AC 2012-4009: PROJECT-BASED SERVICE ORIENTED PROJECTS AS A WAY TO LEARN AND APPLY ANALOG ELECTRONICS

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Project-based Service Oriented Projects as a way to learn and apply Analog Electronics

Abstract

Electrical and computer engineering students at our university are required during their junior year to take a three credit lecture course and a two credit laboratory in analog electronics. Over the past seven years, several attempts have been made to enhance student learning through participation in PBL projects. In Project-based learning “PBL”, since the project is developed by the instructor and the learning path is predictable, student creativity, ingenuity and innovation may be diminished. In order to provide opportunities for student creativity and innovation, a service oriented project was introduced in the fall of 2011. Project-based service oriented learning “PBSOL” is a learner-focused form of active learning where students work to solve a real life problem while also providing a rich learning experience.

Since the major topics of study in analog electronics include the study of such semiconductor devices as diodes, zener diodes, BJT’s transistors, and MOSFETs, the projects were required to be designed around the use of an Amplitude Shift Keying “ASK” transmitter and receiver. The project makes use of previous knowledge such as impedance, resonance, loading, and matching, learned in their Circuits I and Circuits II courses while challenging their search for future topics such as RF communication theory, digital electronics, and microcontrollers, which are learned in later engineering courses. The wireless characteristics of the ASK transmitter and receiver promoted the design of such service projects as a wireless security system, a mail alert system, and a wireless home control system for a handicapped person.

In the lab course, students work in small teams and have 12 weeks to design and implement their service oriented project. During the first two weeks, research is conducted about their project ideas, followed by several weeks of draft designs, re-calculations and testing. At the end of the semester they must write a report, deliver a Power Point presentation, and demonstrate their project. Surveys were conducted before and after each design session, and at the end of the final project. Student understanding and mastery of the course content was measured using quizzes, tests, the project presentations, and written final reports. A comparison between this year’s results and the previous year’s results is included. Improvement of student learning and the development of decision-making skills through service oriented projects may prompt the implementation of other projects that may include multidisciplinary collaboration, integration of projects between classes, and projects across concentrations.

Background

Lecture-based education is known to address only certain learning styles (primarily auditory and some visual, but not kinesthetic learners). The addition of design projects provides students with a broader context to the material learned in class. With project-based learning students shift from a passive to an active learning pattern that is likely to improve knowledge retention as well as the ability to integrate material from different courses.[1] Each project provides students with the opportunity to apply the knowledge they have learned in classes, and each problem they face in the project inspires them to explore the material more deeply in future study [2].

Project-based learning can develop the ability of students to work in interdisciplinary teams. Interdisciplinary teamwork is not only an expectation of industry but also has become a required outcome of the ABET engineering criteria. Many obstacles may arise when working in interdisciplinary teams, but a series of curriculum tools have been initiated at our school to insure that students will have a measure of success in project teamwork [3]. Project-based learning is an instructional method that demands from a student the acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies, and team participation skills [4]

Motivation is a key element in student learning and persistence. Motivated students "exhibit effort on tasks, persist under difficult circumstances, and maintain positive beliefs about (their) academic abilities."[5] Ideally, the motivation is intrinsic motivation, generated internally from a desire to learn, rather than external motivation, generated by external rewards (or punishments).[6] "Intrinsic motivation can be enhanced by providing students with learning which is challenging, which engages curiosity, where they have a degree of control and where there is a game-like or fantasy dimension."[7] We have found that engineering students are most highly motivated to tackle new material when it seems relevant, when it corresponds to things they already know, and when they are already interested in the material or in the resulting skills they will learn.

Charles Wales and Robert Stager developed the philosophy of guided design**.** The Guided Design Process describes a sequential process for solving design problems. Wales and his colleagues believed this philosophy contained five basic principles of teaching: (1) Guide the students' learning by providing them with a series of experiences that build on each other, (2) Provide opportunities for students to apply and practice skills, (3) Evaluate responses and provide feedback, (4) Motivate or reinforce the learner, and (5) Individualize to the learner's style. The goal of guided design is not to get the correct answer, but to know the process by which one gathers information, processes information, and arrives at an acceptable solution.[8]

Service-learning as a curricular educational approach has existed for years in higher education and has been embraced by the engineering field as containing the benefits of hand-on, teamwork, communication and experiential learning with the added motivation of service to communities. The projects done in this course could be considered Service-oriented, rather than pure service-learning, since students originated the ideas rather than having the needs arise from actual persons and situations.

Taking the advice presented by (Barrington L. & Duffy, J AC 201-2149) "Practical Suggestions for Faculty Implementers- it is better to start small rather than not at all". This paper presents our first attempt to start a Project-based service oriented learning experience.

Course History

Like many undergraduate engineering schools in the nation, our university emphasizes a hands-on approach in engineering education. From the beginning of the freshman year through the senior year, students participate in multiple levels of engineering projects (Freshman-Fundamentals of Engineering Design, Sophomore –Engineering Project Management, Junior –Engineering Design Methodology, Senior –Senior Design I and II). Each project provides a challenge to the students along with the opportunity to apply the knowledge they have learned in their previous courses.

In the fall of 2006, we introduced into the junior level Electronics I Lab (a two credit hour course**)** a project-based learning "PBL" experience with the following objectives:

1. Provide students with the opportunity to apply the concepts learned from the lectures and the instructor's predefined labs.

2. Allow students to work on projects that motivate them.

3. Provide a fun and enjoyable problem solving real life learning experience

4. Engage the students in the analysis, synthesis and evaluation process to generate a working solution for their projects

The concepts needed came from the lectures in Electronics I taught simultaneously during the semester. Electronics I (analog electronics), is a three-hour lecture course with content organized to cover the following subjects: diodes and rectifiers, semiconductor physics, MOSFETs, and transistor amplifier design.

Along with the Electronics I lecture course, students are required to take the two-hour lab course knows as EEGR 3112 Electronics I Lab. This lab covers the following topics:

1. Introduction to diode circuits.
2. I-V curves of diodes.
3. Diode circuit applications in clippers, clampers, and regulator circuits.
4. Passive and active, low pass and high pass filters.
5. RLC resonant circuit response.
6. Terminal characteristic of BJT transistors (DC load lines and Q points).
7. BJT transistors and small signal amplification (DC and AC load lines).
8. BJT transistor thermal stability and frequency response.
9. Operation of BJT Transistors: LC oscillator and frequency multiplier.
10. Applications of Operational Amplifiers.
11. Characteristic of MOSFETs (DC and AC analysis).

In this lab course the students designed and implemented PBL electronic projects such as a "salinity tester", an equalizer system, a voice modulator and a musical tuner. In order to minimize the resistance of introducing the extra work load of the PBL project to an already packed lab course, the students were given freedom to work with projects they liked and topics that motivated them. The students, however, selected projects that were within their current knowledge level, with little challenge to force them to search out and apply new concepts.

In order to improve the project-based learning experience of 2006, in the fall semesters of 2007 and 2008 the "PBL" project requirements were set by the lab instructor. In 2007 the students were expected to build an FM transmitter/receiver, and in 2008 were expected to build an AM transmitter/receiver.

The new expectations for this PBL project were changed to:

a) To apply the concepts learned from previous courses, especially Circuits I and II,
b) To apply the concepts learned from their concurrent lecture and lab analog Electronics I class.
c) To challenge students to research, study and apply concepts from future courses such as electronic communication circuits and RF theory.
d) To allow student to work in teams.

