ECE Learning Circuits

Project Proposal

Group 22: Cody Bainbridge, Isha Garg, Neel Patel
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TA: Prashant Shankar

1. Introduction

1.1 Objective

With the variety of subdisciplines of engineering available to choose from, many high school students around the world wanting to pursue a STEM major have difficulty in deciding which major may be the right choice for them to study. A factor that aids this difficult choice is that many high school curriculums do not offer classes specifically designed to teach engineering topics and/or these schools are limited in their curriculums on how much material they are able to teach. This causes students to not have much exposure to the different majors they can choose from and may lead to a major selection they are not comfortable with. In addition, younger students, such as at the elementary and middle school level, also lack an early showcase of engineering topics which can help them appreciate why certain school subjects like math and science are important to learn. Children argue to teachers why they have to learn this and complain when they will ever use a subject like math in their life. It is important that an effort is made to bring students at any grade level a method for them to get exposed to engineering as it can help them to better appreciate the material they are being taught in school and can also guide them to choose the correct education path should they decide to enter in the STEM field.

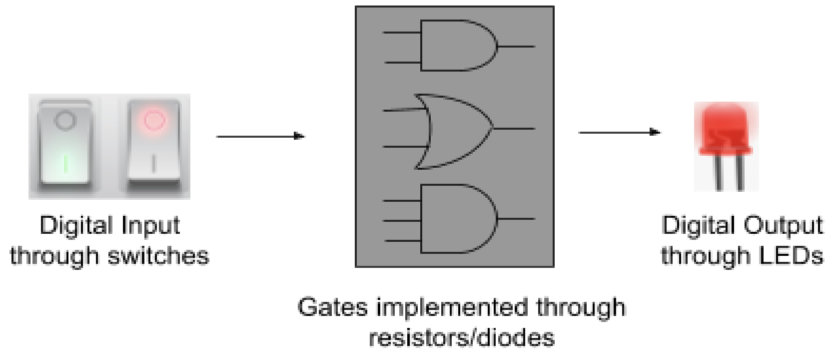
Our purpose is to solve the two cases that are described above. The project will have an emphasis on teaching electrical and computer engineering topics to begin with and in the future, this product can be improved to include teaching more engineering disciplines and other engineering topics. We propose ECE Learning Circuits. Our circuits will help high school students decide to choose an engineering major to get enough background in electrical and computer engineering to consider it as a fit choice for them. Our circuits will also give early exposure to younger children to help them realize the uses for why learning math and science is important and what applications they can bring to the real world outside of the textbook. We will be constructing a series of circuits that teach electrical and computer engineering topics to students of all ages. The circuit will be broken down into a beginner stage, intermediate stage, and an advanced stage. The beginner circuit will teach students about all the logic gates(AND, OR, XOR, NOT, NAND, NOR, and XNOR). The intermediate circuit will teach students about sensor instrumentation and will allow students to build a circuit that has a purpose using these sensors. The advanced circuit will teach students about RF circuits and solve a challenge where they must redesign a circuit in order to fix a frequency issue without changing the original circuit as much as possible.

