

## Wire Recorder

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### *I. Project Objective:*

To create a wire recorder that allows the user to record and playback without the use of an amplifier.

### *II. Background and Theory:*

Valdemar Paulsen, a scientist from Copenhagen, was the first man to invent a wire recorder in 1898 and he originally named this invention the “Telegraphone.” According to the patents and research that can be found on this website, he was able to record voice on a .01” piano wire without the use of an amplifier. He originally connected a telephone’s microphone to an electromagnet inside a carriage. He then moved this trolley along the piano wire as he spoke into the microphone. By moving back up the wire and attaching a telephone receiver to the electromagnet and moving the carriage down the wire at the same speed he was then able to hear the recorded speech. An electromagnet is created by looping copper wire around a steel or iron core. The speech from the microphone is transformed into an alternating electric current through the copper wire. This current induces a magnetic field in the core and when the core comes into contact with a moving steel wire it will leave a magnetic imprint on the wire. Because the magnetism is induced by an alternating current the magnetic field lines will change direction along the wire. When the wire with the magnetic recording on it is then placed in contact with the core, the changing magnetic field along the wire’s length induces an alternating current in the copper wire as the steel wire moves along the core of the magnet. This alternating current is connected to the receiver of the telephone and can be heard as speech. Paulsen was able to create a wire recorder before amplifiers had been invented. With these principles of Electricity and Magnetism the goal should be attainable.

### *III. Method:*

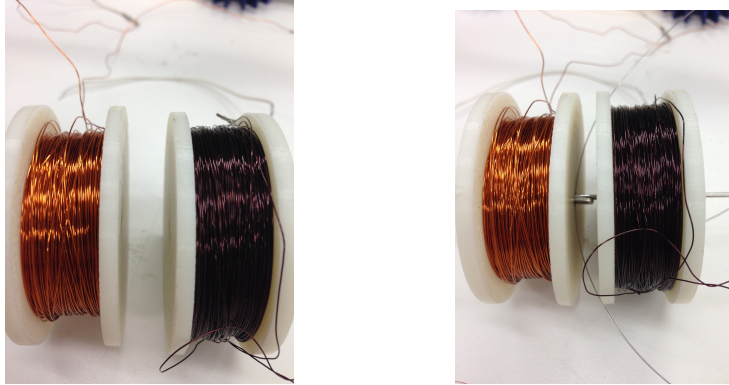
#### (A) Electromagnet:

##### ● Record/Playback Head

The electromagnet was one of the most complicated parts of this project. This is because there were no technical specifications for Paulsen’s electromagnets. From the designs on his patents it was clear that he had two poles for the core. Both poles touched the wire with a very small gap between them. From our knowledge of electromagnets, we knew that in order to create a large enough magnetic field to magnetize the wire, a spool would be very helpful.

By designing a spool with a hole in the center we were able to attach the spool to a drill and spin copper wire such that we would have thousands of turns. In order to have two opposite poles we made sure to have 2 spools wound with copper wire. When we attached the leads of copper wire from both spools to a voltage source a magnetic field was produced in the hole. If this source was DC current then the magnetic field would stay constant and the poles would not alternate like they would with AC current. By placing a magnetic compass near the hole we were able to figure out which sides of each electromagnet corresponded to North poles and

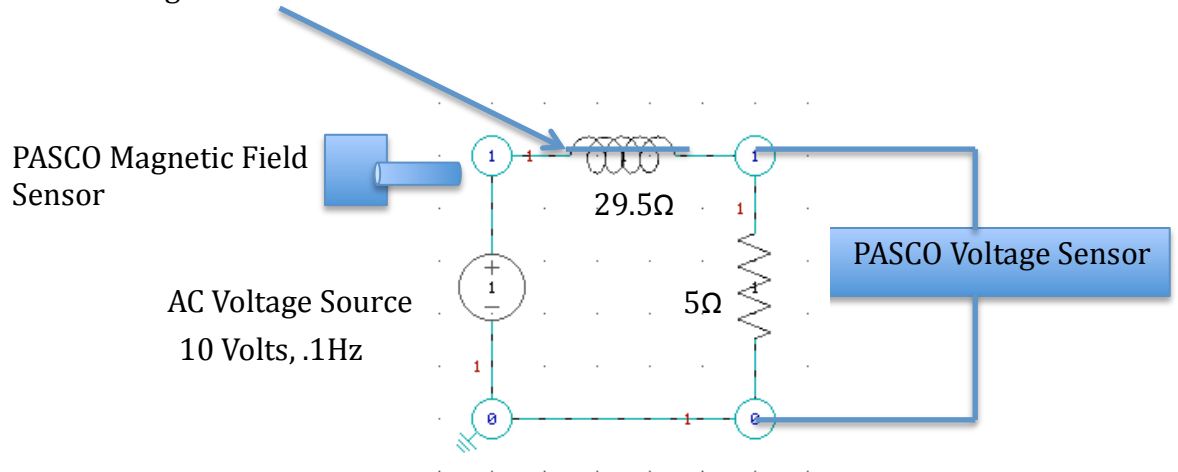
which sides corresponded to South poles. We oriented the spools such that opposite poles were close to each other as seen below.



