THE ELECTRONICS OF COMMUNICATIONS

Neal Amin, Arjun Chandrasekaran, Joanne Dekis, Benjamin Herschenfeld,
Tim Hwang, Kevin Kim, Michael Lurie, Alyssa Master,
Ravi Patel, Michael Tycon, Chen Zhang

Advisor: Brian Holton
Assistant: Karl Strohmaier

ABSTRACT

Several aspects of physics and electronics relating to communication technology were studied, enabling achievement of several goals. A speaker and microphone device was constructed which enabled the measurement of the delay between transmission and reception of an audio-electronic signal being audibly sent and received. This was used to measure the speed of sound within 12%. A similar device was constructed and used to calculate the speed of light within 5%. The physics concept of total internal reflection was used to transmit an electrical signal over an optical medium.

INTRODUCTION

Telecommunications is the science of long distance communication via electronic impulse transmissions [1]. Telecommunications is an essential part of modern life. Whether in telephones, radio, television, and the internet, it is an omnipresent part of our daily experience. Our team project examined how telecommunications works, delving into the basics of the transfer of electronic impulses.

The first advancement in the field of telecommunication was the telegraph [2], invented by Samuel von Somerling in 1809, and later improved by Samuel F. Morse in 1840. Telecommunications evolved further with the development of the telephone in 1861 [2], and later with the appearance of radio. Television was another breakthrough, as images were transferred for the first time.

Fiberoptics are the newest revolution in telecommunications technology, and are probably most identified with modern telecommunications. They are basically long flexible glass rods that are used to transmit images or sound, a practice that was pioneered by Heinrich Lamm in 1930 [3].

In team project 2: physics and electronics, we demonstrated the simplicity and efficiency of the communications infrastructure. However, it was necessary for us to start with the basics and work our way up to more complicated configurations. We started off by learning the essentials of circuitry such as voltage and current. We then explored the world of transmission and reception circuits. We learned how the basic physics concepts can be applied in complex situations, acquired the practical skills necessary to execute a design plan by hand, and discovered how it is possible to make use of advanced circuitry components such as pre-made integrated circuits (like the 555 and 386) to achieve a desired function by manipulating inputs in ways that do not require complete knowledge of the components' inner workings. We also learned to use oscillators to make light emitting diodes blink and speakers produce obnoxious noises.

Two supplements to our project were experimentally finding the speed of light and the speed of sound. Our knowledge of waves allowed us to take advantage of phase shifts to measure these.

Our main project goal was to build a telecommunications device that would allow us to transmit sound over fiber optic cable and to have that sound be clearly received on the other end by a speaker. In order to do this it was necessary for several different and sometimes intricate circuits to be set up and connected. After lots of hard work, our team was successful in creating this telecommunications apparatus.

We learned the basics behind the telecommunications industry and the difficulties that can arise even with simple circuits such as ours.

INTRODUCTION OF BASIC COMPONENTS

As with any technical field, electronics has its own specialized terminology for describing its most commonly used components. During the course of the project, these smaller devices formed the basis for building and testing more complex ones. The ones that appear within the scope of this paper are as follows:

<u>Breadboard</u>
A breadboard is a plastic grid of small holes, arranged in columns of five, column after the other in a row of columns. Those rows of columns of five are themselves in rows. At the bottom of each hole is conductive material connected to the conductive material at the bottoms of the other four holes in that hole's column. Stripped wire ends and conductive component leads can easily be inserted into these holes, allowing for a circuit to be built in a quick, temporary, and easily alterable manner. All the circuits constructed in this project were constructed on breadboards.

<u>Resistor</u>
A resistor dissipated energy, usually as heat, when current flows through it. Its simplest use is to check current flow through a certain path in a circuit. Resistors vary in the degree to which they dissipate energy. Their capacity to do this is called resistance and is defined by current = voltage/resistance. In many circuits making use of pre-made, integrated circuits (discussed below) the resistance of a resistor set up in conjunction with the integrated circuit (IC) serves as an input parameter to control the function of the IC, not merely to lower current. Capacitors (discussed below) are also used as input parameters in this way.

<u>Capacitor</u>
Capacitors consist of two conducting plates placed near each other. They can store electric charge for later discharge. Direct current through a capacitor will charge the capacitor for a short time, and then stop flowing. Alternating current, because of the changing electric fields it

generates, can “flow” across a capacitor. A capacitor’s ability to store charge is called capacitance and is defined by capacitance=charged stored/voltage.

<u>Light Emitting Diode (LED)</u>
Light-emitting diodes are small devices that light up when current flows through them. They are used in gadgets such as remote controls, cell phones, stereos, etc. They are different from incandescent bulbs in two ways. First, a light bulb converts energy into a whole range of frequencies of light and also converts a significant portion to heat. This is because the light is created by current flowing through a metallic solid whose structure allows for many light-emitting-electron-energy-level-transitions. An LED allows for only one kind of electron-energy-level-transition in the light-emitting-material, and so emits only one frequency of light. Related to this is the fact that an LED has an optimal voltage (power) above which it can blow out very easily. Second, unlike a light bulb, an LED is constructed in such a way so that current can flow through it in one direction.

<u>Potentiometer</u>
The potentiometer is a resistor of variable resistance. It has three terminals; a fixed resistance is found between two of the terminals and the third terminal slides along the fixed resistor. Often, it is used to control the volume in an audio amplifier.

<u>Digital Multimeter (DMM)</u>
The DMM is an instrument that is able to measure voltage, current, and resistance in a circuit, or across circuit components and displays its measurements on a digital display.

<u>Integrated Circuit (IC)</u>
An integrated circuit is a pre-made circuit shrunk down to small size and put on a chip. IC’s save circuit makers time by serving common purposes like amplifying a signal which would otherwise have to be done by a new circuit built from scratch every time.

<u>Oscilloscope</u>
The oscilloscope presents a visualization of ac and dc signals while a circuit is in action. It uses an electron beam to strike a screen so that a graph can be displayed of voltage versus time. The oscilloscope allows for measures such as peak-to-peak voltage, dc offset, and period.

