Fiber Optic Communicator

Information and Assembly Manual

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ELECTRONICS

AMERICAN RIVER COLLEGE

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Introduction

This booklet is intended to provide enough information that a novice can assemble the pieces in this kit into a working fiber optic communicator, and in the process learn about transmitters, receivers, fiber optics, soldering, printed circuit boards, and troubleshooting. Therefore it has sections devoted to each of these topics, all starting with the assumption that the reader knows very little about each subject.

How to use this booklet

I recommend that everybody start by building the kit, and filling in with the theory later. The assembly instructions give some important tips, so you should begin there. You may review the soldering instructions if you don't have much experience soldering.

After you assemble your kit, you should test it by following the instructions in the testing section. Hopefully it will work perfectly! Unfortunately, when I solder a new project it rarely works perfectly right away, so I often need to do some troubleshooting. If you are like me, you might need to refer to the troubleshooting section to diagnose and fix any issues you might have.

Once your communicator is working properly, feel free to browse through the rest of this booklet to learn about the theory of transmitters, receivers, and fiber optics. Each section discusses some general background information as well as some details about this kit.

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Background

This kit was developed as a teaching tool for Electronics Technology 302, an introductory electronics class at American River College. This class used to use a commercially produced kit, but that kit was overpriced and used poor quality components. The previous kit included printed circuit boards with flimsy traces that often peeled off. The boards' holes were not plated, which made it difficult for solder to flow through properly. There were lugs, LED's, and microphone legs that needed to be bent in order to fit correctly. Also, the previous battery holders had thick metal legs that would damage precision wire cutters.

This kit addresses all of those issues. It uses high-quality circuit boards with well-bonded traces. These include plated through holes that allow solder to flow through easily and create strong joints. All of the components fit properly, with no need for bending or modification. The new battery holders have appropriately sized legs that do not need to be cut.

In all, we feel that these improvements make the kit easier to build and result in a better end product. That being said, we are always trying to improve the experience, so any feedback is welcome. We hope you enjoy this kit!

Assembly Instructions

General Assembly Tips

1. Always wear safety glasses when assembling your board! This is important because solder can boil and splash when it melts on your iron, and it may get in your eyes if you don't wear safety glasses. Also, when trimming wires or components, loose ends often fly off and may hit you in the eyes.

2. Solder resistors first
   - they are shortest components, they are out of the way.
   - Line up all of the resistor color codes:
     - Tolerance band goes on the right for horizontal resistors
     - Tolerance band goes on the bottom for vertical resistors

3. Electrolytic capacitors are polarized!

4. Use tape to hold large components in place while you solder them.

5. Solder the socket (not the chip!) into board.
   - Line up the notch on the socket with the mark on the silk screen

6. Battery Terminals: Check the silk screen to see where to put the large terminal and where to put the small terminal.

Transmitter Assembly

1. Use the LM 741 chip, not the 386.

2. Use the BLUE fiber optic holder that contains the infrared LED

3. The capacitors have the following codes:
   - C1 = 1uF (Electrolytic, no code)
   - C2 = 47uF (Electrolytic, no code)
   - C3 = 100pF = 101
   - C4 = .003uF = 302
   - C5 = .022uF = 223

Receiver Instructions

1. Use the 386 chip, not the 741.

2. Use the BLACK fiber optic holder that contains the infrared LED

3. The capacitor codes are as follows:
   - C1 = .047 uF = 473
   - C2 = 47uF (Electrolytic)
   - C3 = .047 uF = 473
   - C4 = 220 uF (Electrolytic)
   - C5 = .047 uF = 473
   - C6 = 10 uF (Electrolytic)

An Introduction to Soldering

Preparation

Preparation is the most important part of soldering, and it takes the most time. Once everything is prepared the soldering itself should only take a few seconds per joint.

1. Set the soldering iron to about 650 degrees Fahrenheit and allow it to warm up.

2. Make sure all surfaces are clean because dirt and oil are very bad for solder joints. Brand new parts may not need cleaning. Older parts should be wiped with alcohol or scrubbed with an alcohol-soaked brush.

3. When soldering two wires together, create a strong mechanical connection between the wires by bending them around each other.

4. Optionally you can apply a small amount of flux to your joint.

Soldering

The most important thing about applying the solder is to make sure that all metals are hot when the solder is applied. This allows the molten solder to mix with the external layer of the metal components and form a strong connection, called an intermetalic bond.

1. Hold the soldering iron like you would hold a pencil

2. Put a small drip of solder on the end of the iron. This will help to transfer heat from the iron to the joint.

3. Touch the solder drip and the iron to the joint and heat it for three to five seconds

4. Apply additional solder to the joint
   - Only touch the solder to the component or the board, never to the iron.
   - If the solder doesn't melt, that means the component isn't hot enough yet. Hold the iron on the joint a little longer, then try again.

5. Once the solder starts to melt, apply it so that it covers the whole joint.

Inspection

After you have applied your solder and allowed your joint to cool, you should inspect it to make sure it looks good. Look for the following characteristics:

1. The solder should make a smooth transition between the component and the board. This is called a fillet.

2. The solder should not form a ball that sits on top of the board. This condition is called a cold joint because it happens when solder is applied to a cold component or board. A cold joint makes a poor electrical connection. It may have a high resistance or, in some cases, may not conduct electricity at all. It is also a weak mechanical bond that can easily break.

