for your lab write-up. For each topology tested, you must, at a minimum, describe where the topology might be used, and why it either is or is not the ideal topology for your design. Bear in mind details like component count, cost, stability, how well it meets the specs, and flexibility.

Task Two: Build the output stage

In order to build the output stage, you will need to: (a) build the output stage on the protoboard, and (b) solder connections and a switch for the power system.

After you have tried your two designs, choose the one that worked best. Test your output stage as being a part of the transmitter circuit. Solder that output stage onto your transmitter protoboard as a permanent part of the transmitter. (This has been labeled A_4 in Figure 31). See Figure 33 for a suggested board layout.

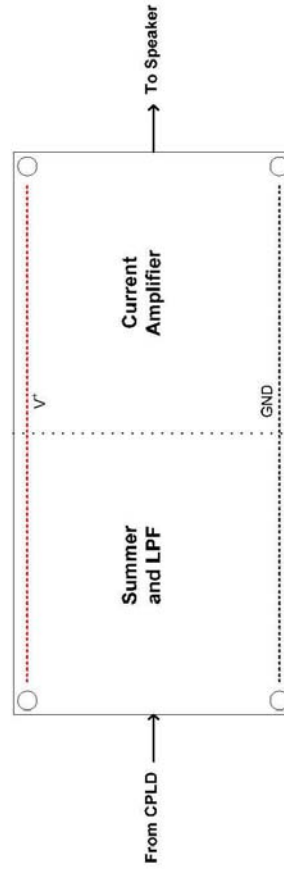


Figure 33: Suggested board layout

Task Three: Assemble the transmitter

Once the transmitter protoboard is completely soldered together, the next step is to assemble the transmitter. In order to do so, follow these steps:

1. Stack the CPLD and transmitter protoboard by using the standoffs.
2. Glue two plastic dividers across the short sides of the transmitter on two of the standoffs, in order to create a surface to which you could attach the speaker and battery.
3. Attach the 9V battery to one side and the speaker to the other side.
4. As part of the power system, include the on/off switch, so that the transmitter can be easily turned off.

Note: A cone for the speaker will be helpful later on in future sections, so that the receiver may receive the generated tones better. See Figure 34 for an example of a completed transmitter.

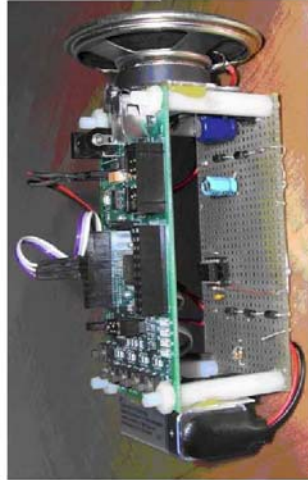


Figure 34: Example of completed transmitter

✓ TA Signature :

- | | |
|--|--------------|
| <input type="checkbox"/> Digital logic board programmed correctly. | (0.5 point) |
| <input type="checkbox"/> Summing circuit soldered and functions properly. | (0.5 point) |
| <input type="checkbox"/> Output stage functions properly and soldered. | (1.5 points) |
| <input type="checkbox"/> Construction is complete and includes: power switch, speaker and battery. | (1.5 points) |
| <input type="checkbox"/> Transmitter is autonomous and outputs tones at reasonable volume. | (1.0 point) |

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the beginning of the next lab (Section Five):

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Four.
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the following Study Questions.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Five.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.

- a) What did you discover about the topologies you chose? Which design worked best and why? Which design was the worst and why?
- b) Did any of your designs or components self-destruct during the lab? Why?
- c) Show how you calculated and measured η . How did the efficiency calculated for the pre-lab compare with the efficiency measured in lab, for the design you chose and built on the transmitter protoboard?

SECTION FIVE

Peak Detector and Schmidt Trigger (One Week)

SECTION OVERVIEW

In the **Pre-lab**, the objectives are:

- Design the peak detector.
- Design the Schmidt trigger.

In the **Lab** part of this section, the objectives are:

- Create, test, and solder the peak detector
- Test the Schmidt trigger.

Figure 35 is an illustration of the entire receiver block diagram. During the pre-lab and lab for this section, you will be designing the peak detector and Schmidt trigger, (which have been highlighted in boldface and a grey background). Following each of the bandpass filters, there is either an AC signal present or not, depending on which frequencies the microphone is receiving. The peak detector serves to transform the AC signal into a DC signal, the level of which depends on the strength of its input.

The Schmidt trigger has two purposes: (a) it cleans up the DC signal into a digital signal, (which is strictly either 'on' or 'off'), and (b) it introduces some hysteresis into the system.

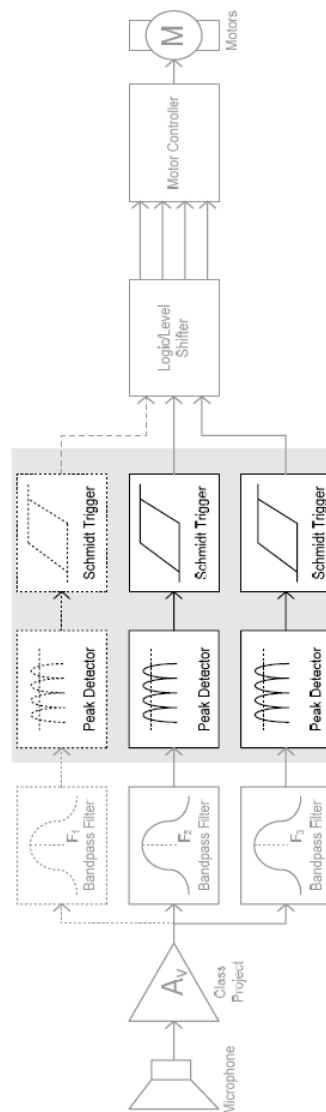


Figure 35: Peak detector/ Schmidt trigger block diagram

PRE-LAB

In the pre-lab, you will be designing the peak detector and the Schmidt trigger.

Design the peak detector

The lab this week involves exploring and building peak detectors and Schmidt triggers. The purpose of a peak detector is to signal high (DC) when an AC signal is present. It will function for any frequency. For use in this system, a peak detector is necessary to transform the presence of an AC signal from the bandpass filter into a DC signal, which can be used by the Schmidt trigger.