<u>Fiberoptic</u>
Fiberoptics are very thin glass fibers that allow for contained light transmission with little loss between ends. The light is contained because of the property of total internal reflection as long as no sharp angles are made in the fiber’s path.

SIMPLE CONSTRUCTIONS

With an understanding of the components at our disposal, combining them into four types of devices was the next logical progression in preparation for constructing a fiber-optic communication device. To gain familiarity with the 555 integrated circuit, the first task was to build a circuit in which a light emitting diode (LED) was made to blink at a specific frequency. Secondly, the LED was replaced with a speaker set to emit a noise at the same frequency. To accomplish this necessitated the use of an amplifier. After this circuit was optimized, a microphone was added making a simple public announcement system. Finally, in preparation for the fiber optic device, the original blinking LED system was revisited and replaced with an infrared LED coupled to a fiber-optic wire.

The centerpiece of the blinking LED circuit is the 555 timer which is capable of producing oscillating or single time delayed pulses. When set to oscillate, the 555 is in the astable mode (a mode that creates a continuous oscillation as opposed to a one-shot pulse) and the frequency of oscillation is controlled by a capacitor and two resistors. In the monostable setting, the 555 is controlled by a capacitor and one resistor. Additionally, the 555 can handle a current flow of up to 200 mA, making it harder to burn-out. For this device, the 555 was used in the astable mode and frequency of oscillation was regulated by changing either of the resistors or the capacitor according to the formula $F = 1.44/ (R_1 + 2R_2)\ C$. For this example, the LED was set to blink at 0.716 Hz. The wiring diagram for the circuit (see Fig. 1) is shown below across the eight pins of the 555. A 12 volt power supply was used, and pin 5 is not involved in any connections.

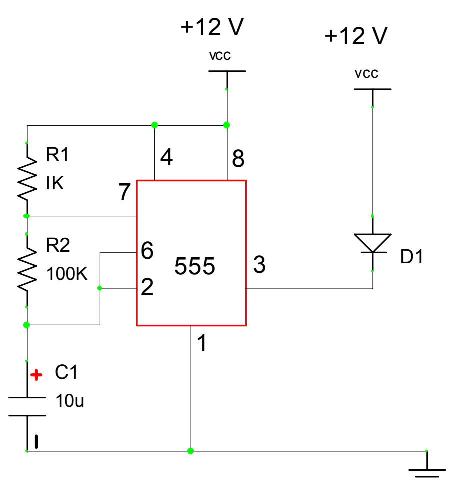

Figure 1: The Basic 555-LED Circuit

As shown above, the capacitor discharges across pin 7 through the 100K Ω resistor switching the transistor to the off position. The capacitor then starts to charge until the voltage reaches a certain point resetting the output as the capacitor discharges again. In the circuit, pin 1 connects to the ground while 4 and 8 connect to the power supply. Pin 6 is connected to pin 2 which is connected to the positive end of the capacitor. Pin 4 runs to R1 with pin 7 attached to the negative lead of R1 and the positive lead of R2. The negative lead of R2 is attached to pin 2. Finally, pin 3, the output, connects to the negative lead of the LED with the positive terminus connecting to the power supply.

After the LED was made to blink reliably, a photoresistor was added to the circuit in place of R_1. The photoresistor contains cadmium sulfide whose resistance varies with light intensity, allowing the LED to blink in response to a change in light. The resistance in response to light is given by the equation $R = (R_o/I_o)\ I^{-k}$, where R_o/I_o and K are constants and I is light intensity.

After making these modifications to the oscillating circuit, the LED was replaced with a speaker. While the device worked, it became desirable to amplify the signal. Accordingly an amplifier was constructed. The amplifier circuit used the previously described 555 circuit to provide the pulse and the amplifier itself is based upon the LM 386 microchip. In an amplifying microchip, the input is directed through the negative terminus of the chip, and the positive terminus connects to the ground. In the LM 386 the input is pin 3, the positive is pin 6, and pin 5 is the output. As the amplifier tries to bring the voltage at pin 3 to match that of pin 6 at zero volts, the output is increased according to the formula $V_{out} = -V_{in}R_2/R_1$. Additionally, a potentiometer (POT) was used to control the voltage and hence the volume. The POT is a device that contains two resistors and has three leads- an input, output, and ground. By manually turning the knob of the POT, the voltage across the output and ground can be varied according to the equation $V' = VR_2/(R_1 + R_2)$. In this amplification device, the 555 circuit output (pin 3) is wired to the input of the POT, with the POT output connecting to pin 3 of the 386. The 220 uF capacitor was used to sink the DC current of the 386 and thereby reduce the "noise" of the circuit and clean up the sound. This circuit (see Fig. 2) provides 20 times amplification.

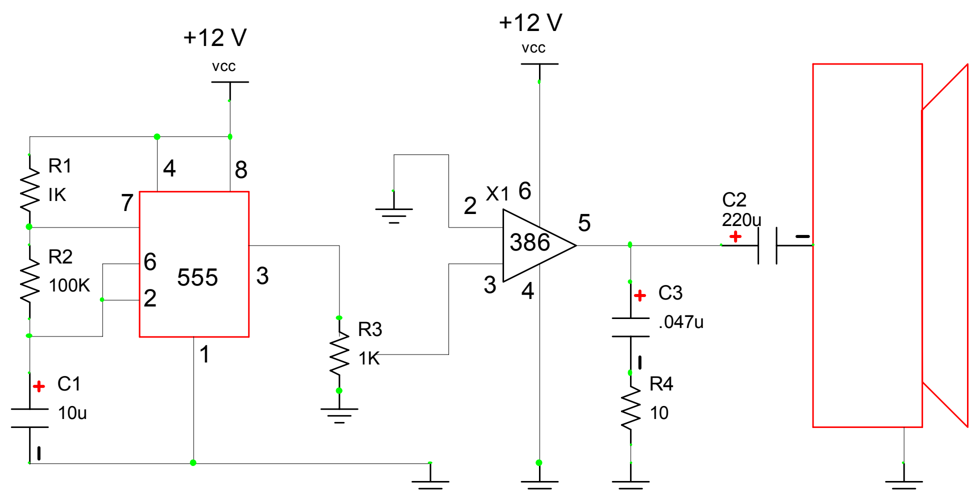

Figure 2: The 555-Speaker Circuit

With the amplifier constructed, the 555 pulse generator was removed and replaced with a microphone. The negative terminus of the microphone was connected to the ground, as was the grounding tab of the microphone (this seems obvious but took awhile to figure out). The positive terminus connected to the output of the POT, while the positive lead of the POT was connected to the 12 volt power supply. To further enhance the amplification, a 10 uF capacitor was installed between pins 7 and 8, boosting amplification to 200 times.