The PBL project requirement to build an FM or AM transmitter/receiver introduced a strong challenge for the students to search and study new topics. The concepts of oscillators, mixers, transmitter and receivers are topics in a more advanced electronics course, and amplitude and frequency modulation are topics in an electronics communication course that students take in their senior year.

Although at the end of the course the students were able to deliver a working FM and AM transmitter/receiver circuit, many difficulties were faced during the process. One of the main problems was that the structure of the lecture and labs did not help the students in their design process. The first four weeks of the course were devoted to studying diodes and their applications. The next three weeks were given to studying the transistor, but only under DC conditions. It was only after the seventh week, that small signal AC analysis of transistor configurations and its applications were studied. These delayed the PBL design process, and shifted much of the design work to the end of the semester, overwhelming and frustrating the students.

To overcome these difficulties, a PBL project with a guided design method was introduced in the fall semesters of 2009 and 2010. The guided design component permitted us to introduce three fundamental parts of an FM or an AM transmitter/receiver circuit to guide the students in the design of their circuits.

The PBL project with the guided design component "PBGD" added a fifth objective:

e) To guide the students' learning with experiences that build on each other, provide opportunities for students to apply and practice skills, and evaluate responses and provide feedback.

With the introduction of guided design into the PBL project the students' design difficulties were minimized. The three basic circuits used for the guided design were the diode detector circuit, a Colpitts oscillator, and a basic transistor circuit. During the third week, when the students were working with their regular diode labs, the design of a diode detector circuit was presented. After working with it in the lab, the students were able to re-design their own diode detector circuit. During the fourth week, when the students were working in the lab with RLC circuits, a basic

Colpitts oscillator circuit was presented as the second guided design circuit. After working with it in the lab, the students re-designed the oscillator to work at their respective frequencies. During the fifth week, the students started working with transistors; the third guided design was handed out, a basic transmitter circuit. After working with it, the students were able to re-design their own transmitter circuit. They were able to use the re-designed Colpitts oscillator to generate their own specified carrier frequency. From the three basic circuits, students were able to apply basic principles to design a receiver circuit with their own carrier frequency, mixer and diode detector section.

During the fall semester of 2009 the students were able to design and implement working AM transmitter and receiver circuits at the specified frequencies using only analog semiconductor devices (diodes and BJT transistors). The following year, fall 2010, the students were also able to obtain the same results with ease. We had found a way to facilitate student success, but we soon discovered that since the learning path was predictable, student creativity, ingenuity and innovation may have been diminished. Students were able to design an analog AM transmitter and receiver, but paths to integrate this electronic analog device into a fully digital environment were missing.

In order to provide opportunities for student creativity and innovation and also to provide ways to integrate analog and digital electronic circuits, project-based guided design with an in-class service component was introduced in the fall of 2011. Students were expected to design and implement a project-based guided service project built around the use of an amplitude shift keying “ASK” wireless radio transmitter and receiver. Using only analog components and the design of the circuit for the service project was based on digital electronic components.

The introduction of the service component into the project-based guided design modified and added two more student objectives:

f) To allow for the integration of analog electronic circuits with digital electronics circuits.
g) To allow for the student creativity and innovation through an in class service project.

The wireless characteristics of the ASK transmitter and receiver promoted the design of service projects such as a wireless security system, a mail alert system, and a wireless home control system for a handicapped person.

Methodology

To allow the use of small group teaching, provide feedback on students’ work, and focus on the stepwise design and implementation of a project-based service project around an ASK transmitter and receiver circuit, a fourteen week project schedule was woven into the fall semester of 2011. The schedule was as follows:

First week:

- The ASK service project was presented to the students.
- Students were organized in groups of four to five.
  - Selected a Team leader and assigned responsibilities

- Conducted a brainstorming session
- Tried to identify the need, the objectives and goal;
- Stated the constraints, assumptions, and facts;

Second week:

- Homework/research assignment: to study AM, FM, ASK and FSK communication theory and how AM, FM, ASK and FSK transmitters and AM receivers circuits work.
- Students met in groups and discussed their ideas of the service project

Third week:

- Students were given the first guided design circuit: a diode detector circuit to build and analyze in the lab
- Students met in groups and discussed their findings from their research on AM, FM ASK and FSK technologies.

Fourth week:

- Students were given the second guided design circuit: a Colpitts oscillator circuit to build and analyze in the lab
- Students met in groups and:
  - Decided on the service project they will implement
  - Narrowed their ideas on the design of the digital circuit for the project.

Fifth week:

- Students were given the third guided design circuit: an AM transmitter circuit to build and analyze in the lab
- Students met in groups and:
  - Decided on the service project they will implement
  - Narrowed their ideas on the design of the digital circuit for the project.

Sixth week:

- Students submitted first draft designs
  - First draft of ASK transmitter/receiver circuit design,
  - First draft of the digital circuit design.
- At the end of the week, students received feedback from their analog and digital designs.

Seventh week

- Students submitted their final analog and digital designs.
- At the end of the week, students received feedback from their final analog and digital designs.

Eighth to thirteenth week:

- Students were given free access to work in the university's electronic labs at their own pace. Only one lab period from the scheduled labs was assigned for the PBSOL projects.
- Students soldered and tested their PBSOL circuits.

Fourteenth week

- All teams presented a report of their findings and calculations.

While students worked in teams, each student had responsibility for particular part of the design.

ASK transmitter circuit requirements

Needed:

A transmitter capable of transmitting at a frequency between 1 MHZ and 2 MHZ, with amplifier stages built only using BJT's (bipolar junction transistors), capable of running from a 9 volt battery and a having a maximum output power between 100mw and 500 mw (to comply with the FCC transmission output power limitations).

The ASK transmitter should be able to:

- Take a digital input to modulate the carrier and create an ASK signal
- Generate its own 1 to 2 MHz carrier oscillating frequency.
- Combine digital input and carrier in an ASK modulator/mixer circuit
- Amplify its output, couple it to an antenna and transmit it to the ASK receiver.

Figure 1 ASK transmitter circuit

ASK receiver circuit requirements

Needed:
A receiver capable of tuning to a fixed frequency between 1 MHz and 2 MHz, with amplifier and oscillator stages built using BJT's only and for the diode detector part a RF diode must be used. The audio amplification stage could be implemented using the LM386 IC. Should be run from a 9 volt battery and have maximum power consumption between 100mw and 500 mw.

The ASK receiver should be able to:

- Receive the ASK signal through the receiving antenna.
- Tune to the 1 MHZ or 2MHz transmitter signal
- Amplify the received signal to the point where it can be detected by the detector circuit.
- Be capable of separating the original signal from the ASK signal using a diode detector circuit.
- Amplify the original digital signal to the value required to interface with the other side of the digital circuit.