A peak detector is a half-wave or full-wave rectifier followed by a capacitive filter. This effectively changes an AC signal into a DC signal. You should have some experience with how this is accomplished from previous courses. First, the AC signal is fully or half-rectified. Then, when the positive crest of the AC signal starts to fall, the capacitor discharges more slowly than the falling crest of the input signal, which levels the signal into a DC signal. Figures 36(a) through 36(c) show a graphical representation of what a peak detector does.

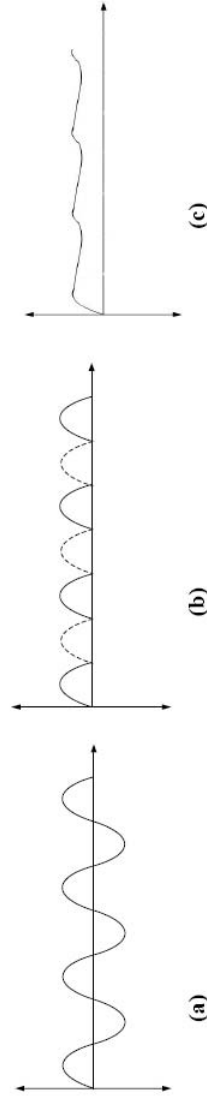


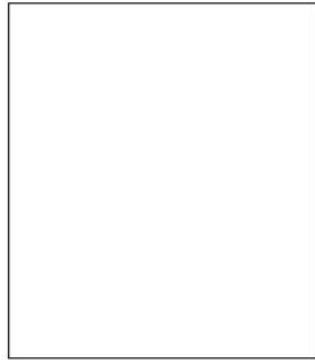
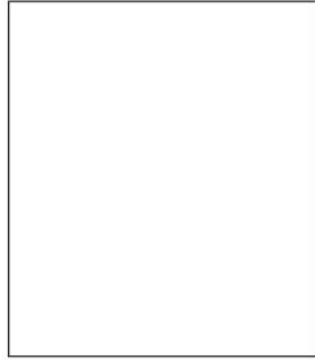
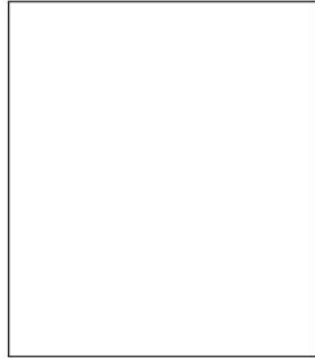
Figure 36: (a) sinusoidal input voltage, (b) output voltage resulting from rectifier, (c) output voltage resulting from capacitive filtering

The capacitor in the peak detector is what provides for a steady DC voltage at the output. As long as the capacitor is charged, the peak detector will output a DC voltage. When the AC signal is no longer present at the input of the peak detector, the capacitor must discharge through a resistor. In order to select an R and C for this circuit, you must consider two cases: the time to fill the capacitor and the time to discharge it.

In order to calculate the values for R and C, you must know what the source and load blocks are. In this case, the peak detector is being driven by the active bandpass filter. It is driving the input to the Schmidt trigger.

Section Five: Peak Detector and Schmitt Trigger

Sketch the basic topology of each stage in the boxes provided. Design a rectifier (full-wave or half-wave) with a RC component at the output.

**Bandpass Filter****Peak Detector****Schmitt Trigger**

ENTER THE VALUES:

R ►

C ►

Design the Schmidt trigger

The detected signal (from the bandpass filter) will eventually be used in a digital system, (which in this case is the motor control board). Therefore, the detected signal must become digital as well. A **Schmidt trigger** has two features which are ideal to accomplish this. First, V_{out} is restricted to one of two DC values: V_{cc} or GND, which represents a '1' or '0.' Also, the voltage which triggers it to turn 'on' can be set at a different voltage from that which turns it 'off.'

Overview of the Schmidt trigger

This lab also includes building a Schmidt trigger, (as shown in Figure 37.) A Schmidt trigger, in general and for the purposes of this lab, is a comparator with **positive feedback** which creates two stable states. When V^- is less than V^+ , the output is in the high state. When V^- becomes greater than V^+ , the output switches to the low state.

Note: The *Schmidt* trigger is also sometimes spelled as the *Schmitt* trigger.

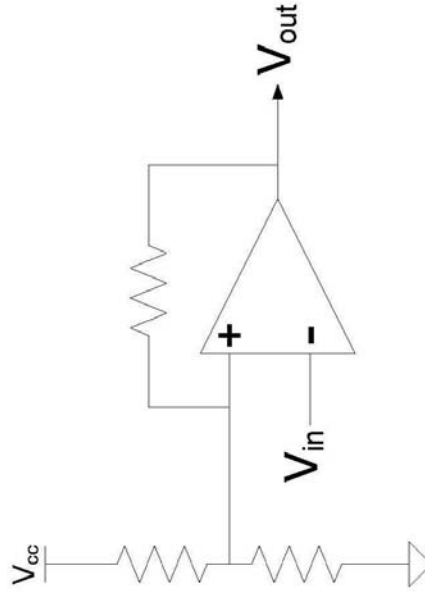


Figure 37: Schmidt trigger

Section Five: Peak Detector and Schmidt Trigger

The points at which the Schmidt trigger switches from the high to the low state or from the low to the high are called the **thresholds**. In Figure 38, it is shown that the output does not transition from low to high until the input voltage increases to the higher threshold. Once the output transitions to a high state, the threshold voltage which appears at V^+ (as in Figure 37) is also changed. Similarly, note that the output does not transition from high to low until the input voltage decreases to the low threshold. This effect is known as hysteresis. Note that this design for a Schmidt trigger actually inverts the output.

Hysteresis is a property of systems whose states depend on their immediate history. The thresholds of the Schmidt trigger can be adjusted by changing the values of the resistors.