1.2 Background

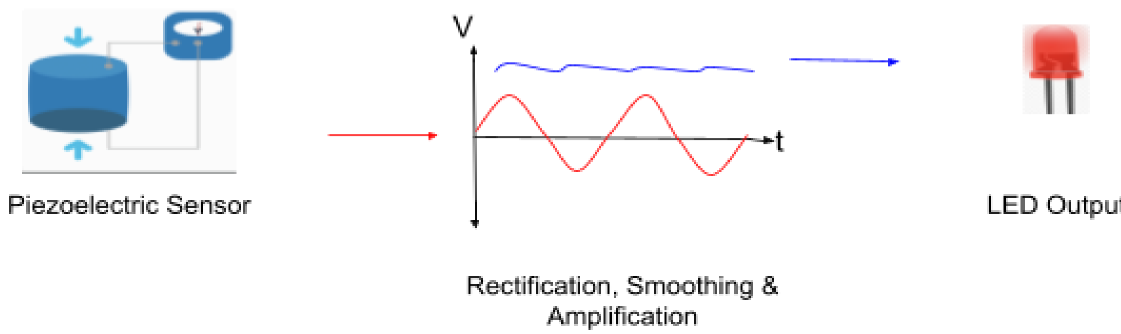
Our approach for these learner circuits differs from other products that already exist in the market. One example would be snap circuits. These are circuits someone can self build onto a protoboard, however, does not end up staying permanent as you can rebuild the circuit again and again. This would be not efficient for larger circuit projects as the wiring can get messy and not be efficient in trying to gain debugging and circuit designing experience. Our solution will be different compared to these types of circuitry learning products as we plan to develop all of our circuits for the beginner and intermediate stages onto a printed circuit board. This will allow for a clear display of the elements and will be made easy for the students to understand and keep track of how each element in the circuit operates. The advanced circuit will require us to design on a protoboard as it is a constraint challenge to rebuild an already made circuit on a protoboard and fix the frequency conflict without changing the circuit as much as possible. Also, when designing the intermediate stage using sensors, our goal is to be able to illustrate a variety of sensors and be able to produce a circuit that has a specific function incorporating all the sensors we will be teaching. This will allow the students to not just learn what a sensor is and how they work, but they will also be able to understand the applications of the sensors in circuit design. Lastly, we will also be allowing the students to get more experience in the soldering process which will allow them to get more hands on experience with the circuit design process as well. To incorporate this, we will be allowing the students to solder circuit elements in for each stage of our project where they will be soldering onto a printed circuit board many elements such as resistors, capacitors, and diodes.

1.3 Physical Design

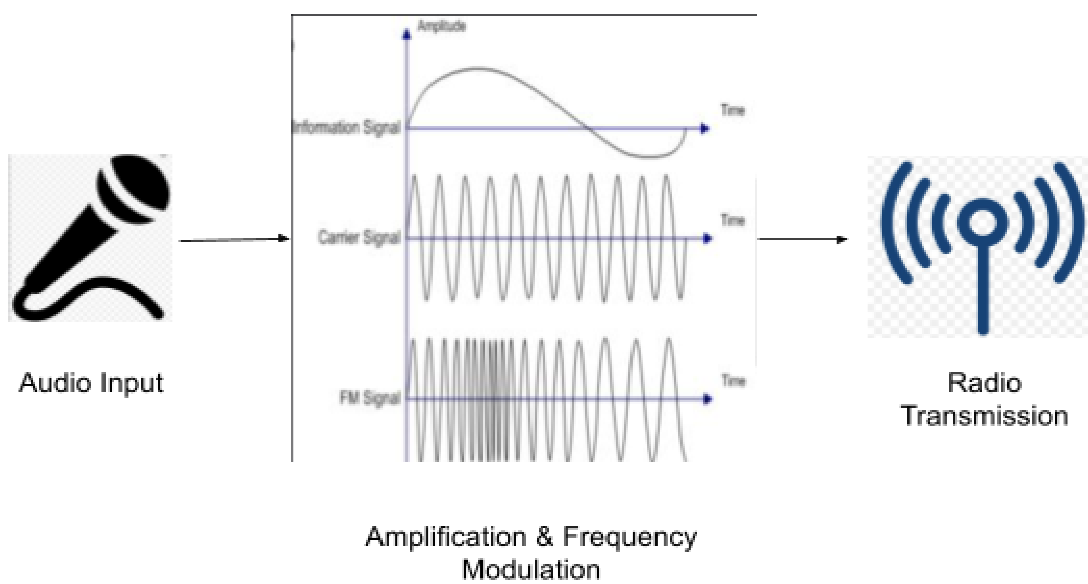
BEGINNER - LOGIC GATES



INTERMEDIATE - SENSORS



ADVANCED - FM TRANSMITTER



1.4 High-Level Requirements

1. We must produce an assistive guide for the beginner circuit stage such that students unfamiliar with logic gates are able to follow the guide to build all of the logic gates. The students should be able to correctly connect and solder the resistors and diodes in the logic circuit to produce the correct logic gate output on their own with the help of the guide. They should also be able to fill in the correct truth tables while putting in their own inputs using switches and record the outputs correspondly from observing the answers to each logic gate computation on the LEDs.