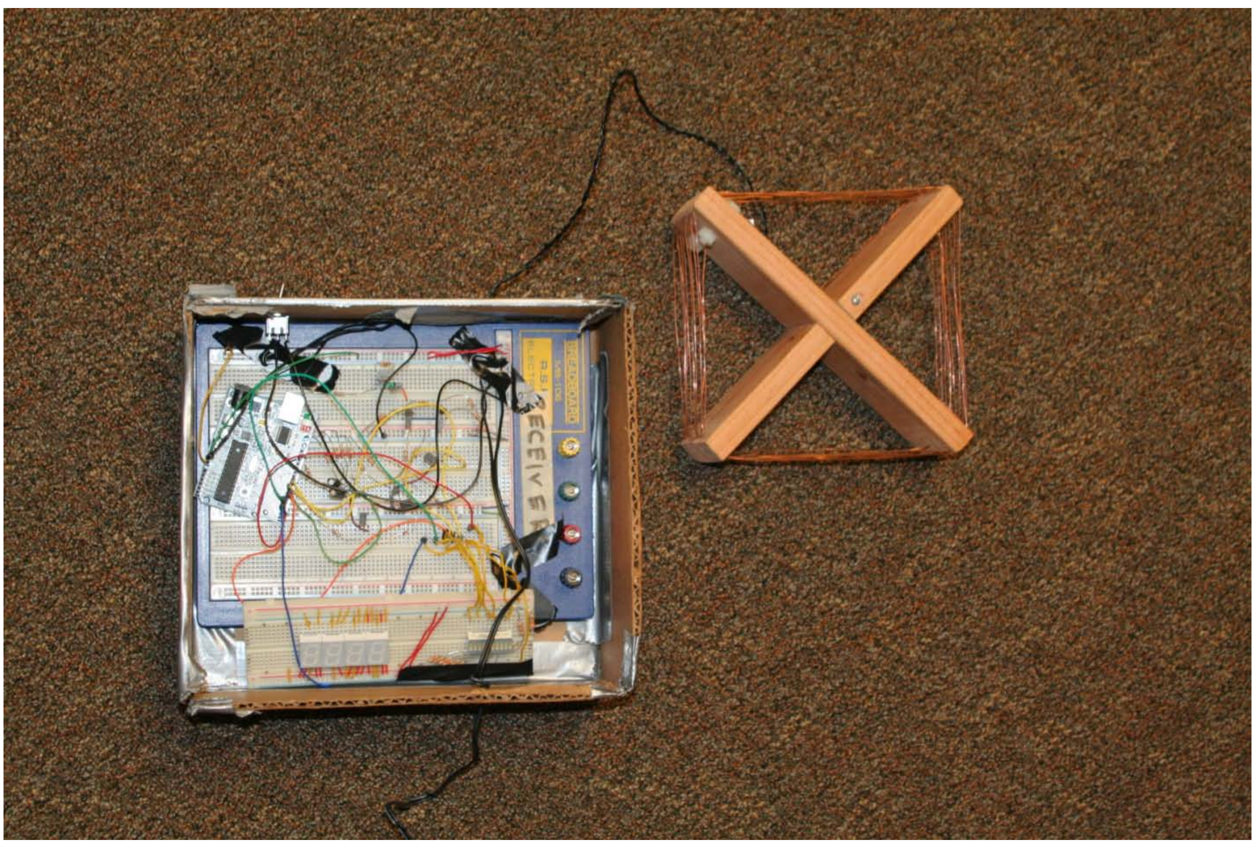

Figure 2 ASK Receiver circuit

Service-oriented Projects

The projects done in this course could be considered service-oriented, rather than pure service-learning; since students originated the ideas rather than having the needs arise from actual persons and situations. After a brainstorming session, using the ASK transmitter/receiver modules as the fundamental building block, students devised digital electronic modules with the purpose of helping individuals with special needs. Following is a short description of the projects:

1. **Wireless alert system**

Description of the project written by the students:

The wireless alert system is very customizable and has a wide range of applications. Such applications might include hospitals, nursing homes or use in a home with a disabled child. The transmitter is controlled by a control box with switches. Depending on which switch was activated, a certain signal is sent from the transmitter through an antenna, the receiver picks up the ASK signal and the receiver decodes the digital message that is sent to a microprocessor that outputs the specified message in an array of 7 segment LEDs.

Figure 3 The wireless alert system receiving a request for HELP signal.

2. **Home security system**

Description of the project written by the students:

The system retrieves a pass-code from the user via 7 toggle switches. The user then flips a final switch to send this pass-code serially to the transmitter. The transmitter modifies the code from a digital signal to an ASK signal and broadcasts the signal via an antenna. The receiver obtains the signal through its antenna and transforms the ASK signal back to a digital signal. The signal is then sent to an array of shift registers where it is decoded. If the code is correct the door to the dorm room can be opened safely. If the code is incorrect and the door is opened, the alarm will sound until the correct code is entered on an 8 toggle switch interface on the receiver. This system could alert any individual or organization of an unauthorized intrusion.

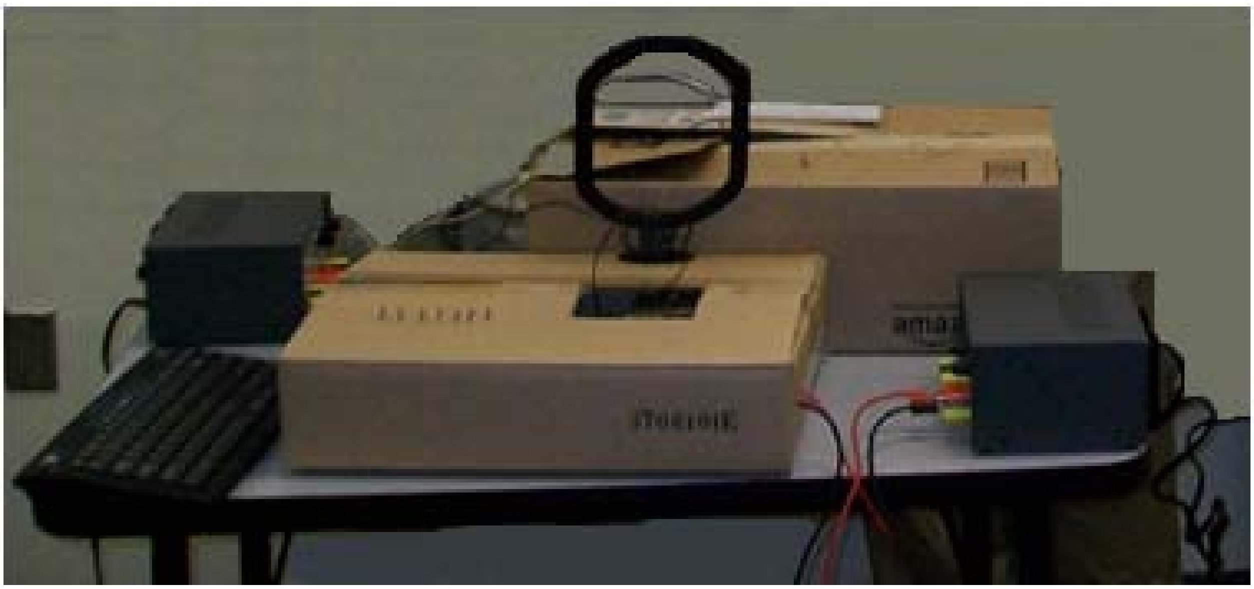

Figure 4 The Home Security system sounding the alarm when a wrong code was entered.

3. A wireless alarm system

Description of the project written by the students:

The goal of our project was to send and receive a signal wirelessly using ASK modulation. The method was to be able to set off an alarm wirelessly using a motion detector. To do this we built a transmitter that sends a certain code. When motion is detected it transmits the code only while it “sees” the target. The receiver would scan for that code and would set off an alarm whenever it received the code. The alarm would stay on until a user could reset it. This system could allow a blind person to know when someone was near their house.