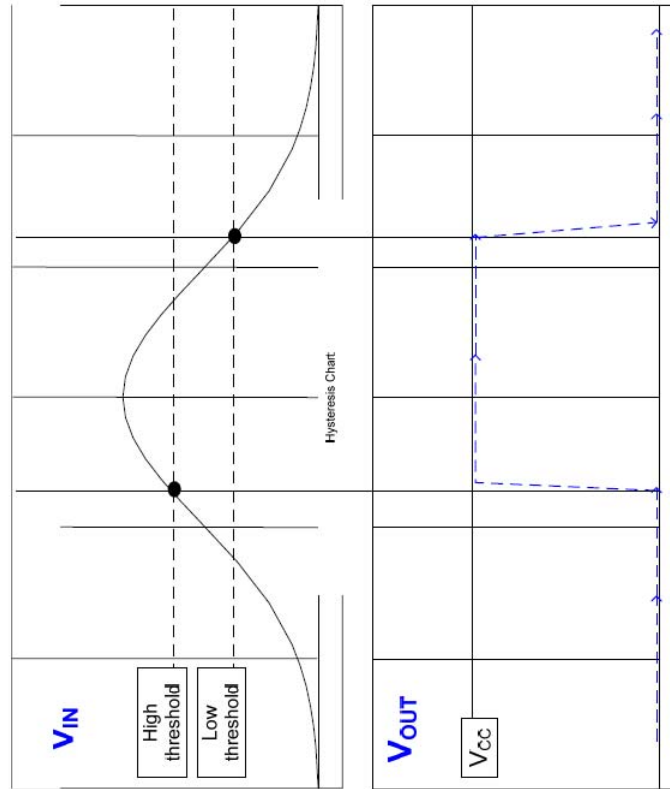


Figure 38: Graphical explanation of hysteresis

Figure 39 illustrates the concept of hysteresis on a plot of V_{in} vs. V_{out} . Following the arrows on the graph, it is shown that the circuit will not transition from the high to the low state until the input voltage reaches the high transition threshold. Similarly, the circuit will not transition from the low to the high state until the input voltage reaches the low threshold.

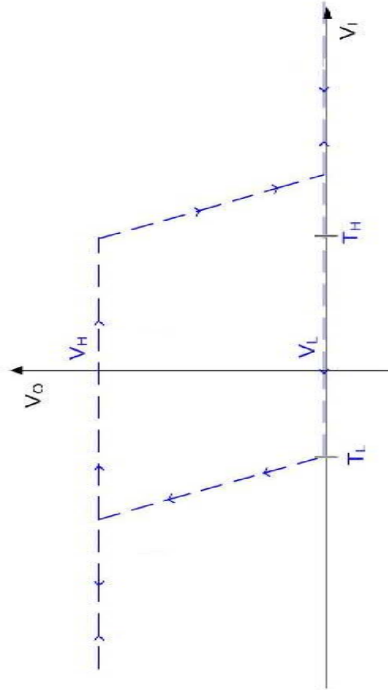


Figure 39: Plot of hysteresis

Applications of the Schmidt trigger

Figure 40 illustrates the circuit implementation of a Schmidt trigger.

With reference to the circuit in Figure 40:

1. Use nodal analysis to solve for the two different threshold voltages at V_{in} in terms of V_{cc} , $R1$, $R2$, and $R3$. Express the high threshold points as T_H and the low threshold as T_L , and record those values. Hint: solve the circuit for $V_{out} = \{0, V_{cc}\}$

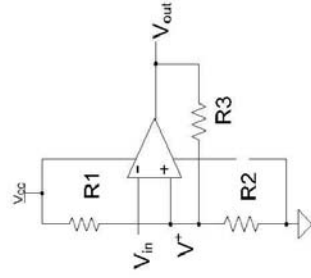


Figure 40: Circuit implementation of Schmidt trigger

ENTER THE VALUES:

T_H ▶ _____

T_L ▶ _____

2. Using your equations from the previous question, determine and record the values of $R2$ and $R3$ for the circuit in Figure 40. Make the following assumptions: $V_{cc} = 5V$, $T_H = 3.8V$, $T_L = 3.2V$, $R1 = 2K\Omega$.

ENTER THE VALUES:

$R2$ ▶ _____

$R3$ ▶ _____

LAB

There are two primary tasks in this lab: (a) to create, test and solder the peak detector, and (b) to test the Schmidt trigger.

Task One: Create, test, and solder the peak detector

In order to implement the above, follow these steps:

1. Breadboard your peak detector and test it using a signal generator.
2. Test it using your bandpass filter to drive the peak detector.
3. Once the peak detector is functioning correctly, solder it onto the protoboard following the bandpass filters, (as shown in Figure 41).

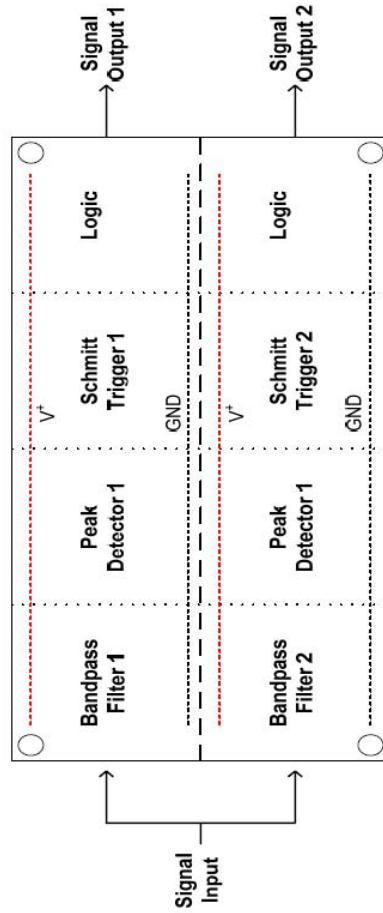


Figure 41: Suggested Board Layout

Task Two: Test the Schmidt trigger

Breadboard (but do not solder) the Schmidt trigger into place. Test the circuit you designed in the Pre-Lab on your breadboard. In the graph below, plot V_{in} vs. V_{out} , sweeping V_{in} from $0V \rightarrow V_{cc}$ as well as $V_{cc} \rightarrow 0V$. The plot should look similar to Figure 39.



Did the circuit function the way it was designed to? If not, fix it before moving on.

This exercise is designed to give you experience choosing threshold values and calculating resistor values for the Schmidt trigger. The actual values you use will depend on the voltages you measure from the output of the peak detectors. These values are dependent on each individual's design and cannot be calculated beforehand. However, these values will be tested for, in a future lab. After you have measured these voltages, you should be able to quickly calculate resistor values for the desired thresholds of your Schmidt trigger, breadboard and test it, and solder it onto the protoboard.

For your **lab demo**, you have the following exercise:

1. You will be assigned one Schmidt trigger circuit to design and build in lab.
2. You need to calculate the resistor values and breadboard that circuit.
3. Ask your TA which one of the following designs you should build:
 - Design A ($V_{cc} = 8V$, $T_H = 6V$, $T_L = 2V$).
 - Design B ($V_{cc} = 6V$, $T_H = 4.5V$, $T_L = 1V$).
 - Design C ($V_{cc} = 9V$, $T_H = 5V$, $T_L = 2V$).
4. Demonstrate the circuit to your TA.