Once the microphone and amplifier system was finished, the sender unit for the fiber-optic communication device was almost complete. The final modification was replacing the speaker output with an infrared LED connected to a fiber-optic cable. The LED was installed in place of the speaker, with the positive lead connected to the 5 pin of the 386. To prevent the LED from burning out a resistor of approximately 486 Ω was installed upstream of the LED. This is a standard procedure used throughout the construction of all our devices to protect the LEDs.

Testing the infrared LED sending unit became the next challenge, since the LED was not in the visible spectrum. Two methods were devised for detecting if the unit did indeed function. The first test involved measuring the voltage across the LED leads with a multimeter. If the LED was emitting a signal, the voltage would waver. Due to the minimal resistance of the LED this technique proved unreliable and the oscilloscopes were employed to detect any output frequencies. To provide a reliable pulse and not be required to rely on the microphones, a previously constructed 555 circuit was installed (obviously the microphone would be re-installed in the actual sender unit since voice transmission was our ultimate goal). The stage was now set for the design and construction of the receiver unit.

MEASURING THE SPEED OF SOUND

Materials and Methods

A 555 chip is set to emit a signal that oscillates at 1 kHz. The signal from the 555 goes through a 386 amplifier and is sent to an oscilloscope and a speaker. A microphone receives the sound from the speaker and converts it back in to an electrical signal, which is amplified by another 386. The amplified signal goes to the same oscilloscope. The inputs to the oscilloscope are put on the same time scale. The input waveform will occur slightly sooner than the output waveform on the oscilloscope. The difference between the two is known as the phase shift (see fig. 3).

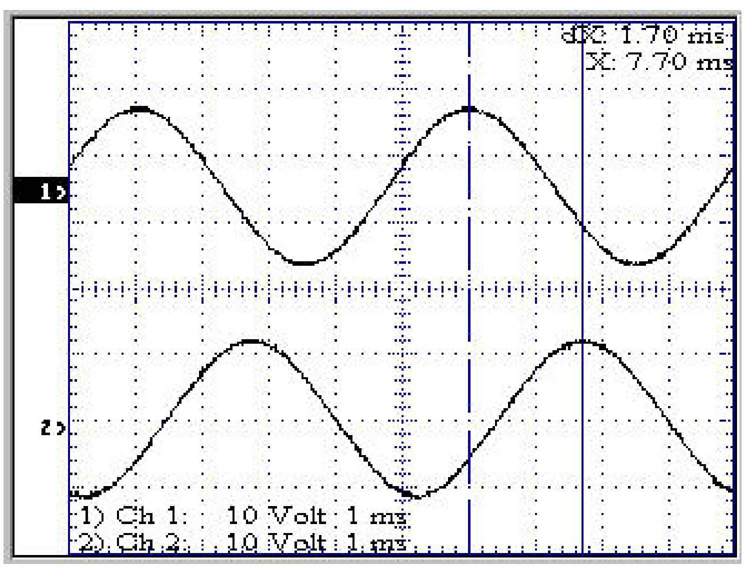

Figure 3: Sample oscilloscope readout of two sine waves of equal amplitude and frequency but with an obvious phase shift [4].

The phase shift in this experiment has two causes: delay due to the speed of sound and delay due to electronic components. The intention of this experiment is to determine the speed of sound, so it is necessary to distinguish between the two causes of the phase shift.

Since the electronic delay does not change when the distance between the speaker and microphone changes, the two causes of delays can be distinguished from each other by varying the distance between the speaker and the microphone. This effectively eliminates the electronic delay and allows the speed of sound to be calculated.

The graph of the distance between the speaker and microphone versus the phase shift between the signals coming out of the 386's (see Fig. 4) has a slope of the speed of sound and an intercept reflecting the delay caused by the electronic equipment.