Figure 5 The Wireless alarm system sounding the alarm when motion was detected.

4. A Package notification system "Pacnosys"

Description of the project written by the students:

Our project goal was to create a wireless system that notified someone audibly if they received a package in the mail. Once package was received, it would be scanned and a signal would be sent out and the recipient Two Arduino microcontrollers were used to handle the encoding and decoding. The ASK transmitter and receiver were built using BJTs and for the antennas two spool of coil were used. This system could allow a blind person to know a package had arrive.

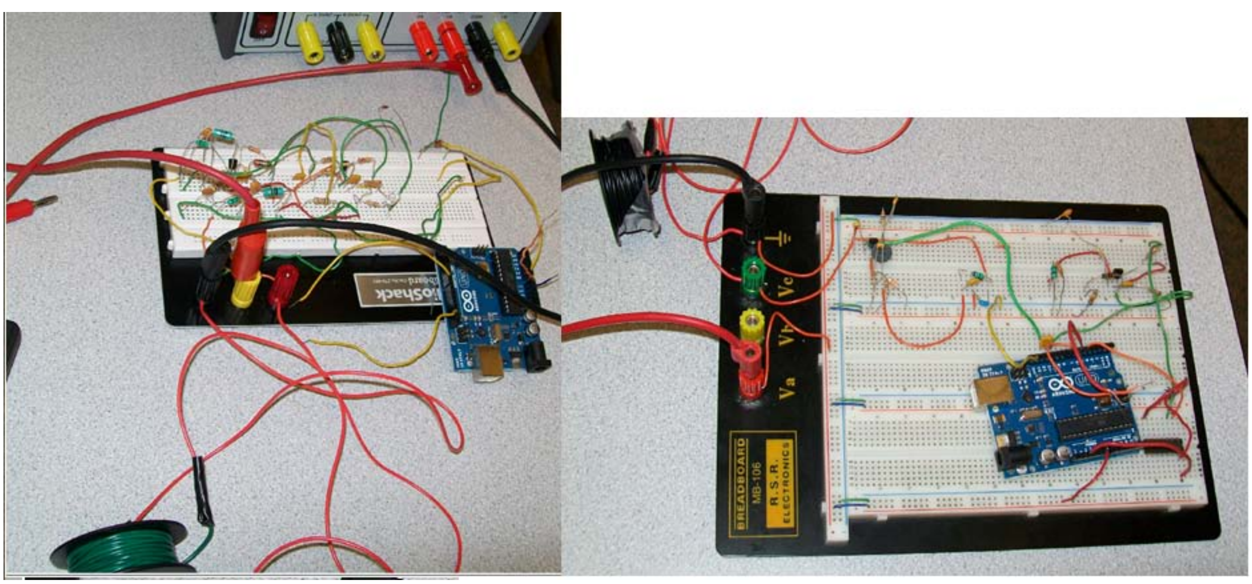

Figure 6. A pictorial display of the Pacnosys transmitter and receiver modules.

Results and conclusions

A survey was developed with questions that would help us to determine if the Project-based service oriented earning helped students understand the basic electronics component studied during the semester. These basic electronic components are: diodes, BJT transistor, MOSFETs and Linear Integrated Circuits. The first survey was given the first day of class and the second survey was given at the end of the semester.

Four of the before and after questions graphs are presented. The legend of the horizontal axis numbers, 1,2,3,4 and 5 for all the graphs correspond to:

1_ definitely no, 2_ mostly no, 3_ neutral, 4_ mostly true and 5_ definitely true

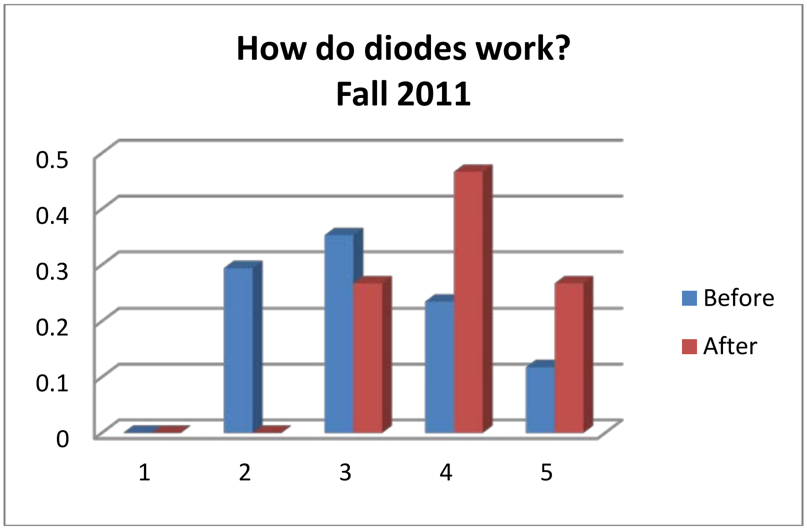

Figure 7 Responses to the question: How do diodes work?

Even with 25% of students responding neutral after performing the project the rest of the students did find the project helped them to understand how diodes work. One possible reason for this 25% was that when the responsibilities were distributed, and some students did not have to work with diodes.

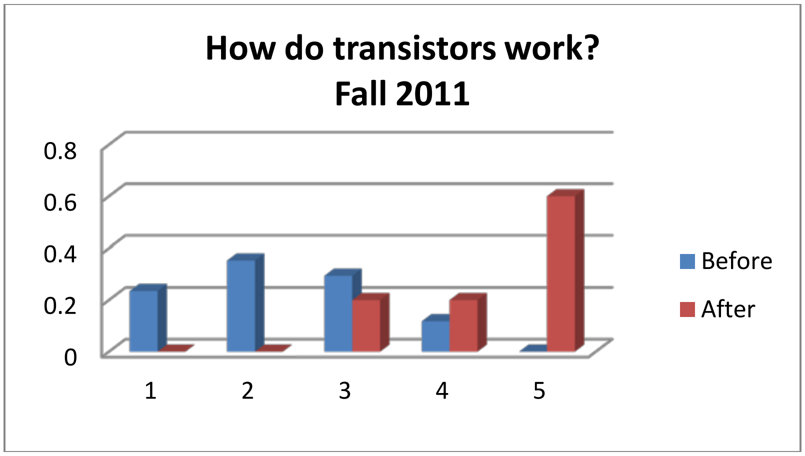

Figure 8 Responses to the question: How do transistors work?

Only 5% of students knew before the class how transistors worked. Only 18% of students responded neutral after performing the project, and the rest of the students did find the project to help them understand how transistors work. As above, one possible reason for this 18% was that when the responsibilities were distributed, some students did not have to work with transistors.