✓ TA Signature : _____

☐ Design A, B or C functions correctly. (2 points)

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the beginning of the next lab (Section Six):

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Five.
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the following Study Questions.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Six.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.
 - a) How would the peak detector behave if the capacitor were very large?
 - b) What is the purpose of the resistor that is in parallel with the capacitor in the peak detector?
 - c) How would increasing (or decreasing) the value of the feedback resistor in the Schmidt trigger circuit affect its function?

SECTION SIX

Microphone and Class Project (Two Weeks)

SECTION OVERVIEW

The pre-lab for this section does not require any design or calculations. However, the lab consists of building and testing the microphone and amplifier. Figure 42 illustrates the receiver block diagram, (with the microphone and class project amplifier highlighted in boldface).

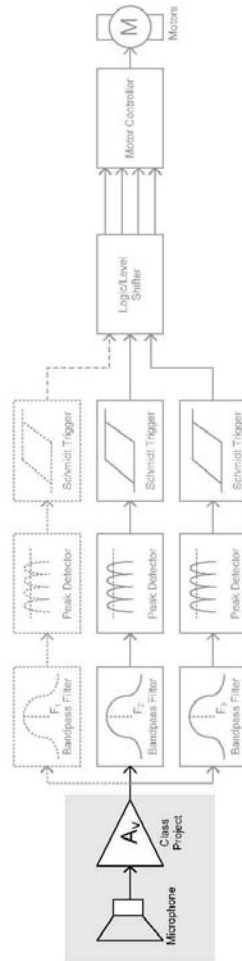


Figure 42: Receiver Block Diagram

PRE-LAB

The pre-lab assignment this week is very simple. You need to bring the following with you to lab:

- A copy of the schematic for the class project amplifier.
- All the components that you will require, to physically build your amplifier.
- All cables and necessary supplies.

For a list of which resistors are supplied in the cabinet in the lab, see the Web-site.

An amplifier is typically a very important part of a system design. In this lab, you will have the opportunity to build, test and characterize the amplifier you designed in lecture. The microphone is the first block in your audio receiver. However, it generates very small voltages, creating the need for the amplifier.

LAB

There are two main tasks for this lab: (a) build, solder, and test microphone circuit, and (b) build, solder, test, and characterize the class amplifier project.

Task One: Build and test the microphone circuit

In order to implement this task, proceed through the following sub-sections:

1. Build the microphone circuit.
2. Tips for building the microphone circuit.
3. Test the microphone circuit.

Build the microphone circuit

To build the microphone circuit:

1. Read the tips in the next sub-section, which will be helpful while building the microphone circuit.

- Note:** Build, but **do not connect the output of the microphone circuit to the input of the amplifier yet!**
2. It may be convenient for you to make a non-permanent connection at this node for future testing purposes.
 3. A good solution is a male/ female connector on each side of the node.
 4. Figure 43 illustrates the microphone circuit.

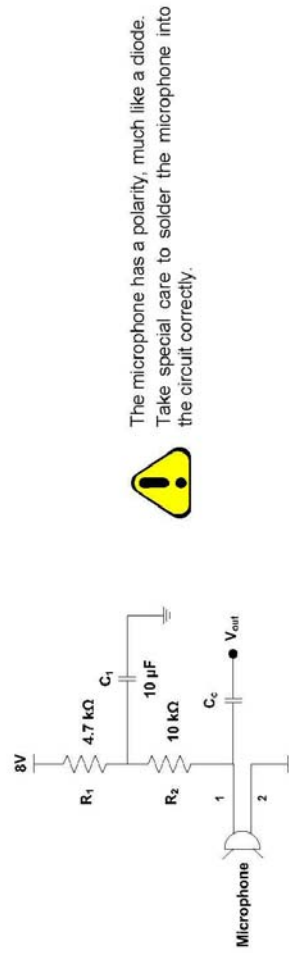


Figure 43: Microphone circuit

Tips for building the microphone circuit and amplifier

Use the following tips to build the microphone circuit and amplifier:

- Refer to Figure 44 for a suggested board layout.

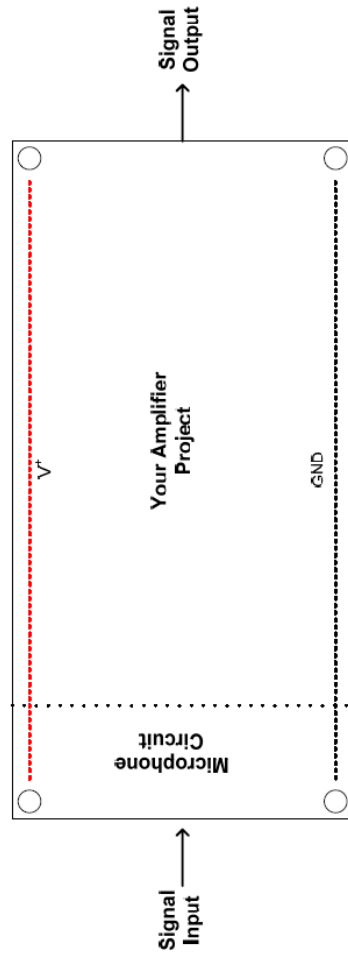


Figure 44: Suggested board layout

- Build your layout to look like the schematic. See Figure 45 for an example of a finished product. (Note that the microphone circuit is not included in the photographed board layout).
- Use a small portion of the board for the microphone circuit, so that more space is left over for your amplifier (as shown in Figure 44).
- Designate a horizontal row for V^+ at the top and GND at the bottom. (See Figures 44 and 45).
- Avoid using the areas close to the mounting holes.
- Solder a two-pin female connector for V^+ and GND so you can route power to the amplifier from your TekBot, (as shown in Figure 45).

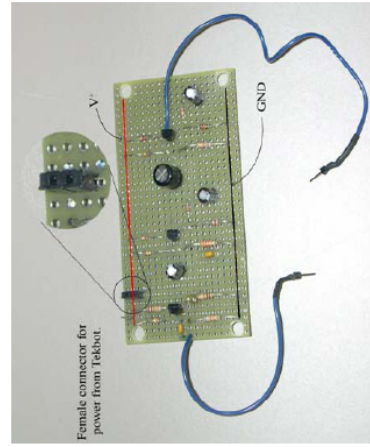


Figure 45: Example of board layout

Tips for building the microphone circuit and amplifier (Contd.)

- Solder wires onto the V^+ and GND nodes. These are convenient for attaching the power supply to when testing. (See Figure 46).