Data and Observations

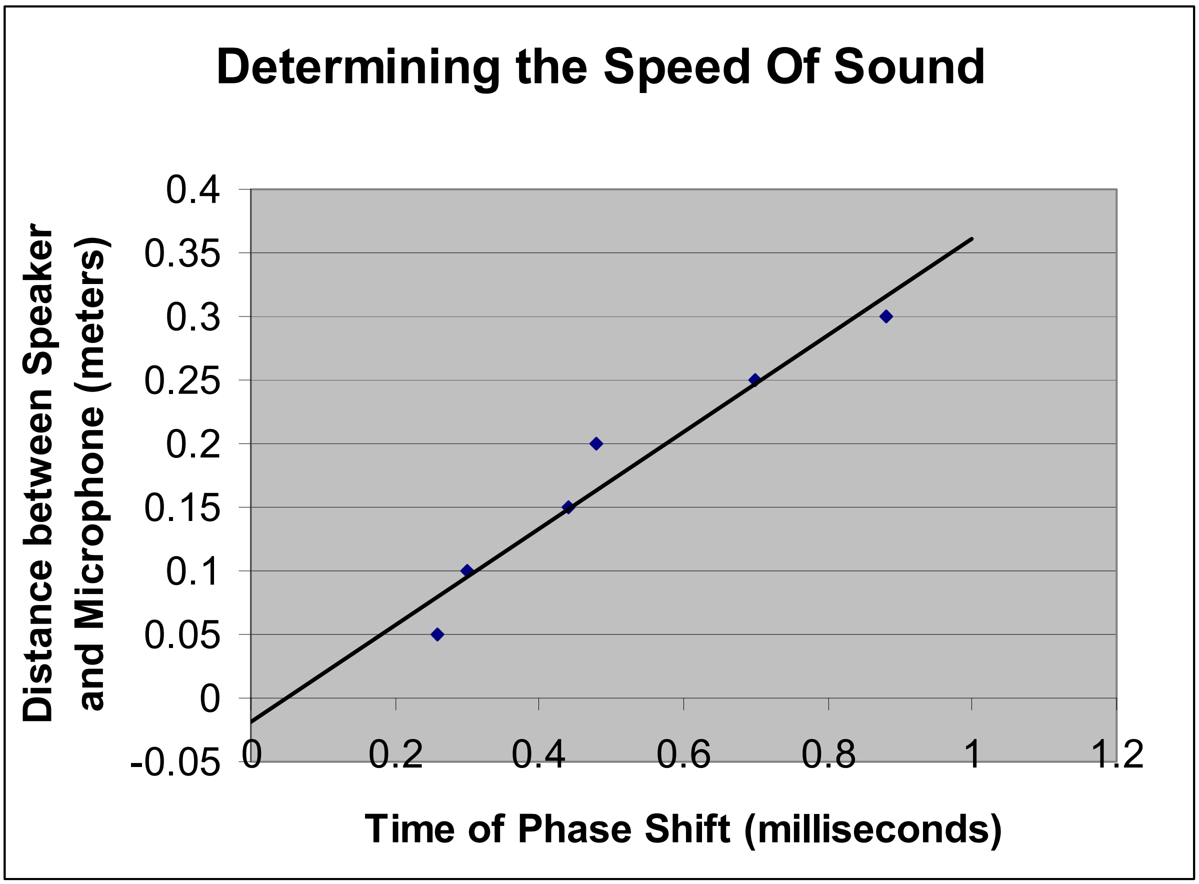

Figure 4: Graph of distance between speaker and microphone versus phase shift between input and output

The equation for the best-fit line is distance (in m) = 0.38m/ms * time (in ms) - 0.019m. The correlation coefficient is .971 and the variance is .943. The observed value for the speed of sound is 380 m/s. The actual value of the speed of sound is 340 m/s, which yields an 11.8% error.

SPEED OF LIGHT

After measuring the speed of sound, our group decided to conduct a slightly more complex experiment using the same fundamental ideas. Using an oscilloscope, a speed of light apparatus, and optical fiber, we set out to determine the speed of light (Fig. 5). Although it may seem near impossible to measure something that moves at three hundred million meters per second, we ended up with fairly accurate data. In simple terms, the experiment was focused around measuring the difference in the time it took for a pulse of light to travel through a short optical fiber and a long optical fiber. Although a stop watch can accurately measure a single second, the oscilloscope we used could accurately measure in nanoseconds (10^{-9} of a second), yielding the required precision.

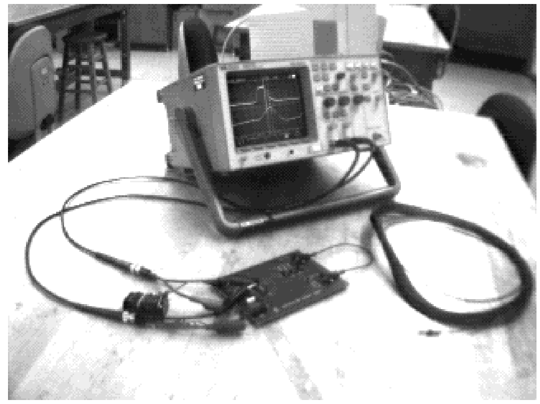

Figure 5: A set up similar to this was used to measure the speed of light [5]

The speed of light apparatus consisted of a transmitter and a receiver. The transmitter regulated the pulses of light sent out by an optical laser while the receiver consisted of a sensor that could sense when the light reached it. A small length of optical fiber was used to connect the two ends of the speed of light apparatus. Both the transmitter and the receiver were hooked up to the oscilloscope through two separate inputs which were displayed on the screen at the same time. The transmitter signal showed the pulse of light in the form of an irregular wave while the receiver showed the pulse of light as a slightly distorted and less intense version of the same wave (this was due to the imperfections of the electronics in the circuit). Another difference between the two waves displayed on the oscilloscope was that the receiver wave was slightly delayed and therefore shifted to the right (the delay was caused by the circuitry and the very small time it took for light to travel through the optical fiber). We aligned the two waves on the oscilloscope so that both overlapped as closely as possible. This was done to clear out all the errors caused by outside factors.

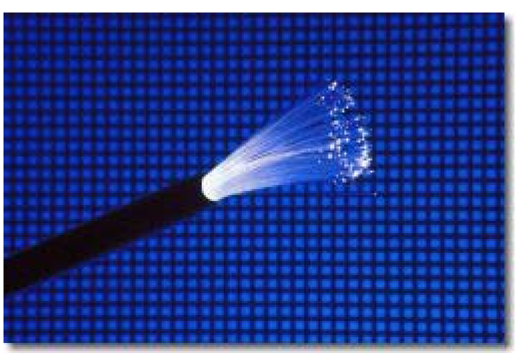

Figure 6: An example of fiber optic cable [6]

We replaced the small length of optical fiber (see Fig. 6) with a much longer one (nearly 20 meters). Without adjusting anything on the oscilloscope, we observed the shift in the waves once again. Because the optical fiber was longer than before, it took slightly longer for the light to travel through (about 100 nanoseconds). Using simple algebra, we calculated the distance the light traveled per second and came up with a value of 190 million meters per second.

At first glance, this data seemed to have an error of around thirty percent, but light travels slower in certain media compared to others. This difference in the speed of light is expressed in index of refractions. In a complete vacuum, the index of refraction is one but in an optical fiber, the index number is 1.5. This means the speed of light in the glass fiber is two thirds the speed of light in a complete vacuum. In actuality, light travels at 200 million meters per second in the fiber which is not very far off from the experimental value of 190 million meters per second. The five percent error that we calculated could have come from various sources; the index of refraction number that we researched online was for optical fiber in general and may not have been the exact fiber that we used. Because the oscilloscope is an analog measurement source, human error in reading the scope could have accounted for more error as well.