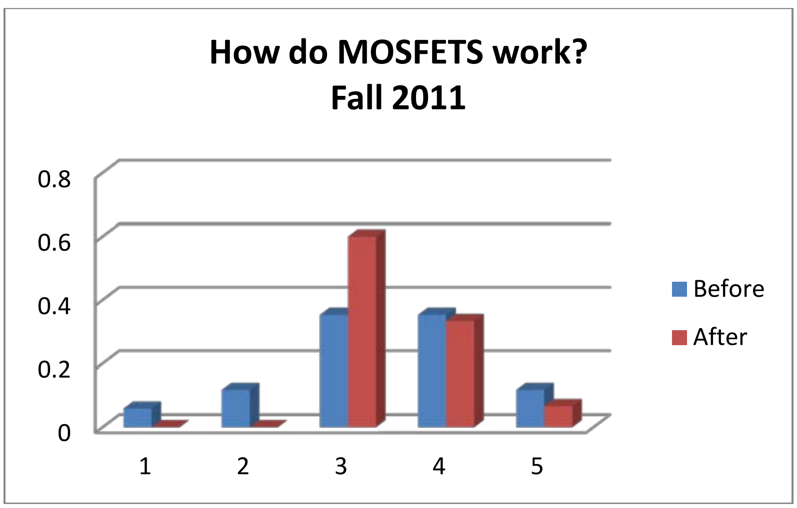

Figure 9 Responses to the question: How do MOSFETs work?

To understand the result of this graph it is important to note that none of the projects used MOSFETS in their designs. The project did help them to improve in their understanding of how MOSFETs work. The students performed a MOSFET lab in their regular lab course.

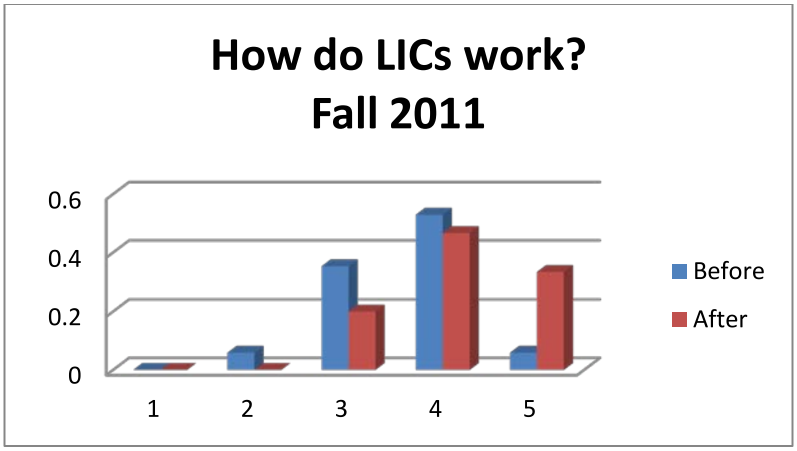

Figure 10 Responses to the question: How do LICs work?

Before taking the Electronics class, students had working experience with op-Amps, and some had worked with logic gates. There was a .06% result of not knowing about LICs, but around 50% of the students had some experience. After the project most of the students did find the project useful to help them understand how LICs work.

From a systems point of view, all groups were able to integrate the digital circuits to the analog circuits. They were able to transfer information from the user to the transmitting devise (digital message modulating an analog carrier), from the transmitting antenna to the receiving antenna, and from the receiver to the digital decoder circuit. Student creativity was observed in the way the students designed solutions applying the knowledge from previous courses, from the labs and the concurrent lectures and from the guided experiments. Although all the projects required students to design and use the ASK transmitter and receiver, each had differences in their design. Some digital modules were implemented using only LICs logic; two groups implemented their designs using audrino microprocessors.

Electronic Projects Summary table		
Year	**Project Approach**	**Outcomes**
Fall 2006	Open ended project – student chose project	little challenge, students not engaged
Fall 2007	PBL + project assigned by instructor	very challenging, many students were engaged, but some ended up frustrated
Fall 2008	PBL + project assigned by instructor	2nd try, very challenging, many students were engaged, but some ended up frustrated
Fall 2009	PBL guided design + project assigned by instructor	Very challenging, students received guidance and were engaged
Fall 2010	PBL guided design + project assigned by instructor	Very challenging, students received guidance and were engaged
Fall 2011	Project-based service oriented – ASK module guided – service oriented application chose by students	Very challenging, students received guidance on the ASK part and were very engage in the in the service oriented digital electronic modules

The author acknowledges that the results derived in this paper are more qualitative than quantitative and a more formal assessment needs to be performed. This paper presents the results of our continuing attempts to provide a project-based service learning experience to help improve student learning. As our experience has taught us, the way to conduct project-based service oriented learning projects does not have a fixed format, but needs to be changed and adapted to the particular situation of each school. Our results each year have been positive and we expect that this may prompt the implementation of other projects that may include multidisciplinary collaboration, integration of projects between classes, and projects across concentrations.

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APENDIX 1 Security System circuit diagrams