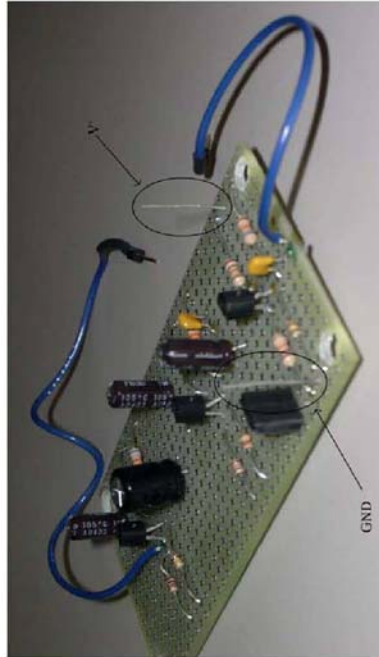


Figure 46: Example of test lead positioning

Test the microphone circuit

In order to test the microphone circuit, perform the following checks:

- ☐ Is the microphone circuit working? Y / N. To check this, you need to hook the power up and probe the output with the oscilloscope. Speak into the microphone, snap your fingers over it, or use the transmitter.
- ☐ What is the expected signal level from the output of the microphone? ▲ _____.
- ☐ What is the observed average signal level does your circuit output? ▲ _____.
- ☐ Are the expected and observed signal levels the same? ▲ _____.

Task Two: Build, test and characterize the class amplifier project

In order to implement this task, proceed through the following sub-sections:


1. Tips for building the amplifier project.
2. Characterize the class amplifier project.

Tips for building the amplifier project

- **Build the amplifier stage-by-stage and verify that each stage is functioning before moving on to the next one!**
- Budget space. You can do this by setting the components in place before soldering, and thus making sure they are placed in the optimal location.
- The signal generator cannot put out a signal that is low enough to meet the specification of the input voltage to the amplifier. How can you fix this? (*Hint:* You need to use a voltage divider.)

Characterize the class amplifier project

Take data points to create Bode plots of the frequency response of the amplifier.

 The magnitude vs. frequency response requires only one oscilloscope probe, but you will need two oscilloscope probes to measure the phase response. Share with your neighbor or purchase an extra one from the bookstore.

Compare with your PSPICE simulation. Remember to include the appropriate source and load when characterizing your circuit. Refer to Figure 47.

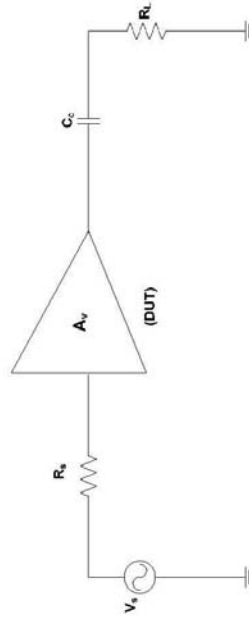


Figure 47: Setup for testing class amplifier project

The following figures are an example of what you can expect to see, when characterizing the class amplifier project. Be sure to label all important points of interest. See Figure 48 for a PSPICE magnitude vs. frequency plot (with -3dB points and max gain), and Figure 49 for the corresponding magnitude vs. frequency plot for the physical amplifier.

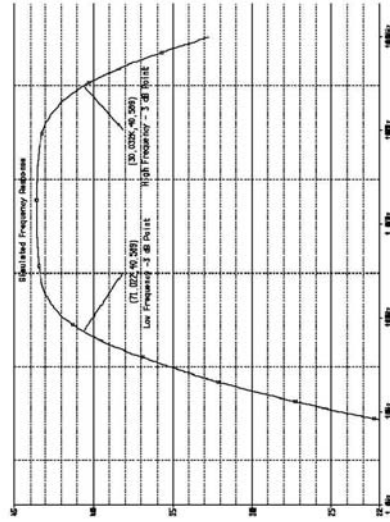


Figure 48: Example of PSPICE simulated Bode magnitude plot

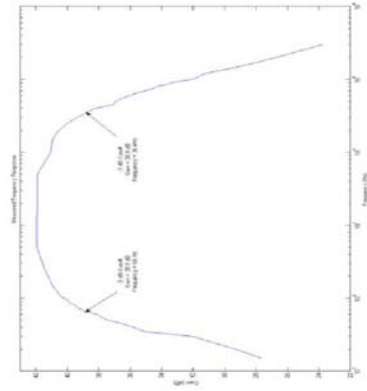


Figure 49: Example of measured Bode magnitude plot

✓ TA Signature : _____

- ☐ Microphone and amplifier circuits fully constructed. (2 points)
- ☐ Mid-band gain is as designed. (2 points)
- ☐ Low-frequency cut-off is as designed. (2 points)
- ☐ High-frequency cut-off is as designed. (2 points)

Note: If the amp does not work, the TA may give partial credit for functionality of various stages, at his or her discretion.

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, at the **beginning of the next lab (Section Seven)**.

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Six.
- ☐ Bode plots for class project amplifier, (from PSPICE).
- ☐ Bode plots for class project amplifier, (from measurements taken in lab).
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the following Study Questions.

The **pre-lab** to be completed (before lab begins next week), includes:

- ☐ Pre-lab for Section Seven.
- ☐ Bring all parts of your transmitter, receiver, and TekBot for next week.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.

- a) Compare and contrast the Bode plots you created in lab with the PSPICE simulation. Are they similar? Why or why not?
- b) What is the purpose of the capacitor (C_c) in the microphone circuit?
- c) What was the most difficult part of this lab? What was the biggest thing you learned that you would do differently for next time?

SECTION SEVEN

Building the Receiver

(Two Weeks)

SECTION OVERVIEW

The pre-lab for this section requires a very small amount of design. The lab consists of putting the finishing touches on the receiver. Once completed, you will have a fully functional transmitter and receiver. Figure 50 illustrates the receiver block diagram.

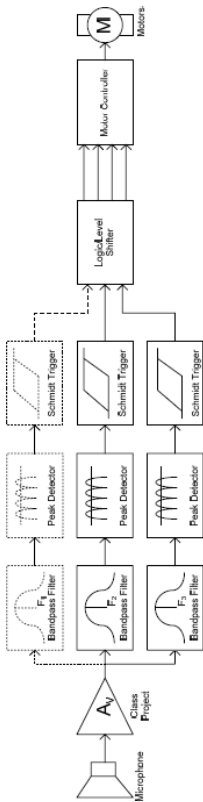


Figure 50: Receiver Block Diagram

PRE-LAB

Design two simple circuits using an NMOS or PMOS gate. Take an input from the Schmitt trigger and control LE, RE, LD, and RD on the motor controller board. Check ahead in the lab (*Task Three: Controlling the Motors*), to see what logic function each signal must perform. **Keep in mind that the motor controller board is only tolerant of input voltages up to 5V.** Refer to Figure 51 for an overview of what function your logic circuits must perform. In summary, your circuit must:

- Perform the correct logic operation.
- Protect the 5V input of the motor controller board.