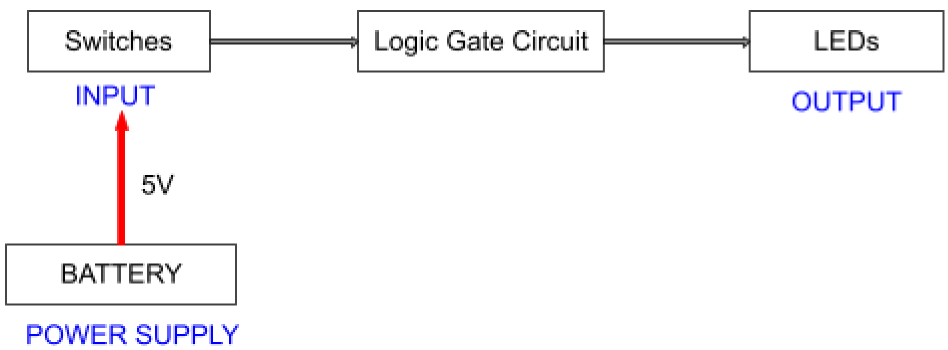
2. The assistive guide that is mentioned above will include a guide for the intermediate circuit. After reading the content we provide, the students should be able to gain more knowledge on the Piezoelectric sensor and its behavior. The students will be able to perform testing by taking measurements of electrical data such as voltage to examine the AC current that is produced when pressure is applied to this sensor. Lastly, the students should also be able to solder capacitors and diodes in order to finish the design of the intermediate circuit with the help of the guide.

3. The advanced circuit will be implemented on a breadboard and some components of the beginner and intermediate circuit will be soldered by students new to building circuits. That can lead to bugs such as accidental connections that could destroy components, especially when left to a novice. Therefore, the circuits, especially the advanced circuit, needs to be easily debuggable and resilient to common errors that one would expect a beginner to make.