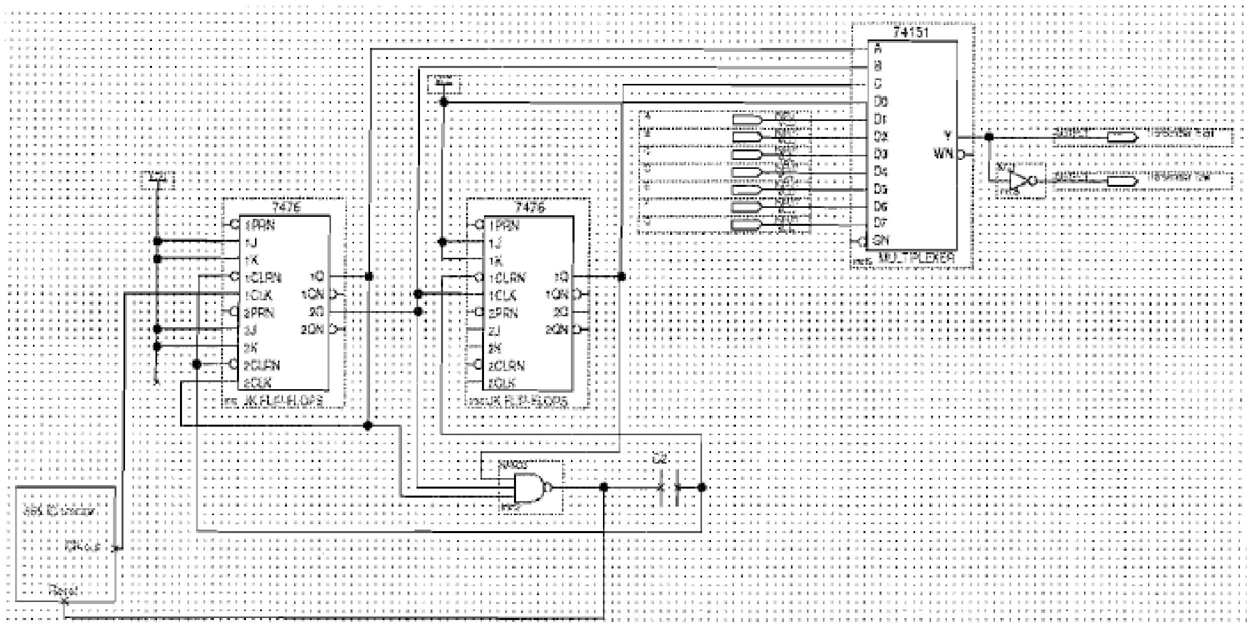

Figure 1 Digital Input

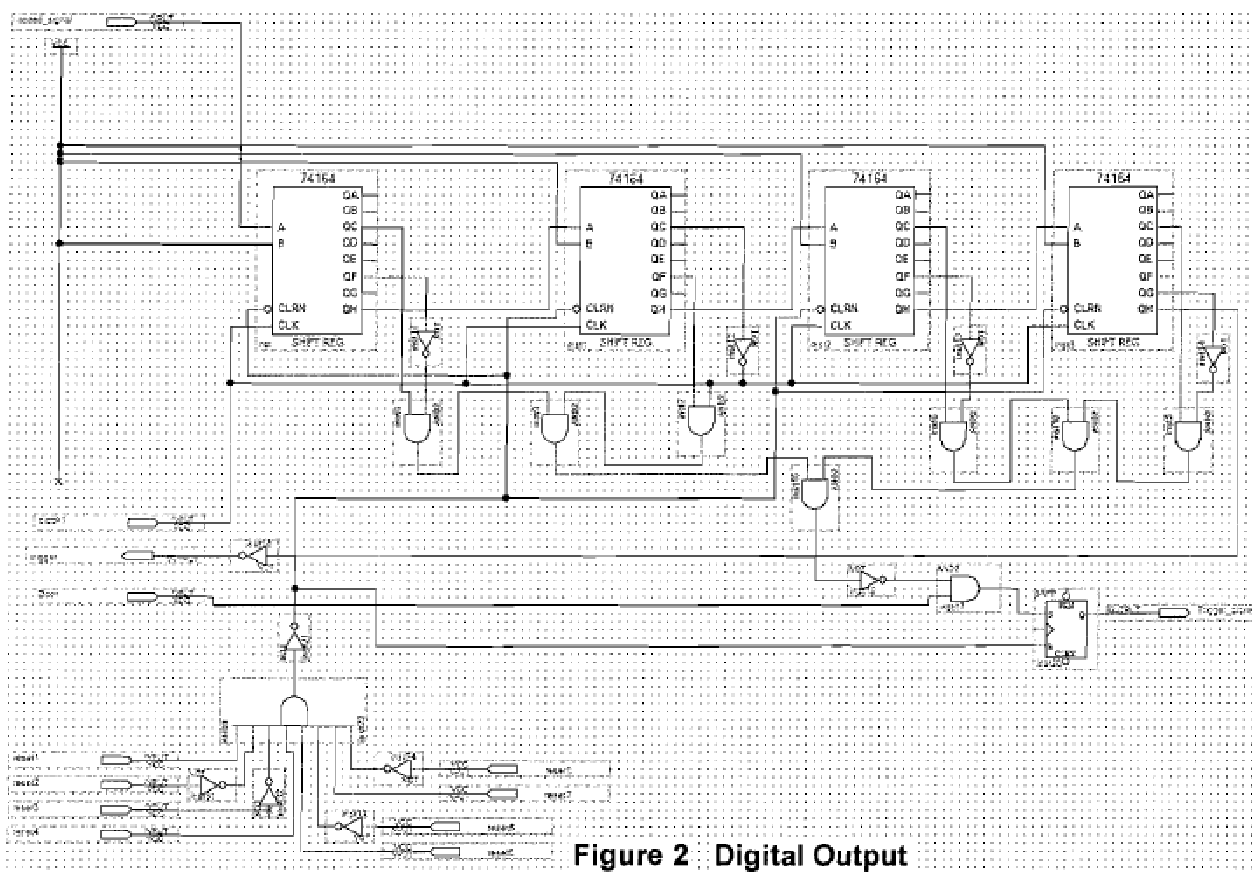

Figure 2 Digital Output

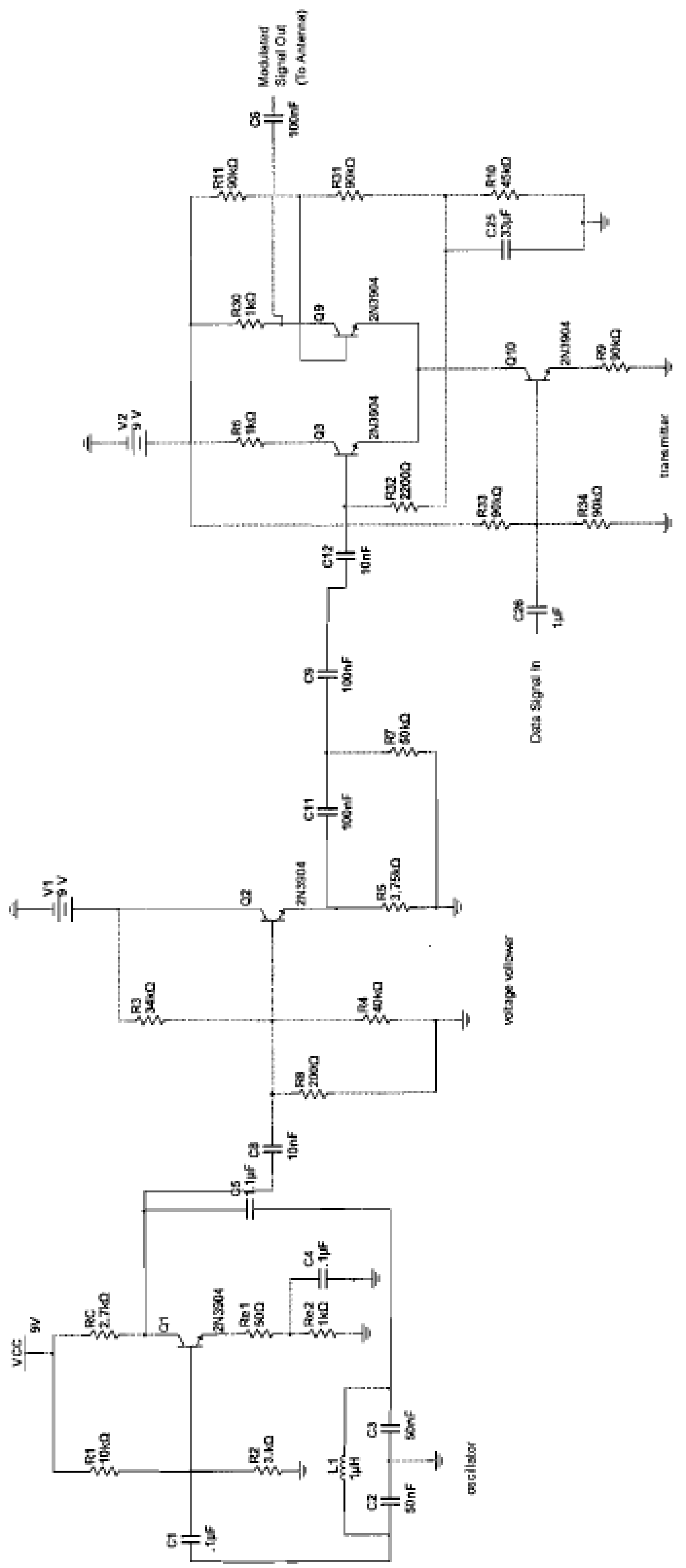

Figure 3 Transmitter

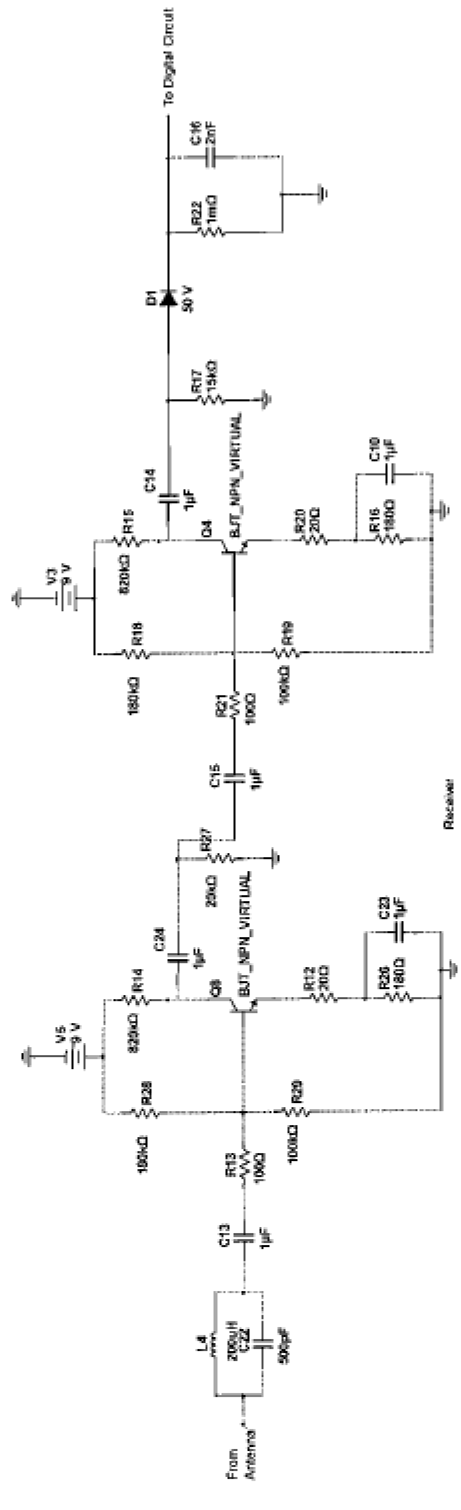