3. A cold joint can be easily fixed by touching it with the iron until the solder melts and flows onto the board more completely.

Fiber Optic Theory

Fiber Optics - What is it?

Everywhere you look Fiber Optics has been changing the way people communicate and control our world.

If you used a cellphone, the Internet, watched television or streaming video, or used a vehicle to attend school today, you most likely used Fiber Optics.

Cellphone towers, which connect your mobile phone to the world, now have switched from microwave radio links to Fiber Optics, enabling them to connect to Central Offices (CO's) where your data is transmitted to other CO's across the country and around the world. Fiber Optics allows you to receive and transmit streaming video and other services utilizing tremendous bandwidth on your mobile phone.

Consolidated Communications, AT&T, and many other telecommunication carriers use Fiber Optic cable to link each individual home and business back to their CO and the Internet. This allows them to offer Triple Play Service, telephone, television, and Internet over one small glass fiber. This provides streaming video, high-speed internet and phone service to your home or business.

Within Sacramento County there are many traffic signals that are controlled from a central office in downtown Sacramento. The communication between the traffic signals and the downtown CO is possible because of Fiber Optics. How do the traffic controllers know how to adjust the traffic pattern at each of these signals? The cameras mounted to the traffic lights allow controllers to observe in real time roadway pictures downtown using the same Fiber Optic cables. Additionally many modern automobiles use fiber optic systems to link onboard computers together, improving performance and efficiency.

Everywhere, Fiber Optics is changing the way people communicate and control our world.

The Basic History of Fiber Optics

AT&T began deploying Fiber Optic transmission lines in the 1960's. In many areas such as the eastern corridor of the United States they had exhausted bandwidth in their current cable and microwave systems. Although Fiber Optic transmitter and receiver electronics were very primitive at that time, as was the purity and transparency of the Fiber Optic cable, AT&T concluded that Fiber Optics was the future and began dedicating a tremendous amount of research funding to create and improve systems.

Corning Glass, a leader in the glass industry worked diligently to develop low attenuation glass while many companies such as Lucent and others devised new electronic transmitting and receiving systems. The advent and perfection of the solid state LASERs combined with advances in other components of the communication system enabled Fiber Optics to become the communication system of choice around the world. Currently Fiber Optic cables crisscross our nation, while undersea Fiber Optic cables link continents together like a spider web.

What Is The Big Deal?

Some students may be old enough to remember when talking overseas meant voice delays, static and variable volume levels. Maybe even some remember something called a MODEM (Modualtor-Demodualtor) or even used a FAX machine. These systems were all high tech just a few short years ago.

Fortunately, voice delay on overseas communication is a thing of the past thanks to Fiber

Optic Transoceanic Cables. Previous overseas communication was accomplished using satellite technologies. The audio, data, and video signals were transmitted to an uplink station on the coast where large antennas transmitted the signal up to a satellite approximately 22,000 miles in the air. There the signal was relayed to other satellites or to ground stations, depending on the data destination. The voice time delay was caused by the time it took the signal to travel up and back down. Now, the signal travels across the ocean using Fiber Optic cables, at distances at less than 6000 miles at the speed of light. That explains why conservations to other countries sound like you are talking to your next-door neighbor.

A few years ago MODEMS were used to enable computers to communicate across long distances. A Modem took digital data from a computer and converted it to analog signals that had the ability to be transmitted on the existing copper telephone cables. At the receiving end of a Modem link, the analog signal was converted back to a digital signal which would input into the computer. Each Modem had a separate transmitter and receiver that operated on two separate frequencies. Even when using a 56-Kilobyte Modem, a high quality photograph could take 30 seconds to download. The technology that we take for granted (such as streaming video) did not exist. Now, Internet providers have the ability to supply extremely high bandwidth service to you home utilizing Fiber Optic cable. These services were not possible using conventional communication mediums.

Theory and Operation of Fiber Optic Cable

The idea behind any type of transportation medium such as Fiber Optics or Radio Frequency (RF) is to be able to take any type of signal, such as digital data or voice and transport it over a distance and have it emerge from the other end as close as possible to the originating signal. Any type of commination link consists of a converter/transmitter, the transportation medium such as Fiber Optics and a receiver/convertor that converts the signal back to the original configuration. Ideally, the communication link is as transparent as possible and would have no effect on the information transported.

Fiber Optics use light instead of electrical current to transport information or data from one location to another. Because of this we do not use a metallic messenger or wire to carry current but instead, use a Fiber Optic link that allows light to travel inside the fiber without escaping.

The higher the communication medium or carrier, the more data the communication link can transport. Electronic communications originally started with Radio Frequency in the Kilohertz or kHz or thousands of hertz. When the need for more data to be transmitted, and technology evolved, systems were increased to Megahertz or millions of hertz. Over time, the need for more bandwidth led to the utilization of microwave systems that operate in the Gigahertz band. Each of these advances in higher frequency represented a new generation of technology and a tremendous jump in bandwidth or data transmittal capacity.

The real advance came with the jump from RF technology to Fiber Optics. The advancement represented over 100,000 times more bandwidth along with a complete new technology and industry where none had previously existed.

