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E4 Final Prototype Memo - Making Waves Section 1

Problem Statement

In E157 students use oscilloscopes and long (up to 50') lengths of cable to observe voltage/current wave propagation in the cables, a technique called time domain reflectometry (TDR). TDR is sensitive to non-uniformity in the cables, especially at the cable connector points, so the design shall organize the cables and minimize strain on the connections caused by the weight of the cables. This design must be easy to set up for students and prevent the cables from being jostled while holding the cable connections in place.

Questions:

1. Is our prototype easy to work and move around, especially given the space constraint of the lab?

Reasoning: Our prototype will end up being constrained to a 50 cm^2 lab bench so it is important that it is easy to work within that constraint.

2. Do the shelves of our prototype support the maximum weight, which is that of 50 ft of cable?

Reasoning: Our prototype will need to hold up to 50 ft of cable, and being strong enough to hold that much cable weight is one of our primary functions.

3. Is our prototype waterproof?

Reasoning: Prof Spencer is concerned with a wooden structure absorbing water from the air and becoming conductive which would disrupt electricity running through the BNC pass throughs mounted on one side of the shelf. We treated our shelf with a waterproof coating and want to ensure that it successfully waterproofed our final prototype.

4. Is our prototype non-conductive? That is, is any voltage lost to the wood? Are our passthroughs successfully conductive without any voltage lost to the wood?

Reasoning: If the shelf is conductive it fails one of our constraints and ceases to become safe as a user could get shocked and if electricity is disseminated into the wood instead of concentrated at the passthrough it would disrupt the lab results when our goal is to make the results better and cleaner.

5. Does our prototype stabilize the cable connection points even when bumped/moved?

Reasoning: Our prototypes main objective was to stabilize connection points so as to not have the oscilloscope signal disrupted.

6. Does our prototype improve the results of TDR?

Reasoning: Our prototype's main function is stabilizing the signals produced from TDR. A successful design will allow the user to get more precise results from their TDR experiments.

These questions are important because they check if our final prototype has successfully met our goals for it.

Prototype

We constructed our final prototype by iterating and improving on our previous low resolution prototype. After our last client meeting, we learned that Prof. Spencer preferred our shelf supporter model to both the dowel and string supporter models. We also learned that he wanted eight BNC connector points, all on one side of the design. Therefore, we set out to construct a sturdy, shelf model that incorporated his design needs.

We had five separate components to our prototype: the wall with the BNC mounts, the wall without the BNC mounts, a thicker bottom layer for the shelf, three shelf components, and support pieces for the shelves. We purchased four 8” x 20” birch wood from Lowe’s and constructed all the aforementioned components in the Harvey Mudd Wood Shop. Before beginning the building process, we determined the size of the shelf and the distance between the shelves with our functions and constraints in mind. We determined the size of the shelf by coiling a cable loosely and determining the area it took up. We ensured that the shelves were spaced far enough apart so that Prof. Spencer’s hand (which we measured in our client) could fit through the shelves and manipulate the connections.

We measured and cut all the pieces of wood (for the walls, shelves, and shelf supports) into the necessary sizes using both the table saw and vertical bandsaw. We then used the thickness planar to thin all the pieces of wood. This was an important step and a constraint in the process, because for the wall with the BNC mounts, the wood had to be thin enough for the mounts to be screwed into the wall and protrude on either side. It was important that the BNC connections fully protrude on either side, because this enforces the cable connections and makes sure they are stable when students switch connections (one of our functions). We also wanted the wood to be thin so the whole prototype would be lightweight and user-friendly, two of our main objectives. Once all of the wood pieces were cut and thinned to size, we drilled holes into our BNC mount wall. We began the process with careful measurements for hole placement, and drilled started holes into the wood to make the holes from the wood mill cleaner. After this, we sprayed all of the pieces with a waterproof sealant to ensure that our design wouldn’t absorb condensation from the surroundings, which was a request and constraint from Prof. Spencer.