By putting needles between the two, slightly offset from one another (as seen above) we were able to run a wire through the holes in the needles and make sure there was contact between the wire and the needles. The offset of the spools allowed a slight gap between the opposite poles. By connecting the spools to the same AC voltage source in the same way that they were connected to the DC voltage source, the needles would constantly remain oppositely polarized, but the polarization for each pole would constantly change corresponding with the frequency set by the AC voltage source.

These electromagnets were not very successful and did not imprint a changing magnetic field on the wire. Our next step was to look at the hysteresis curves of the different types of cores we could use. Below is a circuit diagram of how to set up a hysteresis curve test using the PASCO 850 Universal Interface.

Wire testing inside coil



We wanted a curve that showed low coercivity (High coercivity is when there is a large gap on the hysteresis curve and low coercivity is when there is a small gap). This means that the metal won't retain memory well and therefore changes instantaneously with changing voltage. After many tests we found out that the best core would be a ferrite (which has a sloped line for a hysteresis cure with little to no coercivity). Before testing a ferrite (which needed to be cut with a Dremel

tool as we only have circular ferrites) we tested the ability to record using a wire core with a lower coercivity than the needle. By using a different material we were able to record and play back different tones from the AC voltage source.

The ferrite core turned out to be highly successful, but the small circular form of the ferrite allowed us to only wrap 2600 turns of very fine ( $\sim .004''$  diameter) copper wire. We still had to use 2 levels of amplification to record and playback with this electromagnet. Seen below is a picture of the ferrite we used. Note that the cut here is made such that there is a very small gap in a single location. This concentrates the flux lines onto one point, thereby making the magnetic field the greatest at this point. This high concentration of magnetic field lines helps magnetize the wire more easily.



We then took the recording head out of an old tape recorder. With this type of head we were able to record and playback with only 1 level of amplification when recording with 100 V from our AC voltage source. By looking inside the recording head it was clear that there were many turns of extremely fine wire. The gap of the ferrite was also very small. It was also important to notice that the resistance of the wire around the tape recorder's ferrite was around 3000 ohms while our ferrite only had a resistance of around 200 ohms. This indicated that the next step in the project would be to mimic this design and create a ferrite with more turns. (More resistance comes from a wire being longer and/or thinner. This indicates that there were likely many more turns in the tape recorder's head) By using a bigger ferrite it should be possible to better mimic this design.

In designing this larger ferrite electromagnet we have created circular spools to fit around the ferrite (The design of these spools are linked to the website). By cutting the ferrite into two pieces we will be able to wind the spools with a drill (putting on more turns more efficiently) and then fit the spools onto the ferrite. By gluing the ferrite back together and connecting the wires on the spools together this should mimic the amount of turns on the tape recorder's head and hopefully will allow us to record and playback with less amplification.

We have recently discovered that the tape recorder's head does allow us to record voice on the wire, but with the 2 stage amplifier we have, we are only able to produce 5-6 volts for the current entering the electromagnet and this was only enough to hear the tones of voice but now what a person is actually saying. To fix this we could use a better amplifier for recording. Another solution would be to make an electromagnet with more turns than the tape recorder's head. By doing this we can make the magnet more sensitive to lower voltages and therefore should be

able to record voice with only 5-6 volts and be able to play it back and make out what the person is saying.