Fiber Optic Cable

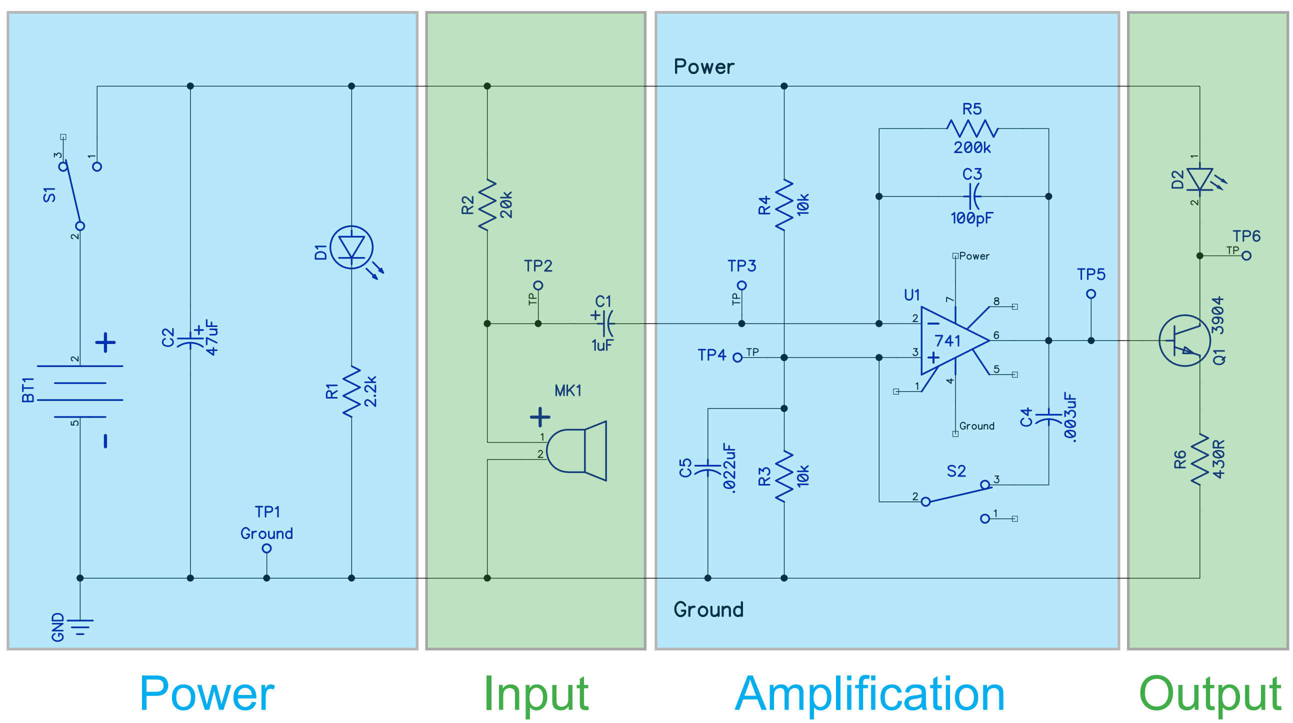
There are two basic categories of Fiber Optic cable. Each of these categories is broken down further into groups of Fiber Cable. In this class we only discuss the primary categories, glass and plastic fiber. Glass fiber is much more expensive and difficult to work with. Because of the precision involved and the associated equipment, including transmitters, receivers, and test equipment it is extremely expensive. However, glass fiber has the lowest attenuation and the highest bandwidth speed so it is primarily used for by long and short distance high-speed communication. The fibers that crisscross the United

States are exclusively constructed of glass.

Plastic optical fiber is significantly less expensive and requires minimal training to install and connectorize. Because of its physical properties, plastic is utilized for short distances, quick installations, and where high data speeds are unnecessary. Many types of automated equipment such as high-speed printers and conveyor systems utilize plastic fiber. Because of the cost, short distance, and low data speed (voice), the Fiber Optic communicator that we assemble and test in class utilizes Plastic Optical Fiber (POF).

All Fiber Optic cable works on the same principal. A fiber optic cable is constructed of two materials, a core and a cladding. Many times an outside protective cladding will be installed over the core and cladding. The POF cable that you will use with your optical communicator is constructed this way. The core and the cladding of the fiber have different optical properties, like water and air. An example would be if you shined a flashlight through the air into water. Depending on the angle that the light enters the water, it would be absorbed into the water, or if the angle was low enough, the light would reflect back up. That is the principal of the core and cladding. As long as light enters the fiber at the proper angle (cone of acceptance) it will reflect into the fiber and continue back and forth down the fiber until it eventually emerges from the other end. Because there are many angles that will cause light to reflect back and forth down the fiber, it is called multi-mode.

Two types of transmission systems are used with Fiber Optic systems. Digital, where the signal is converted to a 1 or 0, or on/off state of light, and analog, where the intensity of light transmitted is dependent on information into the transmitter. Typical communication systems utilize digital technique because it is much more effective, but requires much more sophisticated equipment. The communication system we build in class utilizes analog technology which enables us to observe signals, diagnose problems, and troubleshoot and repair our system using the oscilloscope.



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Filename: Transmitter.dch	Sheet 1	

Fiber Optic Transmitter Theory

Overview

The goal of the fiber optic transmitter is to detect sound and translate it into light that can be transmitted through a fiber optic cable.