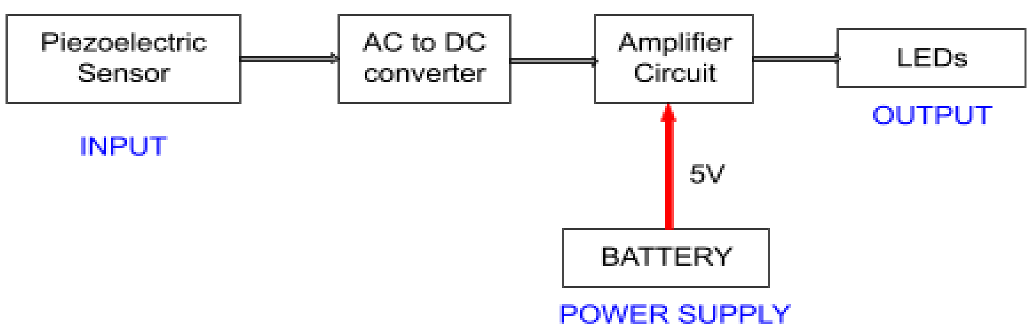
2. Design

2.1 Block Diagram

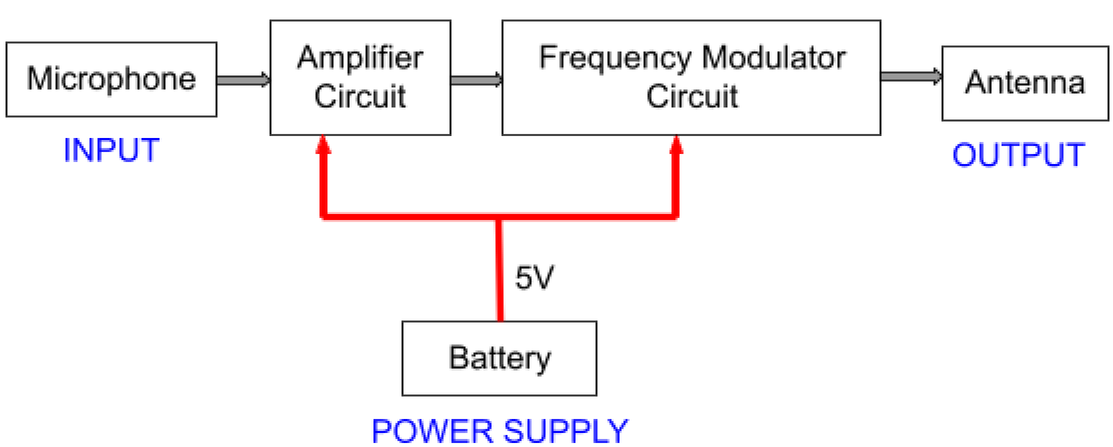
BEGINNER



INTERMEDIATE



ADVANCED



2.2 Functional Overview

2.2.1 Beginner Circuit

Our design begins with the beginner circuit. The beginner circuit will be teaching students about all the logic gates that are used in digital circuit design. More specifically, we will be teaching these gates: AND, OR, XOR, NOT, NAND, NOR, and XNOR. The block diagram above indicates four main components required in order to complete the circuit. The first area of interest is the power supply. We are going to be using a 5 [V] battery in order to supply power for this circuit in our project. Without this power supply, we will not be able to produce an output which will be showcased by lighting up LEDs. The next area of interest is the switches component. Switches are required as it will be the user interface in our circuit and will allow the students to interact with the gates and change the inputs variably. The switch will work as the input for this circuit because we are dealing with two values: logic high (1) and logic low(0). So one switch can take care of both these input choices. We will have at most three switches depending on the logic that the student will be working on. The NOT gate will be implemented with one switch for just one input. The OR, XOR, NAND, NOR, and XNOR will be implemented with two switches for two inputs. Lastly, the AND gate will be implemented using three switches for three inputs. The next area of interest would be the actual logic gate circuit for each of the gates. Our circuits will consist of using diodes and resistors combinations to build each of the logic gates correspondingly. We have decided to use resistors and diodes instead of TTL chips so that the students have a sense of how the logic gates can be built instead of looking at them as black boxes. This component in the block diagram will be dependent on the switches component and LEDs components in order for the student to fully understand the circuit as a whole and gather data to fill in the truth tables correctly. Also, this component would already be connected to the switches and the LEDs on the PCB; the students would only have to solder within the component. The last area of interest are the LEDs and also the output of our circuit. The LEDs are there to display the correct output of the logic gate computation and will light up to indicate a logic high or stay unlit to indicate a logic low. Overall, each component will work with each other to gather the inputs from the students and the students will be able to understand the gate implementation via the logic gate circuits and will finally use the LEDs to correctly fill out the truth tables.

2.2.2 Intermediate Circuit

The next, more complex, part of our design is the intermediate circuit. Through this circuit, we plan to teach students about sensors and how to implement them. Piezoelectric sensors generate an analog voltage when pressure is applied to them proportional to the intensity of the pressure. We will teach the students how to design a circuit that would light an LED using voltage generated by a piezoelectric sensor. We would use the same 5 [V] battery for power supply. The first component in the block diagram of the intermediate circuit consists of piezoelectric sensors that would take the input and generate analog voltage. To be able to use this voltage output, we need to hold it at a constant value. To achieve that, we connect the output from the sensors to an AC to DC converter circuit. For AC to DC conversion, we will implement a bridge rectifier using diodes for full wave rectification; we will add a capacitor in parallel for smoothing. The output from the sensors is generally very small; therefore, to get a significant signal, we would need to connect the AC to DC converter circuit's output to an amplifier circuit. We will implement the amplifier using a BJT, capacitor (to remove DC bias) and resistors. Finally, the amplified signal is outputted through the LEDs. We would have the students solder the diodes and capacitors to the intermediate circuit's PCB to make the bridge rectifier with the capacitor in parallel. We plan to have all the other connections already in place.