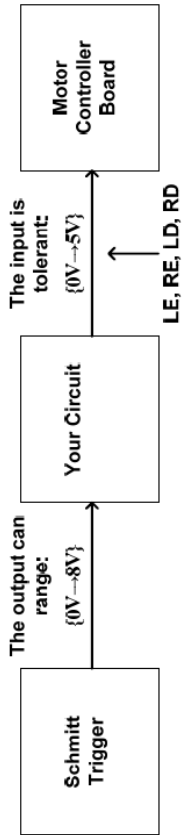


Figure 51: Block diagram of circuit layout

The inputs to the motor controller board (LE, RE, LD and RD) are designed as shown in the circuit in Figure 52.

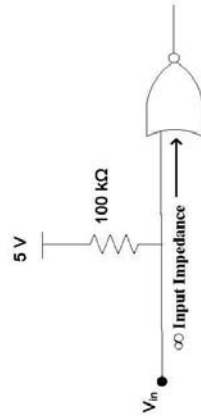


Figure 52: Motor controller input

Design your circuits for each input in the spaces provided for them:

LE:	RE:
LD:	RD:

LAB

There are three main tasks for this lab: (a) build and verify from the microphone to the peak detector, (b) design the thresholds for the Schmidt triggers, and (c) control the motors.

The objective of this lab is to put the entire receiver together. The receiver is designed to receive signals from the transmitter, amplify them, filter out/ detect which signals are present, and control the TekBot's movement based on those signals.

Note: This lab assumes you have the following:

- ☐ Fully functional transmitter.
- ☐ Fully functional microphone and amplifier circuit.
- ☐ At least two fully functional bandpass filters.
- ☐ At least two fully functional peak detectors.
- ☐ A complete understanding of the design and function of a Schmidt trigger.

These last two weeks of lab are designed to give you the opportunity to get any previous sections working as well as to complete the receiver. As such, it is less structured than other labs. If any of the receiver blocks are not yet working, fix them before assembling the entire receiver.

Task One: Build and verify from the microphone to the peak detector

Connect your microphone, amplifier, bandpass filters, and peak detectors. Verify the functionality of this portion of the system. It is convenient to test for this using both the function generator as well as your transmitter.

These are some ideas of possible methods to test and verify your circuit:

- ☐ Microphone, class project amplifier, bandpass filters, and peak detectors are connected.
- ☐ Class project amplifier outputs correct signal at reasonable magnitude when excited by the transmitter.
(Tip: ~2V at the output of the amplifier at a distance of one foot between the transmitter and receiver is reasonable.)
- ☐ Filter correctly passes/ rejects signals from the amplifier at appropriate frequencies. (Test using the signal generator.)
 - ☐ Bandpass Filter 1 ▶ _____ Hz.
 - ☐ Bandpass Filter 2 ▶ _____ Hz.

Task One (Contd.)

- ☐ Peak detector correctly signals (highest DC value), when AC signal is present.
 - ☐ Peak detector 1.
 - ☐ Peak detector 2.
- ☐ Peak detector does not signal high when the signal is not present.
 - ☐ Peak detector 1.
 - ☐ Peak detector 2.

Task Two: Design the thresholds for the Schmidt trigger

In order to determine the proper threshold values for the Schmidt triggers, you need to find out what voltage levels are present when each signal is 'on' and 'off.' The magnitude of the DC voltage from the peak detector of each student's circuit will vary based on the gain of the amplifier and bandpass filters, and the distance from the transmitter to the receiver.

Try the following test set-up as shown in Figure 53, or design one of your own. Figure 54 is the table of values associated with the test set-up.

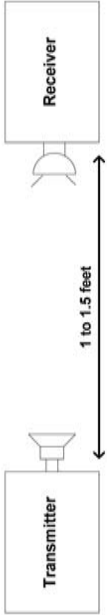


Figure 53: Example test set-up

		f_1	f_2	BPF ₁	BPF ₂	Voltage levels measured after peak detector.
Signal from Transmitter 0=off; 1=on	0	0	0	V	V	
	0	1	1	V	V	
	1	0	0	V	V	
	1	1	1	V	V	

Figure 54: Table for test set-up

Section Seven: Building the Receiver

Based on what voltage appears at the peak detector as 'on' and what voltage as 'off,' you can choose appropriate T_H and T_L thresholds for your Schmidt trigger. Use your equations from Section Five to calculate resistor values. Breadboard your design and test it.

- ☐ Schmidt triggers function as expected.
 - ☐ Schmidt trigger 1.
 - ☐ Schmidt trigger 2.
- ☐ Build the Schmidt triggers on your protoboard. (Refer to Figure 55).

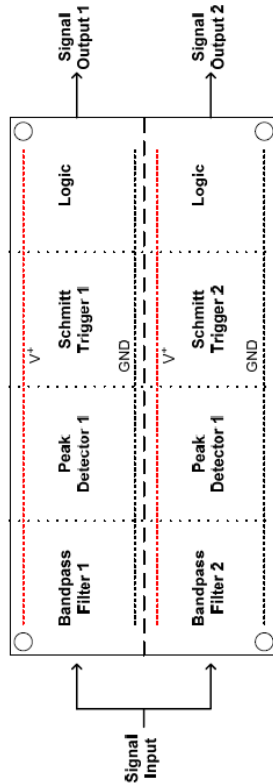


Figure 55: Suggested board layout

Task Three: Control the motors

Use the signals from the Schmidt triggers to control the TekBot and direct its movement as desired.



The inputs to the motor controller board are only tolerant up to 5V.

The following table is a suggested solution for controlling the motors.

Note: You may design for whatever control scheme you like, but keep in mind that it may require more logic. This solution has been provided to you only because this is not a course in digital design.

f_1	f_2	Function	LE	LD	RE	RD
0	0	Stop	1	x	1	x
0	1	Turn Right	0	1	1	x
1	0	Turn Left	1	x	0	1
1	1	Forward	0	1	0	1

From the above table, the solutions for the four control signals may be obtained by inspection:

$LD = 1$
 $RD = 1$
 $LE = f_2$
 $RE = f_1$



Remember that LE and RE are active low, and LD and RD are active high on the TekBot.