Stages

Although the circuit diagram is complicated when we look at it as a whole, it is not so bad if we break it down into pieces (called stages) and examine one stage at a time. Once we understand each stage, we can see how they work together to translate light into sound. The diagram to the left shows that there are four main stages in the transmitter: power, input, amplification, and output. We will now look at each stage in more detail.

Power

The goal of the power stage is to provide constant voltage to the rest of the circuit. This voltage comes from BT1, a 9 volt battery. The voltage is connected to two long wires, one across the top of the circuit (labeled Power), and one across the bottom (labeled Ground). The other stages draw their power from these long wires. Switch S1 is the power switch, and can be turned on or off. Capacitor C2 is in parallel with the power supply, and acts like a reservoir to keep the voltage constant. Diode D1 is an LED that lights up to show us when the circuit is turned on.

Input

The purpose of the input stage is to detect sound and translate it into an electrical signal. The input and amplification stages are based on a reference design created by Texas Instruments, which can be found at http://www.ti.com/lit/ug/tidu765/tidu765.pdf. The reference design paper provides much more detail about this circuit, but we will provide a brief overview here.

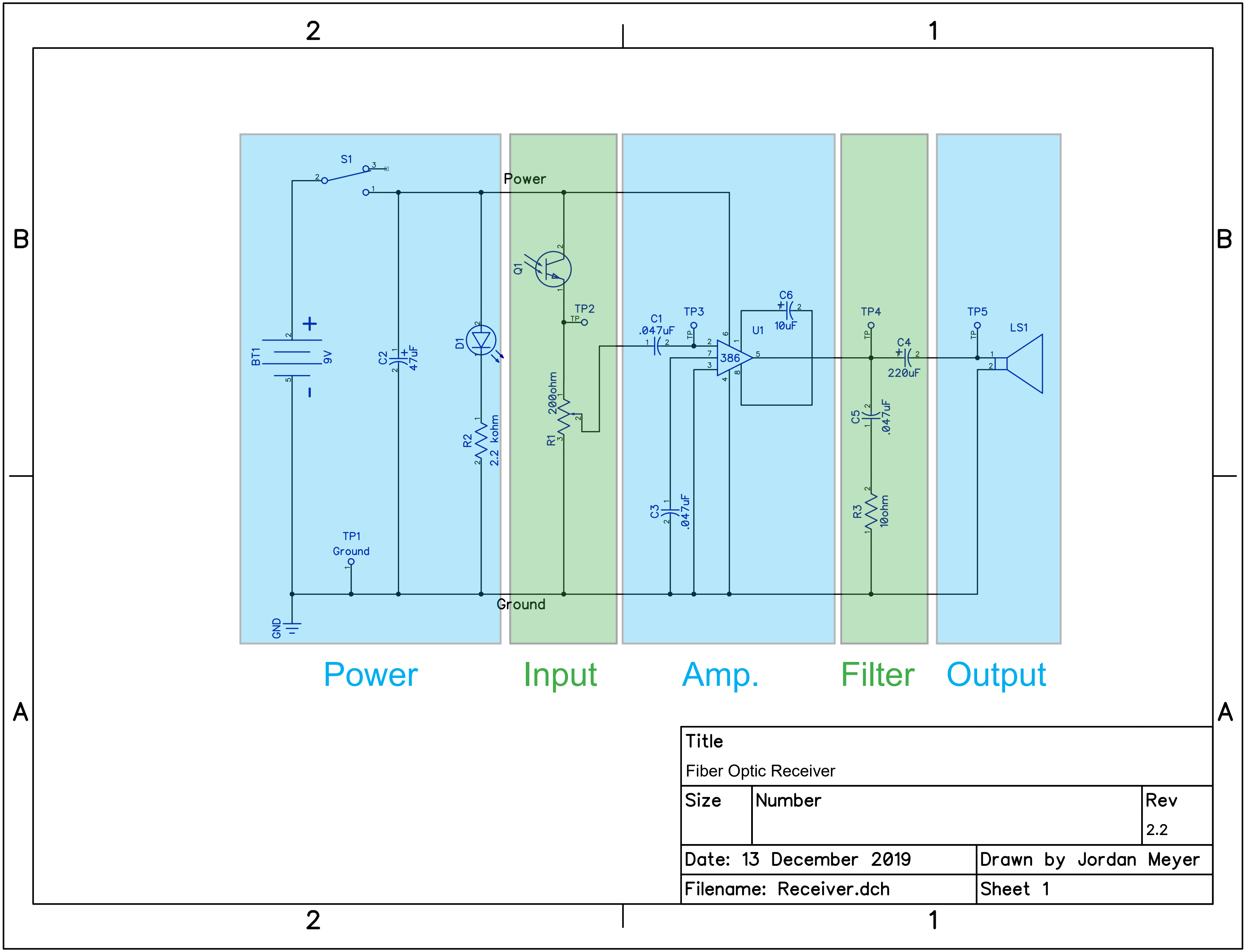
The main component in this stage is the microphone (MK1). This is a type of microphone called an electret microphone. When sound waves hit the microphone, they cause its resistance to change. This allows different amounts of current to flow through the microphone and through the wire that is connected to the next stage. This signal is very small and weak, so it needs to be amplified before it can do any useful work.