Figure 4 Receiver

APPENDIX 2 Wireless alarm system circuit diagrams

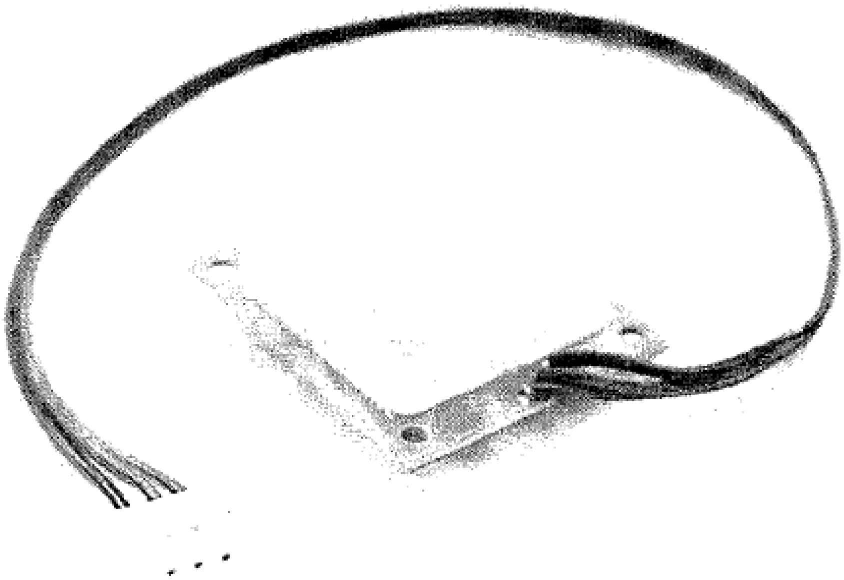

Figure 2.1 Motion detector

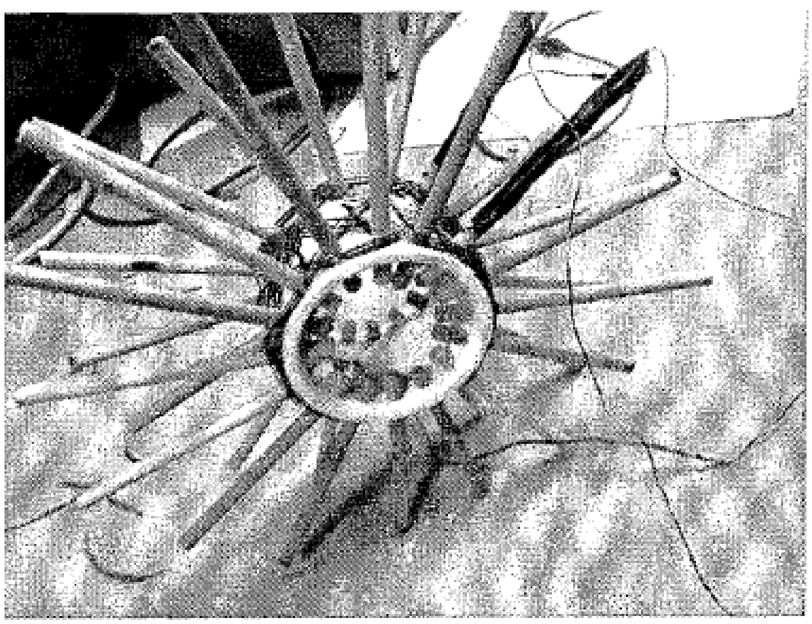

Figure 2.2 Antenna

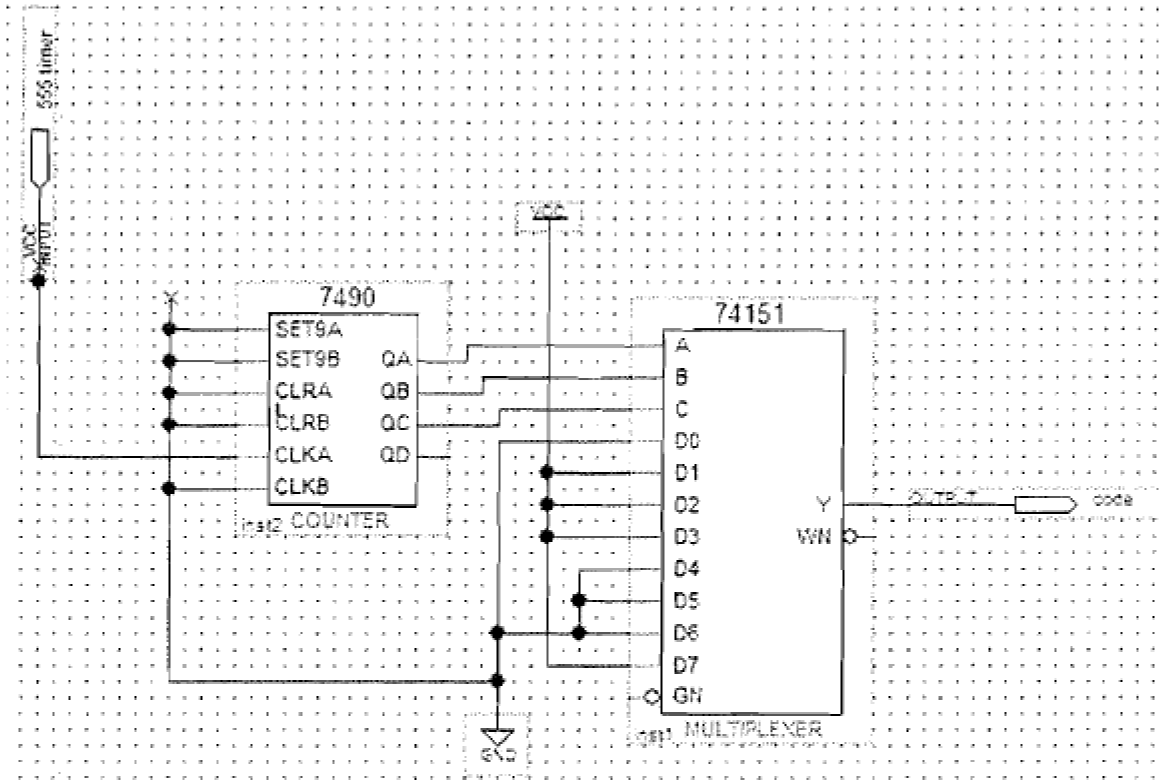