- Erase Head

Recorded information needs to be erased each time before a new recording process starts as to eliminate the interference between two recordings. Erasing can be accomplished in two ways: sliding a permanent magnet along the recording wire, or applying a DC voltage to the record/playback head that will behave as a erase head for now. Both methods “demagnetize” the recording wire by leaving homogeneous magnetic imprints on each point on the wire. The first way is rather convenient and efficient while the second requires a high DC voltage supply (6V battery was not enough as we tested before).

### Assembly

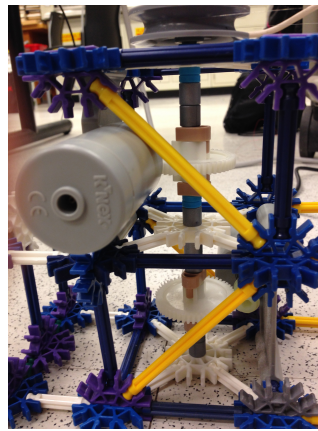
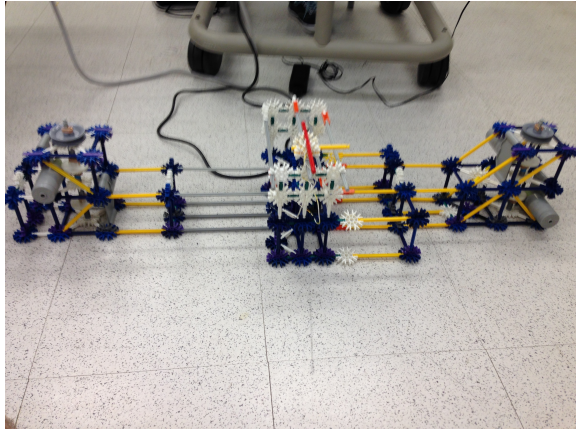
Once it was clear that the recording head could record on a wire and playback a tone from the wire, we built an assembly such that the wire could move over the head and remain in contact. This wire would wind around 2 spools and travel in a highly stretched out elliptical path. Our first attempt at an assembly, built out of K'nex is pictured below.



It's difficult to see the different pieces of this set up, but basically there is on motor that connects to 2 vertical gears, which are separated by a large distance. These gears are positioned on the same side of different horizontal gears (in this assembly they were positioned on the side of each horizontal gear closest to the motor). The positioning was important such that the horizontal gears rotated in the same direction. It was also important that the horizontal gears matched in size and so did the vertical gears. This made sure that the gears moved at the same speed and therefore so would the spools. The wire wound around the assembly at a constant speed. The issue with this setup was that when a wire was attached to the assembly it would pull the gears apart from each other and therefore would not spin at a constant speed. The motor was also incredibly loud so it was difficult to hear the tones playing on the wire.

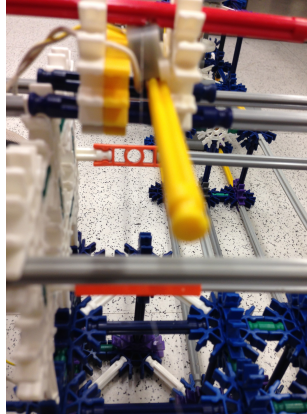
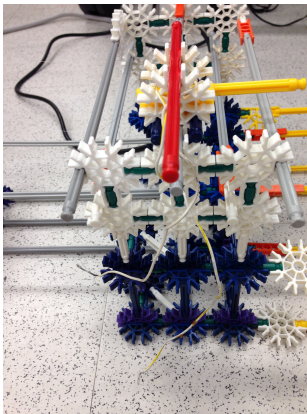
The second assembly had a much better design and can be seen below.





In this assembly, instead of having a gear and rod assembly to turn the spools at the same speed, we had 2 motors attached to each spool (4 in total). These motors are all of the same type, made of a spinning worm gear attached to a gear. The motor assembly is shown above. (Note that you can only see one of the motors because the motors had to be oriented such that they moved the gears in the same way. Both spools had to rotate in the same direction and at the same speed. Two motors of the same kind on each spool ensured that this would occur.

We then built an assembly that would hold the wire in contact with the electromagnet to ensure the recording and playback could take place. You can see this assembly in the photographs below.