Amplification

The main component in the amplification stage is a chip called an operational amplifier, or Op Amp for short. The chip is labeled U1 in the diagram. This particular Op Amp is an LM 741. The amplifier circuit is arranged in a transconductance configuration. This means that it receives a current and turns it into a voltage. R2 determines the transconductance gain for this circuit, which is 200,000. In other words, for every amp that goes into the amplifier, it creates 200,000 Volts! This may seem like a lot, but it is more reasonable when we realize that we only expect to get about 16 microamps in. This leads to an expected output of about 3.2 V.

Output

The main components in the output stage are the infrared LED D2 and the transistor Q1. Voltage from the Op Amp controls the transistor, which in turn controls the current flowing through the LED. This makes the LED get brighter and dimmer.



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Fiber Optic Receiver Theory

Overview

The goal of the fiber optic receiver is to detect light from the transmitter, turn it into an electrical signal, amplify it, then send the signal to the speaker to become sound.

Stages

Just as with the transmitter, the receiver is complex when viewed as a whole. However, when we break it into stages as shown at left, each stage is easier to understand. Once we understand each stage we can see how they work together to accomplish the goal of the receiver.

Power

The goal of the power stage is to provide constant voltage to the rest of the circuit. This voltage comes from BT1, a 9 volt battery. The voltage is connected to two long wires, one across the top of the circuit (labeled Power), and one across the bottom (labeled Ground). The other stages draw their power from these long wires. Switch S1 is the power switch, and can be turned on or off. Capacitor C2 is in parallel with the power supply, and acts like a reservoir to keep the voltage constant. Diode D1 is an LED that lights up to show us when the circuit is turned on.

Input

The purpose of the input stage is to detect light from the transmitter and turn it into an electrical signal. The component that detects the light is called a phototransistor, and is labeled Q1. This transistor essentially changes its resistance depending on how much light hits it.

The phototransistor is in series with a potentiometer. This is a resistor with an extra wire that can be moved from one end of the resistor to the other. Since these two components behave like two resistors in series, they form a voltage divider. In a voltage divider, the voltage across a component is proportional to its resistance. So when the phototransistor's resistance increases, the voltage across it increases too. Likewise, when its resistance decreases, so does its voltage. Therefore the variations in light intensity hitting the phototransistor create a variable voltage signal. This signal can be measured at a test point (TP2).

The potentiometer functions as a volume knob. The way it works is that the voltage signal is connected to one end, and ground is connected to the other end, and along the resistor the signal decreases from full strength to nothing. When the third wire of the potentiometer is connected to the signal side of the resistor, the output signal is full strength. When it is connected to the other side the output is zero. In between the signal strength varies.

Amplification

The purpose of the amplifier is to take the small voltage signal from the phototransistor and increase its voltage and current so that it can create an audible sound from the speaker. The main component responsible for this is the LM 386 audio amplifier chip. When it has a capacitor connected from pin 8 to pin 1, as in this circuit, it has a voltage gain of 200. That means that a one millivolt input signal creates a 200 millivolt output signal.

Filtering

The filtering stage removes frequencies that are too high or too low to hear, but it allows audible frequencies to pass through.

Output

The output stage is a speaker that turns electronic signals into sound.

Printed Circuit Board Theory

Overview

A circuit board's main purpose is to make electrical connections between components. Many circuit boards are also rigid, so they create a solid foundation that holds the components too. In this section we will learn a little bit about how circuit boards are built to fill these purposes. We will also learn about some of the key terms that describe circuit boards.

Circuit Board Construction

There are many different types of circuit boards, but the most common kind is rigid and consists of several layers. The part that gives the board its rigidity is in the middle and is called the substrate. The most common type of substrate is fiberglass. The top and bottom of the substrate are covered with a thin layer of copper. Parts of this copper layer are etched away, leaving behind a copper pattern that will allow components to be soldered on, and will create connections between the components. The copper is covered by a layer of insulating material called the solder mask. Finally, fine designs and text are added on top of the solder mask in the silk screen layer. This layer does not serve any electrical purpose, but it can provide important information, such as part values or orientations. It can also include company logos, or it can be purely decorative.

There are many other types of circuit boards as well. The boards described above have two layers of copper, so they are called two layer boards. It is also possible to have boards with 4, 6, 8, or more layers. These boards are created by essentially stacking several two layer boards on top of each other.

Rigid circuit boards can also be made from a variety of materials to fit various needs. Gold plating can be applied to any exposed copper to reduce corrosion, other substrates may be used for high-temperature or vacuum environments, special solder masks may be used for clean rooms. By choosing the right combination of materials, circuit boards can be made to withstand almost any environment.

Another type of circuit board is called a flexible board. These boards don't use rigid fiberglass as a substrate, but instead use a heat-resistant flexible plastic. Flexible circuit boards can be used as cables, or in wearable devices.

Traces

Traces are thin strips of copper, almost like wires, that connect one component to another. Traces can be made in various sizes. Traces can be made very thin so that many can fit on a small board. The downside to this is that the thinner a trace is, the more resistance it has. This causes thin traces to heat up. Traces that handle high currents must be made larger to avoid overheating.

Lands

Circuit boards usually include areas of bare metal around component connections, to allow operators to easily solder components to the board. These areas are called lands.

Vias

Vias are connections between two layers. They normally made by drilling small holes and plating them, just like the holes that components are soldered into. The only difference is that vias usually have a smaller diameter.

Copper Pours

It is often beneficial to cover large sections of your circuit board with copper, and these large sections are called copper pours. These are often used for power and ground points that need to connect to many other wires in a circuit. The copper pour makes it easy to make all of the connections. The pour also creates large pathways for the power and ground to flow through.