2.2.3 Advanced Circuit

The final part of our design, the advanced circuit is a Radio Frequency circuit pitched by Professor Lynford L. Goddard. Through this circuit, we plan to teach students how to design an FM radio transmitter. The power supply is the same 5 [V] battery. The audio input is taken through a microphone. Since the input signal is usually weak, it is sent to the amplifier circuit consisting of BJT, capacitor and resistors, same as in the intermediate circuit. The amplified signal is connected to the frequency modulator circuit that combines this amplified signal with the carrier frequency at which the signal has to be transmitted; it consists of a BJT and a tank circuit (tunable capacitor and inductor in parallel). The tank circuit generates the carrier signal. The amplified signal is connected to the base of the BJT. Changes in the amplified audio signal cause changes in the junction capacitance of the BJT, leading to modulations in the frequency of the carrier signal. The modulated carrier signal is connected to the antenna that transmits this signal. For this circuit, we plan to use a breadboard and would have the students assemble the entire circuit.

2.3 Block Requirements

2.3.1 Power Supply

A continuous supply of 5[V] through a battery is crucial to the functioning of all the three circuits - beginners, intermediate and advanced. In the beginners circuit, we need to supply power to the switches for them to send a High/Low signal to the Logic Gate Circuit. In the intermediate and advanced circuits, we need a voltage supply to bias the BJTs to set their DC Operating Points. In the advanced circuit, we also need to supply power to the tank circuit that would store energy and generate the carrier wave.

2.3.2 Beginner Circuit

Switches: The switches in the beginners circuit will take the user input of 1 or 0 that would be sent to and processed in the logic gate circuit.

Logic Gate Circuit: This circuit is the main component of the beginners circuit. This will be implemented using resistors and diodes. If the students solder the components correctly, the correct output of the logic gate computation will be displayed on the LEDs.

LED: LED must light up if the logic gate circuit's output is 1 or turn off if its output is 0.

2.3.3 Intermediate Circuit

Piezoelectric Sensor: This sensor should sense the pressure applied to it and produce an analog voltage that will be used to light an LED.

AC to DC converter: Piezoelectric sensors produce an AC voltage at a very high frequency. To be able to see the LED light up, we need to convert the signal to DC. The AC to DC converter should take the piezoelectric sensor's input and do a full wave rectification with smoothing on it to hold the input signal at a constant value.

Amplifier Circuit: The maximum voltage the piezoelectric sensors we would use can generate is 5V. This means that when maximum acceptable pressure of the sensor is not applied, it may not be able to generate enough voltage to light up the LED. Therefore, we would have to amplify the voltage generated by the sensor through this circuit. This circuit should amplify the current from the AC to DC converter by at least a gain value of 110.

LEDs: LED is connected to the amplifier circuit. If the students build the AC to DC converter and amplifier circuit correctly, the LED should light up when pressure is applied to the sensor and should stay lit till the sensor is vibrating.

2.3.4 Advanced Circuit

Microphone: Microphone should take a sound input that would be converted into an electrical signal that would modulate the frequency of the carrier radio wave.

Amplifier Circuit: The output of the microphone is generally weak and needs to be amplified before it can be used. This amplifier circuit should amplify the output of the microphone by at least a gain value of 110.

Frequency Modulator Circuit: This circuit should generate the carrier signal that will be transmitted. This circuit should also modulate the frequency of the carrier wave according to the frequency of the message signal received from the amplifier circuit which is proportional to the sound input.

Antenna: The antenna should convert the carrier signal to radio wave and transmit it.