Figure 2.3 Digital circuit

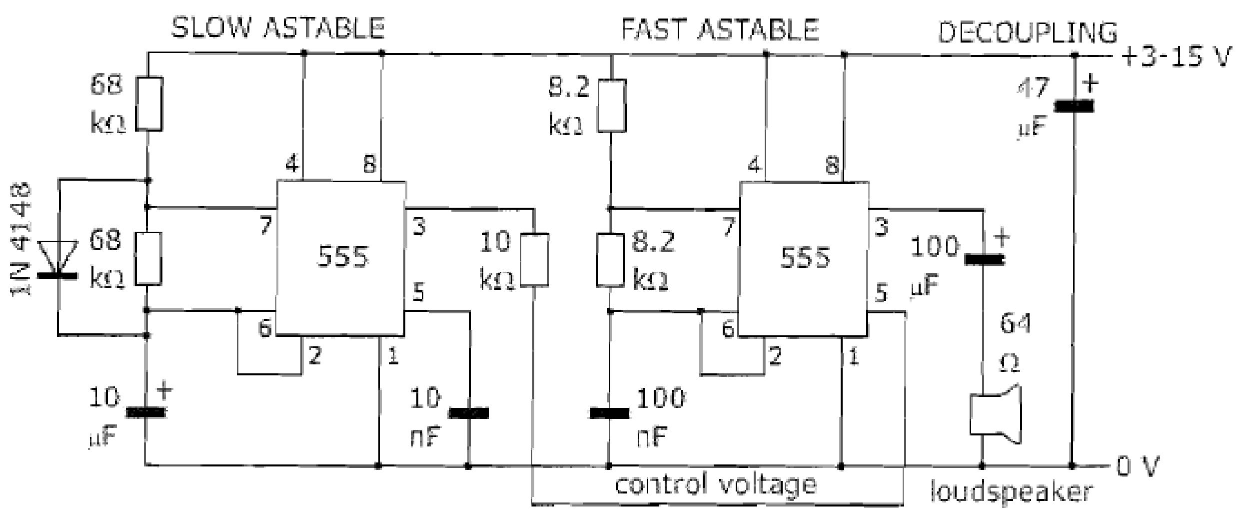

Figure 2.4 Siren circuit diagram

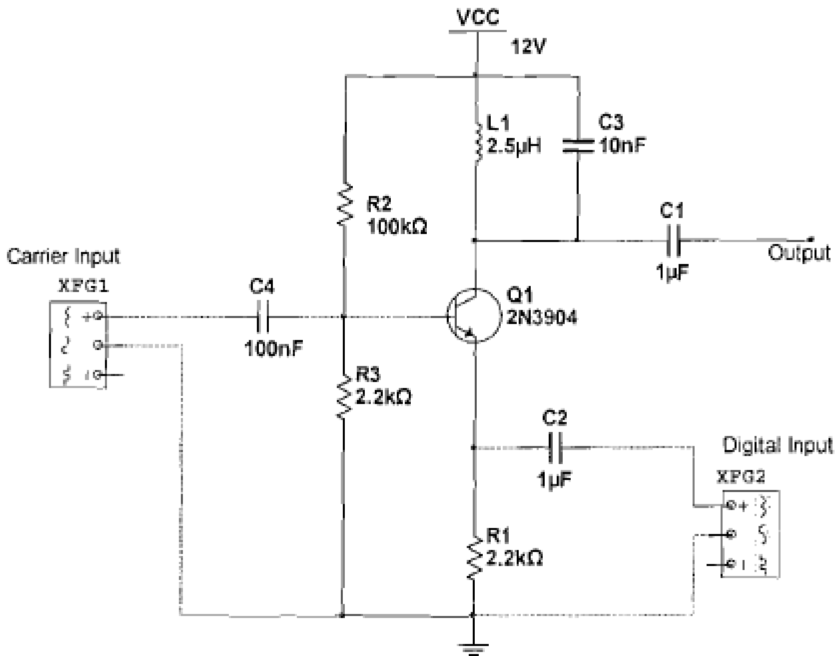

Figure 2.5 Transmitter

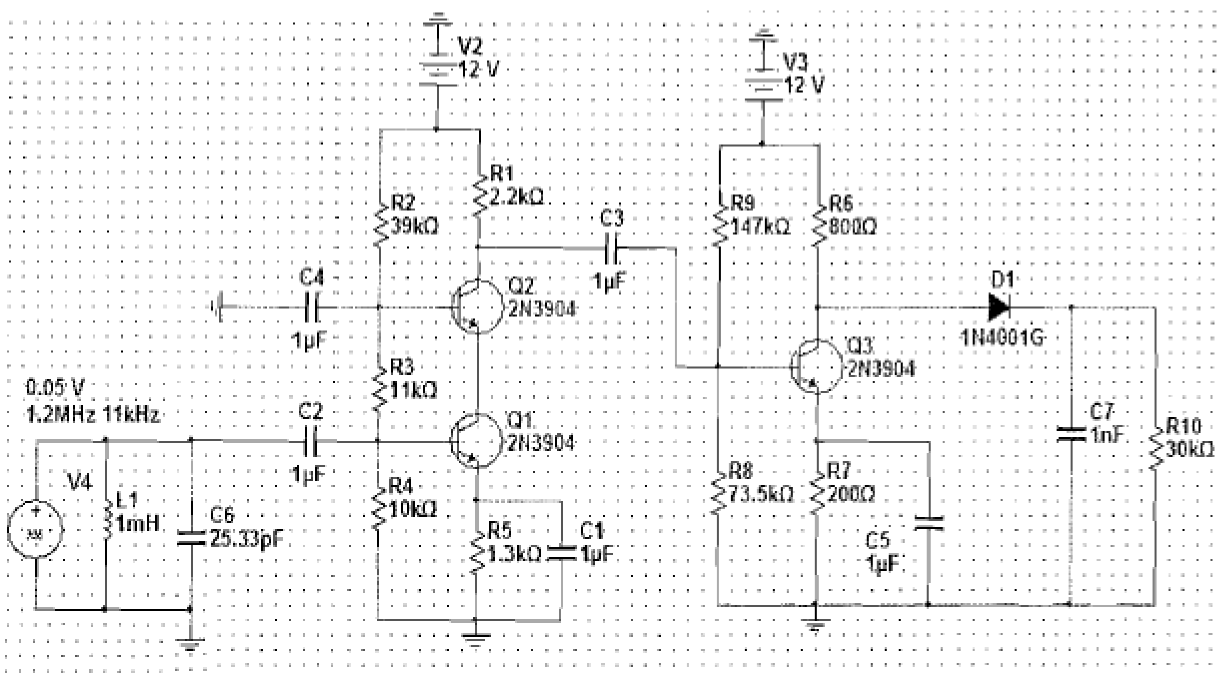

Figure 2.6 Receiver