Surface Mount Vs. Through Hole

There are two basic ways to attach components to a circuit board: the component might have metal legs that are soldered into holes in the board, or the component may have metal pads that get soldered onto the surface of a board. The first method is called “through hole”, and the second method is called “surface mount”.

Through hole connections were used when circuit boards were first invented, and they have several advantages. First, they are relatively easy to solder and desolder by hand. For this reason they are used in many prototype applications, and in many beginner kits, including this one. They are relatively large, so they can conduct a lot of electricity without excessive heating. Unfortunately their large size can also be a drawback when trying to create small electronic devices.

Surface mount components are used in most modern electronic circuits. The primary reason is that the components can be made smaller, so the devices that they go into can be smaller too. Their small size makes them difficult to solder and desolder by hand.

Solder mask

The solder mask is a thin layer of insulating material that covers the copper on the circuit board. The solder mask prevents unintentional connections to the board or between traces on the board. It also protects the copper from corrosion. The solder mask is often green, which gives circuit boards their familiar green color, but solder mask comes in a rainbow of other colors too.

Silk Screen

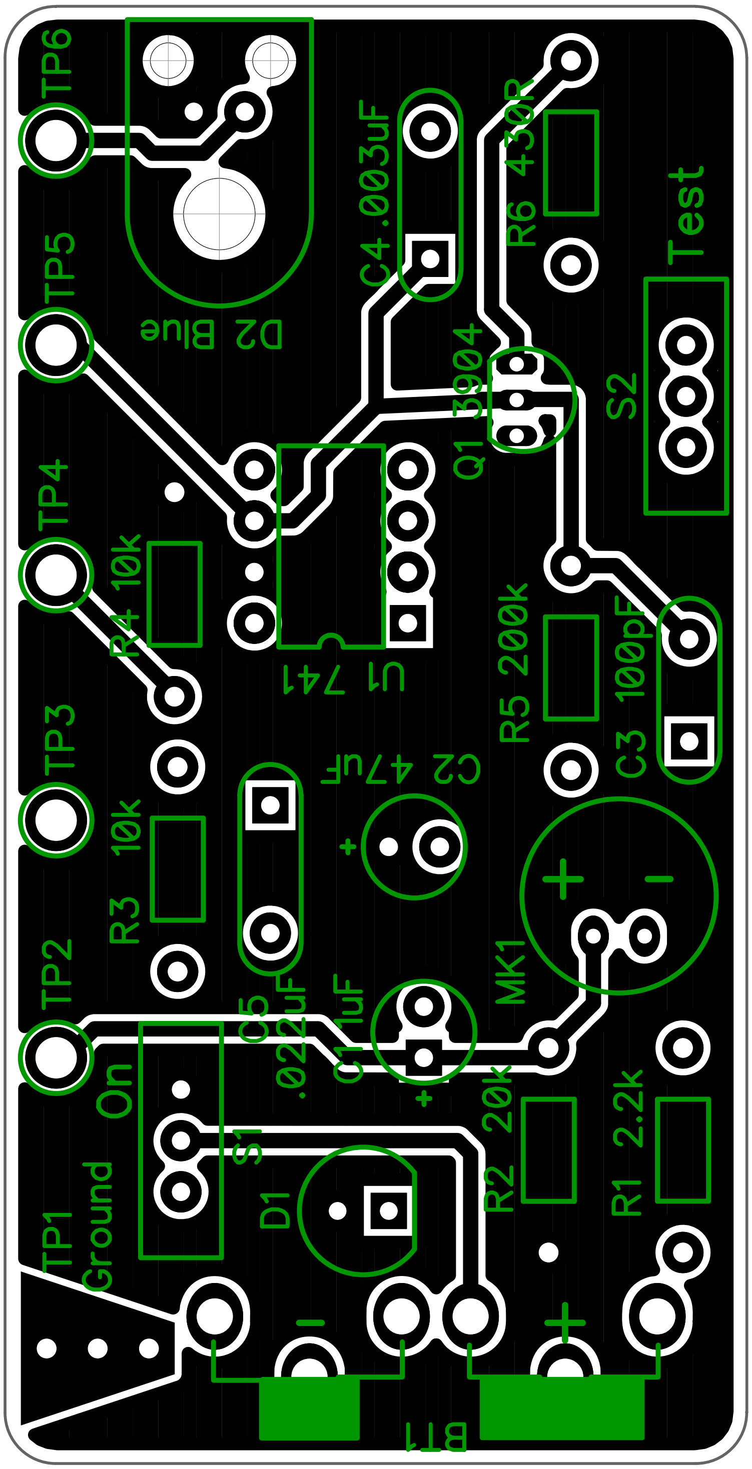
The silk screen layer provides finely-detailed designs or writing on the top and bottom of a circuit board. It is often white. Silk screen can include important information, such as part names, values, and orientations. Silk screen can also be decorative, displaying artwork or company logos.