FIBER OPTIC SENDER-RECIEVER DEVICE ARCHITECHTURE AND CONSTRUCTION

The ability to construct this variety of unique, relatively simple components naturally lends itself to a consideration of how they can be integrated to produce a circuit of greater complexity which will exhibit properties of technical interest due to their application to real world situations. Taking into consideration the fact that an exploration of communication formed the basis upon which the entire enterprise and its smaller projects were completed, it is not surprising that the group set out to create a scheme involving the use of light as a medium of information transfer. To be precise, the goal was to construct two units. The first would act as a sender, which would translate sound waves into pulses of light. The second would play the role of receiver, taking pulses of light and translating them back into sound. Connecting these two would be a length of fiber optic material that would function for the light as a directed "pipe" between the devices.

The light that we used was in the visible and infrared spectra of electromagnetic radiation, and in the final set-up it was produced by an infrared fiber-optic LED. Still, it is important to remember that this set-up could also have used radiation of longer wavelength, radio waves, for example. With that in mind, an apt analog for the device is readily apparent. The device functions very much like both ends of an AM radio set-up comprising a microphone, amplifiers, transmission towers, receivers, amplifiers, and speakers. The difference lies in the nature of transmission: powerful and omnidirectinal radio signals designed to allow reception by anyone over a whole area versus low energy but highly directed and contained shorter wavelength signals sent along a specific path directed by a fiber optic cable. Despite that difference, the overall similarity between the structures of the two communication systems allows the analogy to the familiar AM radio to serve instructively to remind the reader of the function of each component within the context of the device as its specifics are being discussed. The following (Fig. 7) illustrates the similarity between the architectures of the two systems as discussed above. More technical schematic diagrams of the sender and receiver can be seen in Figures 9 and 10.

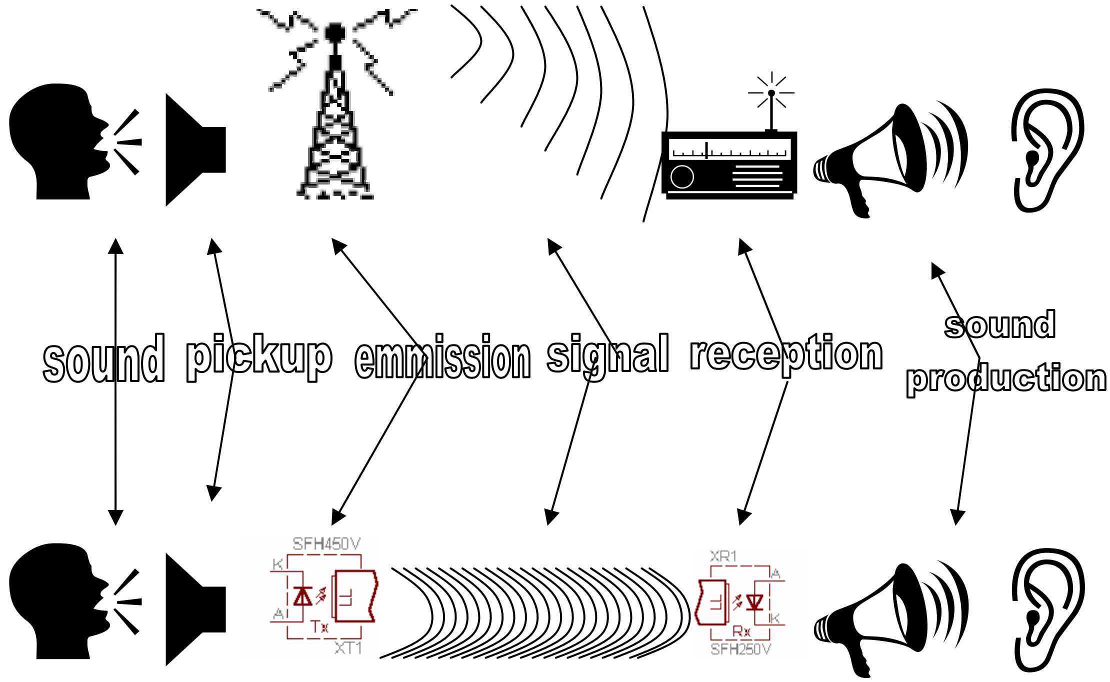

Figure 7: A visual representation of the similarities which link AM radio and the fiber optic communicator.

Construction Considerations

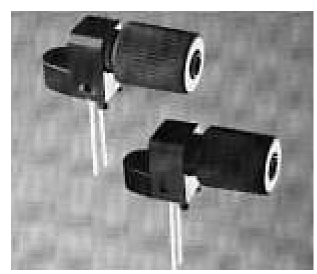

Figure 8: An example of the type of fiber-optic LED used during the project [7].

As far as the sender was concerned, the group had already produced one. By replacing the speaker in the PA circuit with an LED, it had been established how the amplitude of light emission could be modulated to represent sound. (The fact that the amplitude is being modulated is the reason that the above analogy uses AM radio specifically.) Needless to say, the LED produced light and the system could have made use of that light as a signal, possibly along with something like a photoresistor as a receptor, which had been done previously in one of the earlier single tone producing circuits. However, a major disadvantage of that approach would have been that the light generated was highly diffuse in nature. A better alternative, one that effectively avoided this problem, was the use of a fiber optic emitter (Fig. 7) substituted in place of the LED. Essentially, the emitter consisted of a plastic housing with a single aperture. The aperture was in turn fitted with a cinch clamp which allowed for the end of a fiber optic cable to be fitted tightly into the device and emit a concentrated source of infrared light necessary for the production of a strong signal. With this adjustment to our sending apparatus, the group began work on the construction of a viable receiver and amplifier to complete the communicator. The final design schematic (Fig. 9) of the sender was as follows:

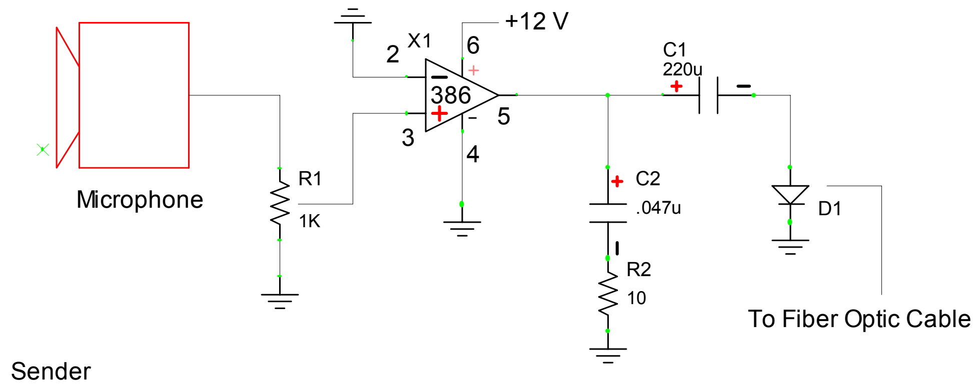

Figure 9: A schematic diagram depicting the construction of the sending component of the fiber optic communicator.

Upon considering the problem of the receiver, one might be initially tempted to think that the solution would be apparent to the casual observer. This is to say, that the receiver could be simply constructed by connecting a fiber optic receiver to the input of a 386 amplifier and subsequently attaching it to a speaker- a reversal of the emitter circuit. Such a circuit would, in theory, take in the relatively faint signals of the sender, magnify them, and turn them into current that could be sent to a speaker and then outputted as audible sound. However, there are a series of technical issues associated with attempting to use a 386 in signal amplification, particularly in situations in which slight distortions can cause a loss of important information. Unsurprisingly, transmission of human speech is one of those situations. First and foremost, the 386, while being a reliable and highly effective amplifier, it is not particularly sensitive to very low amplitude signals. Additionally, subtle aspects of such signals that are important in the reproduction of human voice could easily be lost. Like many similar amplifiers, the chip often produces a large amount of amplified background noise. If the noise is not much lower in amplitude than the signal, it is detrimental to the ultimate quality of the reproduced sound. Finally, given the weakness of the signal, the 386 would not be able to produce a great enough amplification to make it clearly audible through the speaker. To remedy this problem, it was necessary to find a component (or series of components) which would facilitate not only a sensitive amplification of the signal, but also a great enough intensification to make the received signal understandable.

The solution was to be found in a single integrated circuit, the 081. Connected to the circuit as the initial receiver of the signals from the sender apparatus, the chip would act as a pre-amplifier, setting up the signal in such a way so that by the time it reached the 386 it would be appropriately amplified and prepared to become understandable sound. The 081 was ideally suited to the purposes of dealing with the transmission because of its ability to amplify signals while remaining highly sensitive to small changes in the input. When combined with the 386, the receiver was capable of creating clear signals which translated well through the speaker into sounds of reasonable volume and clarity. With this addition and a variable resistor added between the two chips to act as a volume control, the group had a plan for the development of a receiver. The following (Fig. 10) is a complete schematic of that receiver as it was built:

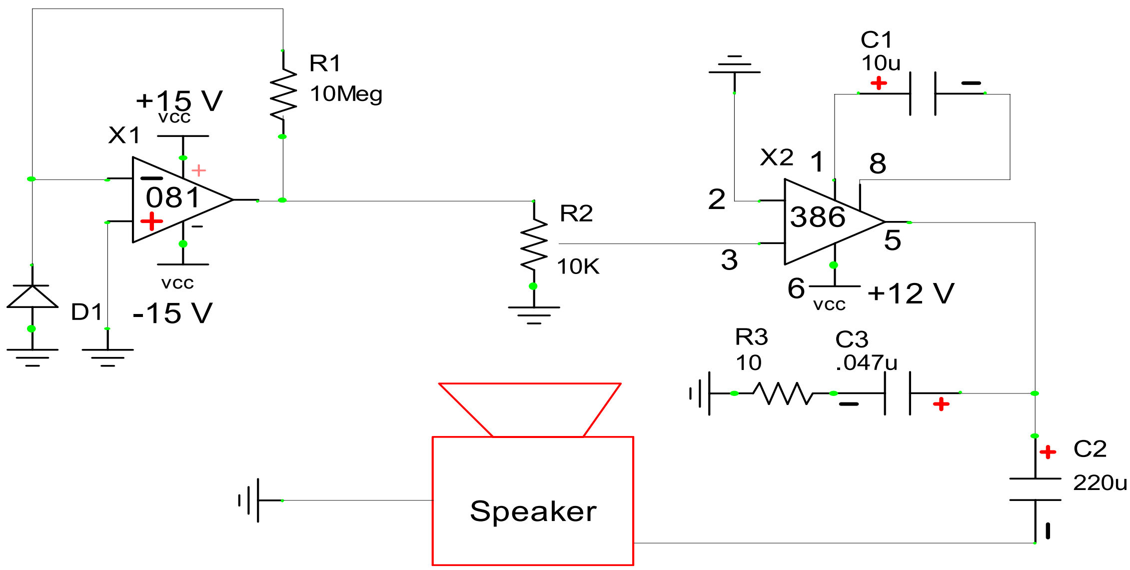

Figure 10: A schematic diagram depicting the construction of the receiving component of the fiber optic communicator.

<u>Issues During Implementation</u>

It is an unavoidable aspect of placing a plan into action that unforeseen problems will arise to complicate the completion of the final goal. In the process of putting together the sender and receiver, it became apparent that a number of issues would play a significant role in inhibiting the proper functioning of the device.