The first photograph (Left) is a picture from the top looking down. The second picture (Right) is a picture from the side. The first photograph shows the basic structure that puts the electromagnet in set position over the rest of the structure to match up with where the wire turns. The second picture shows more important details. The magnet is difficult to see, it is the grey object between the yellow and red K'nex rods. The yellow K'nex piece holds the K'nex piece upwards. The red K'nex rod keeps the wire in place and has a small gap cut into it for the wire to move through. The yellow and white K'nex holders are arranged in such a way to hold the motor tightly from the sides for extra support. They are connected by blue rods below and the red rod above. There are also gray rods at a lower position (In the right picture it is the rod closest to the camera and there is one on the other side). It isn't clear, but if you look closely at picture 2, the wire passes under a gray rod before passing over the motor and under the red rod. This grey rod, along with

another rod on the other side of the magnet (at the same height) keeps the wire in contact with the magnet above.

By plugging in all 4 motors, the wire will turn around the assembly. We tested three different types of wire, a .0025" diameter steel wire which was used in a wire recorder, a .01" diameter piano wire, such as the one Paulsen used in his original experiment, and a .03" diameter music wire. All of these were magnetic and showed a wide hysteresis, thus exhibiting descent memory. (The wire recorder wire did not show much coercivity, but we did not have a function generator capable of producing a high enough voltage to be able to magnetize it at a low frequency, thus the testing on it would appear invalid). Research indicated that finer wires were better. We did find this as we tested wires. The piano wire retained magnetism but it did not sound good. The music wire could be magnetized, but even with large spools to keep it straight and in place, it kept falling apart even after spot welding it. It was too flimsy and did not retain magnetism nearly as well as the wire from the wire recorder. The wire recorder's wire worked best on small spools and retained a tone very well. It was the only wire we were able to record a voice on so far. Because it had such a good memory we think the hysteresis of this wire would be wider if it were magnetized with a low enough frequency and high enough voltage.

In order to record a tone on the wire, the two leads of the coil were first connected to an AC voltage source. When the source had heated up we turned the motors on and let the wire travel around the assembly. We then disconnected the leads from the AC voltage source and connected them to the input of a L.K.G Industries Solid State Stereo Phono Pre Amplifier PRE600. Headphones were connected to the output side of this 2-stage amplifier (Note that in order to make it a 2 stage amplifier a wire must connect the output of one side to the input of the other side and the electromagnet must be connected to the remaining input and the headphones to the remaining output). As the motor spins the wire around the assembly, a tone can be heard in the headphones.

We have also recorded a Frequency modulated signal from an Agilent Waveform Generator 33220A. We first set the amplitude to 10Vpp and the frequency to 440 Hz. We then pressed the "Mod" button on the generator. We pressed the blue button under "type" and entered "FM." The "Source" was "int." The "Freq Dev" was 400 Hz and the "FM Freq" was 0.1 Hz. We changed the shape between sine, triangle, square and upramp. For each shape we connected the leads of the record head to the output of the generator. By pressing "output" a current was sent through the wire, inducing a magnetic field in the electromagnet and thereby magnetizing the wire. After the steel recording wire had wound around the assembly, we disconnected the leads from the coil and plugged them into the input of the preamplifier. By connecting the headphones to the output of the 2-stage amplifier we were then able to hear the recording. For a triangle and sine wave the frequencies went up and down. For a square wave they jumped between frequencies. For the upRamp signal the frequency went from a low frequency to a high frequency and then jumped down. Being able to record a variety of frequencies is important because it indicates the possibility of recording a human voice.

We have only recorded a voice once. This used the recording wire and the electromagnet from the tape recorder. In this experiment we connected a telephone

receiver to the input of our L.K.G Industries Solid State Stereo Phono Pre Amplifier PRE600. We then connected the leads of our electromagnet head to the output of the 2-stage amplifier. By speaking into the receiver we created a current that was amplified by the pre-amplifier and sent to the coil. The coil then induced a magnetic field, which was then recorded on the wire. When the steel recording wire had been magnetized we could then connect the leads of the coil to the input of our amplifier and connect the microphone to the output of the 2-stage amplifier. We were able to make out the voice in the headphones, although it was very blurred and impossible to understand.