Breadboard and test your circuit.

Once it works, build it on your protoboard in the space reserved for 'Logic', as shown in Figure 55.

Put the entire system together and enjoy listening to the controls that make your TekBot move!

FINAL DEMO EVALUATION

Fully functional and constructed transmitter

Class project amplifier

- ☐ Microphone circuit soldered onto protoboard
- ☐ Soldered onto protoboard
- ☐ High and low frequency cutoff
- ☐ Correct gain

Bandpass filters

- ☐ Soldered onto protoboard
- ☐ Bandpass filters correctly pass/reject appropriate signals

Peak detectors

- ☐ Soldered onto protoboard
- ☐ Correctly detect presence of AC signal

Schmidt triggers

- ☐ Soldered onto protoboard
- ☐ Trigger at designed level

Logic soldered onto protoboard

TekBot moves in direction as signaled by transmitter

- ☐ Forward, left, right and stop

Extra Credit (for each additional channel)

- ☐ BPF functioning and soldered
- ☐ Peak detector functioning and soldered
- ☐ Schmidt trigger functioning and soldered
- ☐ Extra movement (i.e., spin right, etc.)

✓ TA Signature : _____

Total points: _____

(14 POINTS)

(1.0 point)

(0.5 point)

(1.0 point)

(1.0 point)

(1.0 point)

(1.0 point)

(1.0 point)

(0.5 point)

(1.0 point)

(0.5 point)

(1.0 point)

(0.5 point)

(4.0 points)

(1.0 point)

(0.75 point)

(0.75 point)

(1.0 point)

STUDY QUESTIONS/ TURN-IN

The following need to be turned in, **with your final demo, during dead week.**

1. Turn in **this lab sheet**, with all of your work written on it, to your TA. Please make sure that your TA can read it! If there is any doubt, you may need to re-copy your work on a fresh sheet.

The **written lab work** to be turned in includes:

- ☐ Completed Section Seven.
- ☐ Make sure all the sheets are stapled together.
- ☐ Answers to the following Study Questions.

2. Please **type** your answers to the following set of **study questions** on a different sheet of paper. Keep your answers clear and concise.
 - a) When one frequency (f_1) is transmitted, the peak detector for the other bandpass filter (BPF₂) still receives some signal. Why is this? How could you reduce the signal “leaking through”?
 - b) What problems did you encounter in this lab? Briefly explain each problem and solution you implemented.

**APPENDIX E – SURVEY AND RESULTS FOR NEW ECE 323,
FALL 2006**

Laboratory Evaluation Form, ECE 323 Fall 2006

Please write comments in addition to numerical responses.

Labs

Introduction to PSPICE (recall how to do circuit simulation using PSPICE and refresh Bode plots)

____ How did you like this lab? (Please rate on scale of 1-5 where 1 = hated it, 5 = loved it)

Comments?

Frequency Generator, Summing Circuit and Low Pass Filter (begin creating the transmitter by using the Digital Logic Board to generate frequencies and process them)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Single Stage Amplifiers and Filters (experiment with different styles of single stage amplifiers and use the knowledge to build a filter, including testing the effect of parasitics)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Output Stages (experiment with a couple different current amplifiers and implement one for your transmitter)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Peak Detector and Schmitt Trigger (design your own peak detector and trigger the signal afterwards)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Microphone and Class Project (solder up the microphone circuit followed by the amplifier, which you designed and built and tested)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Building the Receiver (finish putting the receiver together and ironing out the last problems for the TekBot to move)

____ How did you like this lab? (1 = hated it, 5 = loved it)

Comments?

Lab Reports

1. ____ How useful were the Pre-lab Questions? (1 = waste of time, 5 = a great learning tool)
2. ____ How useful were the Study Questions? (1 = waste of time, 5 = a great learning tool)
3. Rate the difficulty of the Pre-lab Questions ____too difficult ____just right ____too easy
4. Rate the difficulty of the Study Questions ____too difficult ____just right ____too easy
5. How many hours per week did you spend doing the labs? _____hrs/wk
6. How many hours per week did you spend writing the lab questions?
_____hrs/wk
7. Did you work cooperatively with other students on reports? YES NO (circle one)
8. Other comments on the lab reports?

Lab Staff

Name	Teaching skills (1 = poor; 5 = excellent)	Comments?
TA: Marjorie Plisch		
TA: Omid Rajaei		

Did you make use of office hours? YES NO (circle one) Why or why not?

Facilities

___ How was the lab room? (1 = find somewhere else, 5 = perfect)

What did or didn't you like about the lab room?

Overall

___ How worthwhile were the labs overall? (1 = waste of time, 5 = extremely valuable)

What was the most interesting concept that you learned from the labs?

Did the labs stimulate your interest in circuits? YES NO (circle one)

If offered, would you take another course in circuits? YES NO (circle one)

What is your sub-specialty or what sub-specialty(ies) are you considering? _____

Has this course influenced your choice of sub-specialty in any way? YES NO (circle one)
Explain?

Would you recommend this course to another student? YES NO (circle one)
Comments?

What aspect(s) of the labs do you feel need the most improvement?

What aspect(s) of the labs did you like the best?

What new lab topics would you recommend for a future version of this course?

Any other comments on the labs?

Thanks for filling out this evaluation!

Laboratory Evaluation Results, ECE 323 Fall 2006

Note: This is an abbreviated summary and includes only numerical and tabulated scores, but omits student comments.

Labs	Average score (1 = hated it, 5 = great learning tool)
1. Intro to PSPICE	3.6
2. Summing Circuit, etc.	3.6
3. Amplifiers and Filters	3
4. Output Stages	3
5. Peak detector and Schmitt trigger	3.2
6. Class project	3.3
7. Building the receiver	2.9

Lab Reports			
1. Usefulness of pre-lab questions	(1 = waste of time, 5 = a great learning tool)		
	2.9		
2. Usefulness of study questions	2.3		
3. Difficulty of pre-lab questions	Too Difficult	Just Right	Too Easy
	3	15	0
4. Difficulty of study questions	0	12	5
5. Hours/week in lab	6.5		
6. Hours/week writing questions	0.8		
7. Working cooperatively	yes	no	
	6	10	

Lab Staff	Teaching skills (1 = poor; 5 = excellent)
Marjorie Plisch	4
Omid Rajaei	3.4

Facilities	(1 = find somewhere else, 5 = perfect)
1. Lab room	3.6

Overall				
1. Labs are worthwhile	(1 = waste of time, 5 = extremely valuable)			
	3.3			
2. Stimulate interest in circuits	Yes	No		
	9	7		
3. Take another circuits course?	10	8		
4. Course influenced choice of sub-specialty	4	11		
5. Recommend to another	12	4		

APPENDIX F – SURVEY FOR ECE 473

The following survey is what was mailed out to students who had taken ECE 473 over the past five years to gather pre and post data for the changes made to the course by introducing a PFL.