2.4 Risk Analysis

The beginner and intermediate circuits will come with lower risk for the design of our project. To reduce the risk, we will design the circuit we are planning to teach for each stage on a breadboard and do testing to ensure that the circuit is behaving as intended. We will only move to designing the final circuit on eagle software after we ensure that our circuits are behaving as intended on the protoboard. This will reduce the risks for these two stages of our project as having a working design on eagle will allow the ECE shop to correctly implement what we need onto the printed board circuits.

The greatest risk in order to successfully complete our project will come from the design steps we take in fixing the Antenna output of Professor Goddard's RF circuit. There will be many risk factors involved for this stage that can cause us to have an unfinished design. The first risk factor is that we are constrained to not be able to change the circuit too much in order to fix the issue. We will only be able to move around a few circuit pieces and or add a few circuit pieces to the original design. This may lead to an issue because the RF circuit has many sub-circuits in order to be able to output the correct radio frequency audio. If we are not careful in examining the device characteristics and outputs for these sub circuits, then it is likely that they may not work as intended when we add or subtract elements to the original circuit. For example, if we add more capacitors in the frequency modulation circuit or more transistors in the amplifier circuit, then we are potentially altering the frequency values and gain values of each sub circuit respectively. This can cause us to produce unwanted noise or introduce more interference or extra noise at the output antenna. Another risk factor involved in fixing the antenna issue is that we will have difficulty in correctly impedance matching the antenna to the correct impedance such that we are able to cancel out the unwanted noise and avoid any leakage of excess power into the circuit. If we do not find a proper impedance match, then we will continue to hear this unwanted noise each time we send in an audio input into the microphone.

Overall, while designing a solution to our advanced circuit, we can potentially increase the risk in an unsuccessful circuit as we make changes to the circuit by adding or removing circuit elements. The risk will also be increased as we debug and figure out ways for the antenna to successfully impedance matched to the correct impedance in order to get the correct audio output from the antenna and thus solving the unwanted noise issue as the unwanted frequencies in the circuit will be attenuated.

3. Ethics and Safety

We must consider safety precautions when designing each of circuits from the beginner stage to the advanced stage. While we may be designing circuits, the actual circuitry will be done for us by the ECE electronics shop based off of our eagle design that we send to them. However, some circuits will be implemented for testing on a protoboard. This leads to the first ethical code we must follow: “Avoid harm”. The ACM code of ethics states, “unjustified physical or mental injury, unjustified destruction or disclosure of information, and unjustified damage to property, reputation, and the environment”[1]. In order to maintain this code, we will be using an adequate power supply of no more than 5 [V] and making sure that proper connections are made such that we don't fry the board. This can lead to harm as the user can touch the circuit board not knowing it is burning and can burn themself. We will also examine the data sheets for all the circuit elements we use such as TTL chips to make sure that the correct data is transferred properly and right connections are being made. Overall, along with making sure that the design is neat and making sure to not go over this power supply, there are no other areas in our design that may lead to harm. Another ethical code that we must follow is that we must “respect each other's ideas, be fair, and make sure to be trustworthy” [1]. This is important because for a project where we are not in person all the time, we need to have strong communication with each other. This will allow us to solve problems quicker and also makes sure that everyone is getting a chance to contribute to the project. One way to meet this code is to schedule additional meetings throughout the week using zoom in order to discuss everyone’s ideas and also make sure that everyone in the group is at the same pace contributing and finishing what they need to have done before the meeting. Lastly, we need to consider the safety for the public and or people who will be using our product. The ACM code of ethics continues to say, “ensure that the public good is the central concern during all professional computing work” [1]. This is important because we need to make sure that the users of our product, when building the circuits, are following correct procedures in the design process. To solve this and ensure the safety of the public, we will be creating a user guide that will illustrate and detail the procedure of making and testing the circuit from start to finish. The user guide will inform the user as well about safety hazards so that care is taken when making our learner circuits.

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