Further Reading

This has been a brief introduction to circuit boards. There is much more information available. You can learn more by searching online, and by reading information at the following link:

https://learn.sparkfun.com/tutorials/pcb-basics/

Transmitter Top



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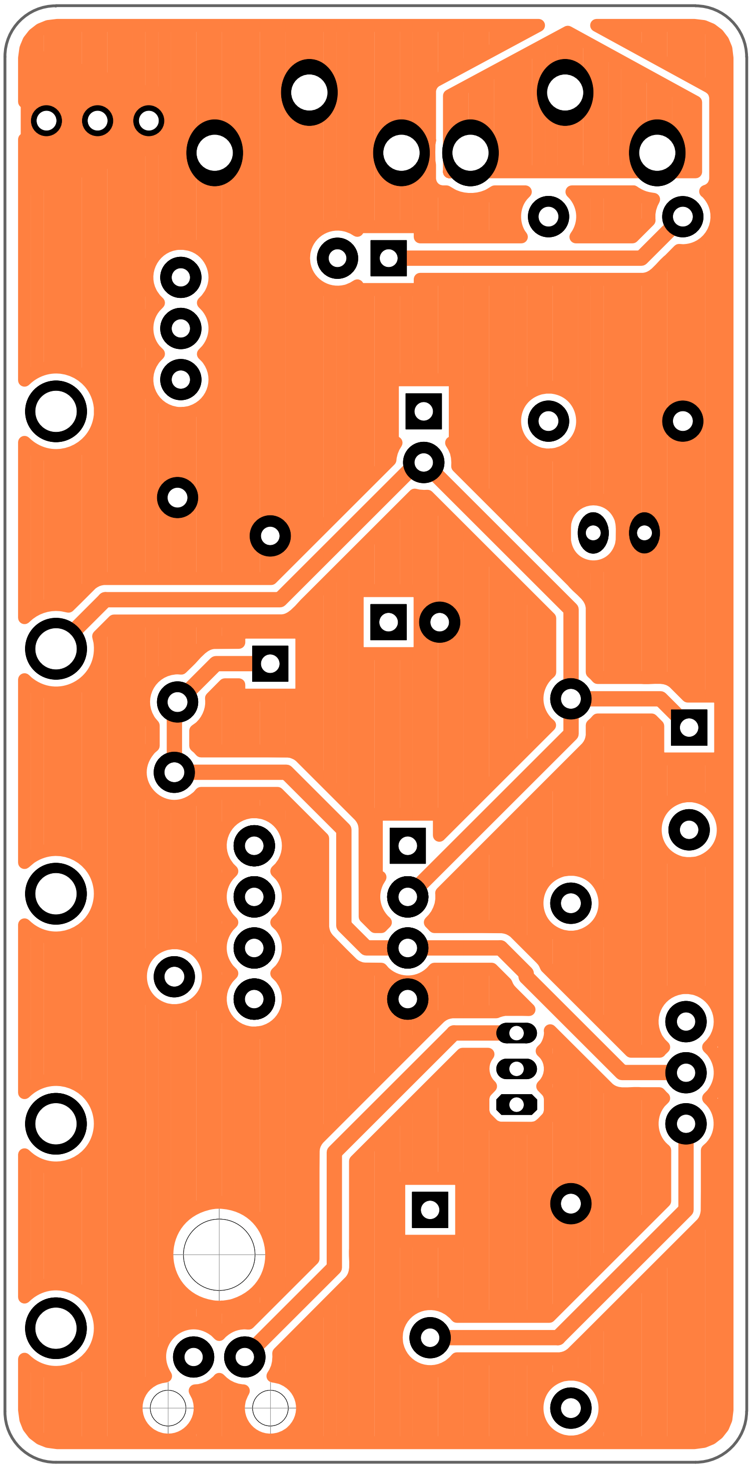
Transmitter Bottom



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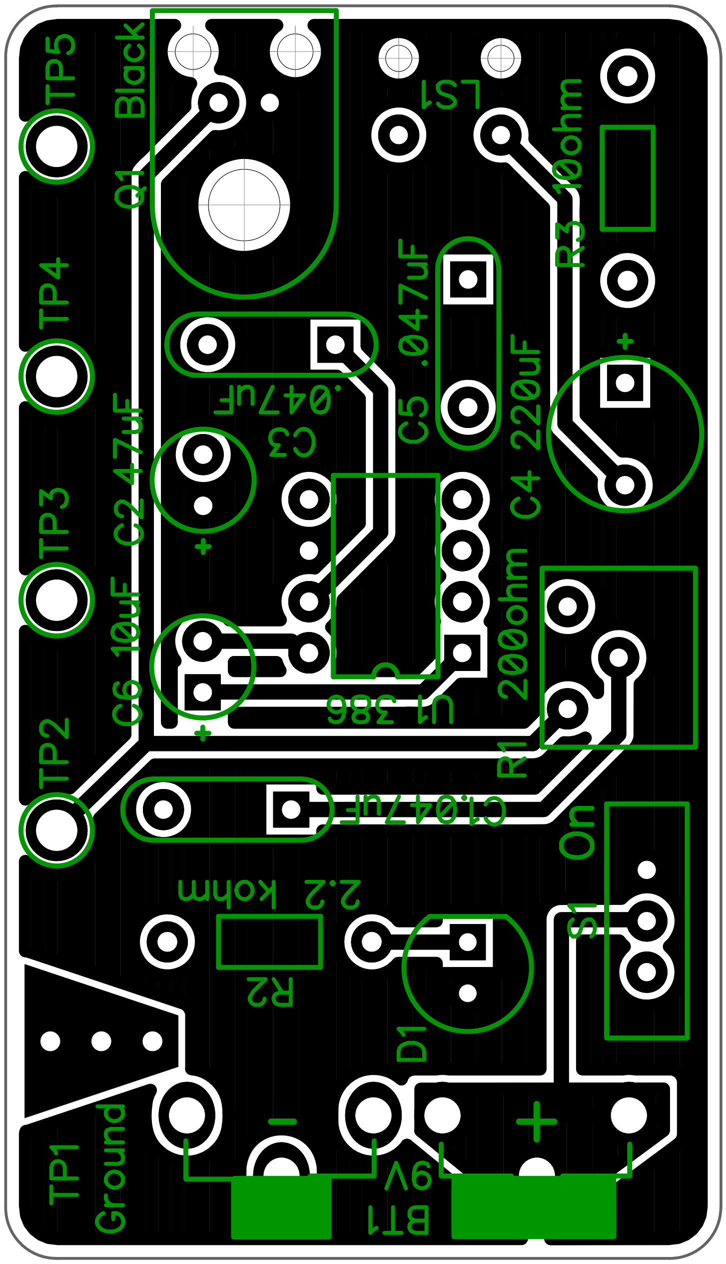
Receiver Top