ECE 473 Course Survey

Please circle the choice that best represents your answer.

- I took ECE 473 in: 2003 2004 2005 2006 2007 I don't remember

- I clearly remember what was done in the lab for ECE 473.

Definitely Somewhat Neutral Hardly Not at all

- I found the material I learned in the ECE 473 lab to be useful (perhaps in a job or other class.)

Definitely Somewhat Neutral Hardly Not at all

The effect that ECE 473 had on...

- The sense of pride/ownership that I take in my projects was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My ability to understand how the material taught in ECE473 relates to other courses I have taken was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My learning and understanding through application and hands-on experience was ...

Strongly Positive Positive Neutral Negative Strongly Negative

- My excitement to learn was...

Strongly Positive Positive Neutral Negative Strongly Negative

- *My understanding of the difference between theory and reality was...*

Strongly Positive Positive Neutral Negative Strongly Negative

Survey continued on next page...

The effect that ECE 473 had on...

- My understanding of the core concepts underlying microprocessor system design was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My understanding of the basic concepts of engineering was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My skills of communication, teamwork, project management and ethics was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My ability to identify, isolate and resolve problems was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My ability to solve problems in a new or unique way was...

Strongly Positive Positive Neutral Negative Strongly Negative

- My ability to work together in a team was...

Strongly Positive Positive Neutral Negative Strongly Negative

Print your name here

Please note: If you have forgotten what year you took ECE 473, your name can be used to look that information up. Other than that, the response from your survey will only be used after being averaged with your classmates. You will not be individually identified in any publication.

Thank you for your time!

APPENDIX G – RESULTS FOR ECE 473 SURVEY

This appendix contains the results of the survey from Appendix F.

ECE 473 Survey results

ECE 473 Course Survey - Summary of Results														
Survey	Year Taken	Remember	Material Useful	Ques1	Ques2	Ques3	Ques4	Ques5	Ques1	Ques2	Ques3	Ques4	Ques5	Ques6
1	2002	2	1	2	1	2	2	1	1	1	1	2	2	3
21	2002	1	1	2	2	2	2	2	3	2	2	2	2	2
2	2002	2	2	2	2	2	1	2	2	2	2	2	2	2
3	2002	1	2	2	2	1	1	2	2	3	2	2	2	3
AVG		1.5	1.5	2	1.75	1.75	1.5	1.75	2	2	1.75	2	2	2.5
4	2003	1	2	3	2	2	2	1	2	2	2	2	2	2
22	2003	2	3	1	1	1	1	1	1	1	1	1	1	2
5	2003	1	2	2	3	3	3	3	4	2	3	2	3	3
AVG		1.3333333	2.3333333	2	2	2	2	1.667	2.333	1.667	2	1.667	2	2.3333
6	2004	1	1	1	1	1	1	1	1	1	1	1	1	1
7	2004	2	1	2	2	2	3	2	2	2	3	2	3	3
9	2004	1	1	1	1	1	1	1	1	1	1	1	1	1
AVG		1.3333333	1	1.333	1.333	1.3333	1.667	1.333	1.333	1.333	1.667	1.333	1.667	1.6667
8	2005	1	1	1	1	1	1	1	1	1	2	1	1	2
11	2005	1	1	1	2	1	1	1	1	1	2	2	1	2
12	2005	1	1	1	1	1	1	1	1	1	1	1	1	1
13	2005	1	2	2	2	1	2	2	2	1	2	2	2	3
14	2005	1	1	2	1	1	2	1	2	2	1	1	1	3
15	2005	1	1	2	2	1	2	2	1	1	3	2	2	3
17	2005	1	1	1	1	1	1	1	1	1	2	1	1	3
19	2005	1	1	1	1	1	1	1	1	1	1	1	1	1
20	2005	1	2	2	2	3	3	2	2	2	3	3	3	3
AVG		1	1.2222222	1.444	1.444	1.2222	1.556	1.333	1.333	1.222	1.889	1.556	1.444	2.3333
10	2006	1	1	1	1	1	1	1	2	1	1	1	1	1
16	2006	1	1	1	1	1	1	1	1	1	2	1	1	2
18	2006	1	1	1	1	1	1	1	1	1	1	2	2	1
AVG		1	1	1	1	1	1	1	1.333	1	1.333	1.333	1.333	1.3333
23	2007	2	1	2	2	1	2	2	2	1	1	2	2	2
24	2007	1	1	2	2	2	2	2	2	2	2	2	2	2
25	2007	1	2	1	2	1	1	1	2	2	2	1	1	2
26	2007	1	1	2	1	2	2	3	1	2	3	1	2	1
27	2007	1	3	1	1	1	2	2	1	1	1	1	1	1
28	2007	2	1	2	2	2	2	2	2	2	2	2	1	1
29	2007	1	1	1	2	1	2	2	2	1	3	1	1	3
30	2007	1	1	1	2	1	2	1	1	1	3	1	1	3
31	2007	1	1	1	1	1	1	1	2	1	2	2	3	3
32	2007	1	1.5	2	3	1	2	3	1	2	2	2	2	2
33	2007	2	2	2	2	1	1	2	2	1	2	1	2	1
34	2007	1	1	1	2	1	1	3	2	2	1	1	1	1
35	2007	1	1	2	2	2	2	2	2	2	3	2	2	3
36	2007	1	1	2	1	1	1	1	2	2	1	2	1	1
37	2007	2	1	3	2	2	2	2	3	1	2	1	2	2
38	2007	1	1	2	1	2	2	1	1	2	2	1	2	2
39	2007	1	1	1	1	1	1	1	1	1	1	1	1	1
40	2007	1	1	1	1	1	1	1	1	1	1	1	1	1
41	2007	1	1	2	2	1	2	1	1	1	1	1	2	2
AVG		1.2105263	1.2368421	1.632	1.684	1.3158	1.632	1.737	1.632	1.474	1.842	1.368	1.579	1.7895