Noise of all sorts is always an issue. Noise is any kind of unwanted modulation of the current running through a circuit and comes from imperfections in the cycle of an AC power source, any fluctuations in a DC power source, and the ever-present magnetic fields generated by interactions between circuit elements, nearby electrical equipment, and even, to some extent, the earth and the sun (Cell-phone networks will occasionally shut down on days of intense solar activity). As the group's circuits got more complicated more noise entered the system in more forms, but noise was there even in some of the simplest circuits. For example, when the emitter circuit was first set up by itself, the group looked at the output signal with an oscilloscope. There was so much noise that an output intended as sound could only be detected on the screen as a slight increase in fuzz. The solution that eventually cleared the signal to undistorted sine waves, with only the sixty cycle noise from the power lines still present, required two steps. First, a large capacitor, on the order of 3300 µF farads was inserted between power and ground on the amplification circuit. Since a capacitor cannot normally be considered a closed circuit element to DC, this did not short the circuit. However, as described in an earlier section, a capacitor is not exactly an open circuit element either. AC current, current that fluctuates, can to some extent travel through a capacitor. Since noise is fluctuations in current, a capacitor gives noise a path to ground that avoids the circuit elements (keeping their inputs and outputs relatively clear). Also, large sudden shifts in voltage could be absorbed as stored charge into the capacitor and then let out less violently in a slower capacitor discharge. The addition of the capacitor helped significantly; the sound was now intelligible but it was not sufficiently clear. A further improvement in sound quality was achieved by grounding the metallic body of the microphone.

That way, any currents set up in the body of the microphone by electric field noise went to ground instead of being picked up and used as inputs into the amplification circuit.

Audible noise is fairly simple to troubleshoot because it is an expected problem and its causes tend to be obvious, even if the ways to combat them are not. However, electric circuits, especially those that incorporate integrated circuits, are prone to other noise issues, some of which defy diagnosis. The group ran into several of these and often the only solution was to dismantle the circuit, rebuild it from scratch and hope that the problem would go away. One of the earlier microphone pickup circuits would output as if there were feedback if a person moved close to it, which was odd since feedback was normally a result of moving the speaker close to the microphone. One emitter had a potentiometer (variable resistor) that changed the pitch of a steady input instead of changing its volume as intended. Another emitter would give a pitch in pulses. That means a fluctuation in already fluctuating current, which seemed impossible given that there was only one circuit element designed to pulse in any way. At one point, it was discovered that some circuits would function properly only if the variable power sources to which they were connected were turned up very slowly from zero volts to the functional voltage, otherwise their behavior was noisy and unpredictable. Sometimes the first time a circuit was built it simply did not do anything. Although a careful examination of a circuit would yield explanations for some troublesome behaviors, a loose connection or overheated component perhaps, other times the circuit could not be figured out, which is a testament to how easily one can step outside his or her area of understanding when putting together electronics.

That is not to say that the group was mostly helpless in the face of obstacles. Several tools and methods were used routinely and fairly effectively to troubleshoot mundane and bizarre circuit malfunctions alike. First a circuit's connections were checked by eye by one group member as another read them off from a drawn schematic. If that failed, then a digital multimeter was used to test if the appropriate voltage drops, resistances, and current flows occurred across, in, and through the appropriate circuit components and sections. If it appeared that a particular component was not functioning properly then it was replaced. Obvious signs of blowout like intense heat, popping noises, and smoke were checked for in components capable of such things: integrated circuit chips, diodes, microphones, and large polarized capacitors. One technique that worked surprisingly often was to simply switch the connections of polarized components that seemed likely to be involved in a problem. When doing these things the group learned to constantly keep in mind the human ability to be absolutely positive about what end of something is positive and what is negative until the fifth or sixth check when the error is all of a sudden apparent. The troubleshooting tended to be most successful when everything was checked several times by two sets of eyes.

The techniques described above were mostly used to combat huge flaws in a circuit's function. Sometimes, however, an output was almost clear but not quite, or it was desired that a signal be truly optimized. For that kind of circuit improvement the oscilloscope (also used by the group in measuring wave speeds) was the most valuable tool. Since the purpose of the circuits was to accurately send, modulate, and receive "voltage waves" which represented sound waves, the oscilloscopes capacity to visually represent real time waves in a detailed manner was invaluable. One time, for instance, the flattened peaks of a signal led the group to the conclusion that distortion was being caused by the fact that an intermediate signal had too high an amplitude for a sensitive component further ahead, effectively lopping off the high and low ends of a wave. That allowed for the easy solution of lowering the amplitude of a particular output, a course of action which would probably never have been taken had it not been for the oscilloscope's image.

The circuit eventually functioned, in the form shown by the included schematics, demonstrating the relative simplicity and ease with which an essential modern communication technology can be constructed- even by a group starting not far from scratch both in terms of materials and experience.

APPLICATIONS OF OPTICAL COMMUNICATIONS

The applications of optical communications are as varied as they are ingenious. In this half century [8], there is hardly a region of science, business or technology that has not in some way been transformed by the marvel of Optical Communications.

Previously, most telecommunications systems relied on electrical signals transmitted via copper wire. The advantages bequeathed by optical systems are numerous. With them, data signals (transmitted in the form of light) can travel much further without the use of repeaters (currently, a distance of about 1000km). Also, the bandwidth at which that information can travel is much higher in optical systems than in old-fashioned copper wire communications. As far as communications are concerned, the speed of light is fast enough to be considered instantaneous. Essentially, the speed at which information can be transmitted depends only upon the speed at which the signal can be modulated and received at the source and end locations, which has climbed well into the GHz regions. Fiber optics are also much more immune to many of the forms of interference that an electronic signal may encounter. Copper wires are notoriously susceptible to electromagnetic radiation interference in the forms of radios, motors, and other nearby cables. Since fiber optics work on the transmission of packets of light, they are innately free from these forms of interference. It is also much easier to detect signal loss due to electronic tapping (hacking) into the system in a fiber optic network than in conventional copper wire networks.

Major companies have not failed to notice the potential of fiber optic cables over copper wire and AT&T, MCI WorldCom, and Sprint have all but replaced their old copper systems with state of the art optical fibers. Local telephone providers have planted optical systems between central hubs to carry large amounts of data quickly and efficiently, and have even extended optical fiber services into individual homes. Many cable TV companies have incorporated fiber optic systems into their infrastructures in order to send high definition TV signals to their subscribers.