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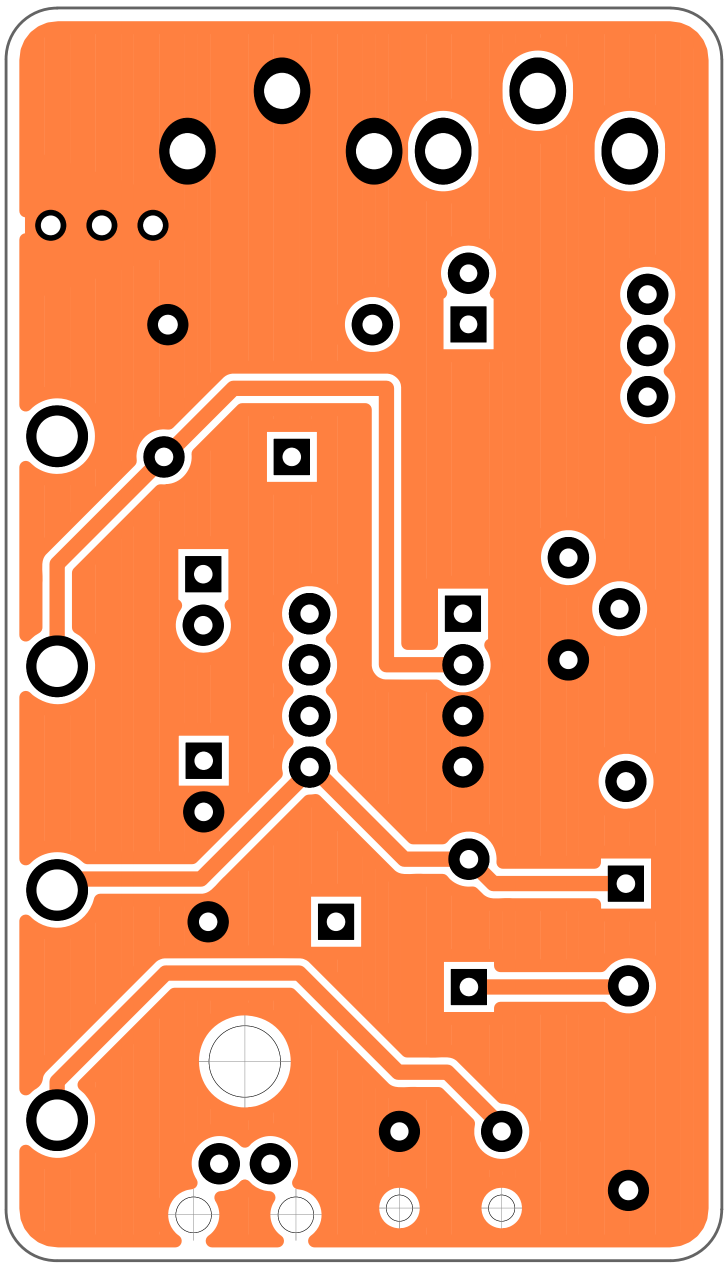
Receiver Bottom



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Fiber Optic Receiver
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Receiver.dip
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Parts List

Part Description	Quantity for Receiver	Quantity for Transmitter
10 Ohm resistor	1	0
430 ohm resistor	0	1
2.2 kOhm resistor	1	1
10 kOhm resistor	0	2
20 kOhm resistor	0	1
200 kOhm resistor	0	1
200 Ohm pot	1	0
100 pF Capacitor	0	1
.0033 uF Capacitor	0	1
.022 uF Capacitor	0	1
.047 uF Capacitor	3	0
1 uF Capacitor	0	1
10 uF Capacitor	1	0
47 uF Capacitor	1	1
220 uF Capacitor	1	0
Red LED	1	1
Speaker	1	0
Infrared Receiver	1	0
Infrared Transmitter	0	1
LM 386 chip	1	0
741 Op Amp	0	1
8 pin socket	1	1
9V Male clip	1	1
9V Female clip	1	1
SPDT .1" pitch switch	1	2
2N 3904 Transistor	0	1
Electret Microphone	0	1
Transmitter PCB	0	1
Receiver PCB	1	0
Fiber Optic Cable	1	0