Fiber optics are seeing wide use in local area networks (LANs) as well. LANs are used to connect groups of computers in relatively close physical proximity to each other so that they can share common equipment such as printers, scanners and servers. LANs are known to expand readily to accommodate additional equipment and users. Many large firms and businesses such as IBM, Wall Street brokerages, banks, and Universities send and receive large amounts of data between computers and buildings via LANs and optical fibers to increase the rate of data exchange and network security. LANs are notoriously difficult to penetrate electronically unless a physical connection to the network exists – a feature that most hackers would find impossible to obtain.

Fiber optics are also well known for their beauty as well. In amusement parks, clubs, museums, and novelty stores around the world, fiber optics have made their mark. It is commonplace to see dazzlingly illuminated light shows built around optical fibers and lasers. One of the largest of these exists in Las Vages, Nevada to which millions of tourists pilgrimage yearly to be dumbfounded by the beauty of light and man's current level of control over it. (Fig. 11)

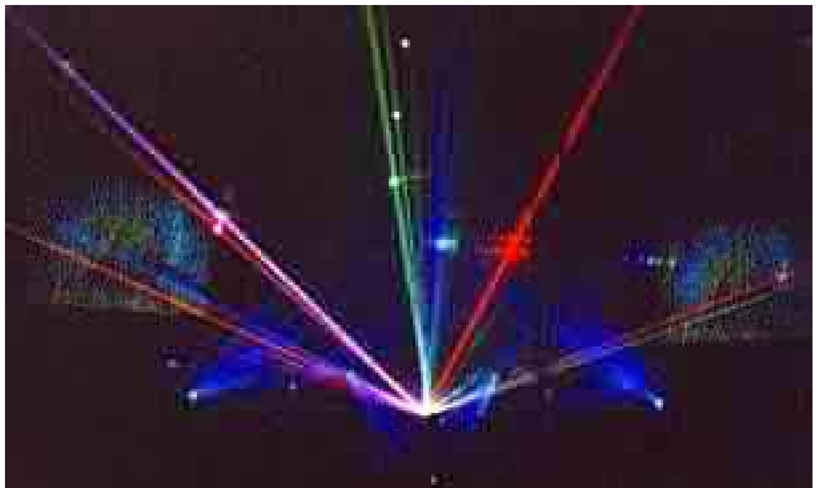

Fig. 11: Image from Laser Dreams Light

Fiber optics are pathways of data transport, but they are helping to shape and change another area of transport, that is, vehicular transport. One of the biggest frontiers for fiber optical systems lies in their integration into roadways and highways. They could provide for "smart highways" which would be fitted with wireless networks that would allow motorists to log onto the internet from their laptops, intelligent traffic lights that would change color based upon the level of traffic waiting at each intersection in the city in order to reduce gridlock and traffic congestion, and changing road signs that would warn motorists of impending hazards.

The major factor that defines the limitation of a fiber optic cable is the clarity of the glass. The clarity of SiO_2 glass has improved remarkably in the past 30 years. And still, clarity of the fiber remains the major factor causing loss of signal in an optical fiber. In general, the biggest cause of loss in the glass itself lies in the fact that certain electromagnetic frequencies vibrate the chemical bonds in certain functional groups. This phenomenon is very similar to the one that is used to identify materials in IR, UV, or visible light spectrophotometers. As electromagnetic waves pass through an atom, specific frequencies can vibrate the bonds in the atom. As they do, the light energy sent into the medium is transformed into kinetic energy. Thus, there is a loss of signal in this process. This loss however, can be kept to a minimum if the glass is devoid of impurities. The most important impurity that must be kept out of a fiber optic cable is water which leads to the presence of OH groups in the glass. These OH groups have a maximum absorption at a wavelength of around 1400nm – directly in the middle of the infrared region where maximum transparence would otherwise exist. New methods of fabrication however eliminate the old OH torches and thus the presence of OH in the fiber.

CONCLUSION

At the very basic level of telecommunications lie resistors, capacitors, metallic wires with rubber coverings and ideas. The fundamental idea in telecommunications is to connect peoples the world over through a networked infrastructure. This network, once made of copper wires, is now rapidly being converted into one of glass tubes and light emitting diodes. During the past four weeks, team project two attempted to learn the basics of this new network infrastructure of lights and glass tubing by applying the physics of electronics to the basic concepts of electronics. While exploring the exciting world of telecommunications and electronics, many resistors were blown out, microprocessors fried, and pickles lit to a luminescent hue of orange. As a team, we gradually learned what the proper things to do were and conversely, what the improper things to do were. For instance: Light emitting devices used for fiber optics should not be soldered onto wires.

On a more serious note, the team learned how to use many different electronic components and how to wire various microprocessors; such as the 555 and 386. In addition, the teams learned the basic physics of electronics and later applied this knowledge to measure and calculate the speed of light as well as the speed of sound. Because of this knowledge that we gained from our smaller projects, we were later able to take on the larger project of creating a communications device. This device, although simple, was successful and our first foray into the world of telecommunications has been made.

While creating the communications devices, the team was able to view the technology of the telecommunications industry at its most basic level, while being challenged with the complexities inherent in building an electronic device. Our knowledge of the basics of communications and the physics of electronics has helped us to achieve all that we have during the past four weeks.

REFERENCES

[1] The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company; 2000.
[2] http://www2.fht-esslingen.de/telehistory/chrtable.html
[3] http://www.sff.net/people/Jeff.Hecht/history.html
[4] http://www2.ifjf.uib.no/gravitymeter/test/images/PS_0V_phase_A_B.jpg
[5] http://www.haverford.edu/physics-astro/Demonstrations/optics/speed_of_light.htm
[6] http://www.webcohosting.com/fiber.jpg
[7] http://www.fiberopticproducts.com/Connectors.htm
[8] "Fibre Optics," Britanica. 2002. Volume 4, P,756
[9] http://www.laserdreams.com/