Once we built all of the individual pieces, we began assembly. We secured the base of the design to the walls using wood screws. Rather than just using wood screws to attach the shelves to the wall, we decided to include extra reinforcements by adding shelf support pieces beneath them. We decided to satisfy our objective and function of ensuring that our system was stable when holding the weight of all 50 ft of cable. Figure 1 shows the built and assembled final prototype.

Figure 1. The image on the left shows the front view of the prototype, and the image on the right shows the side view, highlighting the wall with the BNC mounts.

Evaluation Plan

- Have Prof. Spencer test the prototype in his Radio Frequency lab
  - We will have Prof. Spencer performs the usual TDR using our prototype. We will get verbal feedback on how easy our prototype is to work around.
- Testing if our shelves can hold 50 feet of cable
  - We will put a 50 foot coil of BNC cable on the shelves and see if the structure can support that weight. Any warping of the wood or breaking of the structure will indicate a failure to support 50 feet of cable.
- Testing if our prototype is waterproof
  - In order to test if our prototype is water proof we will put water on the shelf and check to see if it got absorbed by the wood. If the water beads on the wood's surface and is easily wiped off then we will know our prototype is waterproof.
- Simulate earthquake/bumpy environment to see if the cable connected are still in place
  - In order to test stability we will connect our BNC cables in series using the through connection and then run a sinusoidal function through the BNC cables using an oscilloscope. If the sinusoid remains unchanged by shaking of our shelf then we will know that the connections are stable.
- To test non-conductivity and to see if any voltage is lost, use a voltmeter.
  - Using a voltmeter we will put the positive and negative probes to both sides of the wood and see if a charge is successfully passed through by listening for a beep. We will do the same with the passthroughs.

Evaluation Results

Our group's evaluation results were focused on assessing how well the prototype fulfilled our project's main objectives, constraints, and functions. As mentioned above, when Prof. Spencer performed TDR in his lab space using our prototype, he mentioned that he liked its size. He told us that he liked that it was narrow enough to slide into the back of the lab bench, as shown in Figure 2. He also mentioned that he thought our design was aesthetically pleasing and fits well within his lab station. Therefore, we concluded that the constraint of our prototype fitting within a 50 cm^2 lab station was satisfied. When working with the prototype, Prof. Spencer was also able to fit his hands into the shelves and manipulate the BNC connection points to assemble and disassemble the oscilloscope cables from the wall with the BNC mounts. He was able to work and move around it quickly without structural hindrance, which ensured that our design was user-friendly (one of our objectives). He From these tests, we were able to conclude that our prototype was easy to work and move around, even in a tight lab space.

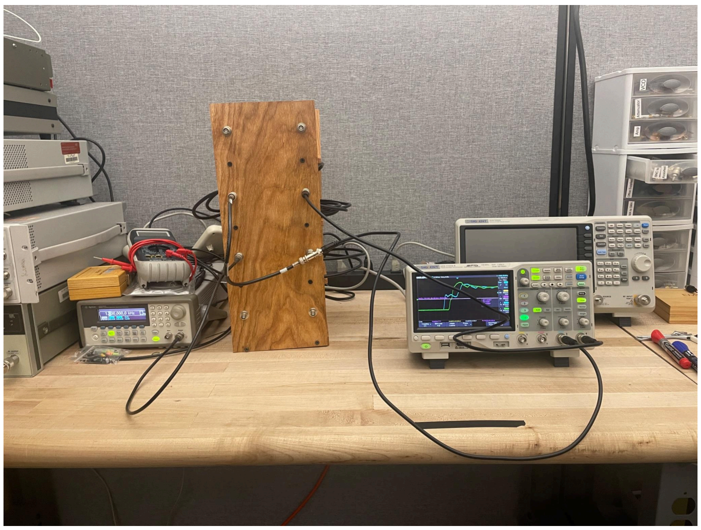

Figure 2. This image depicts our prototype at work in Prof. Spencer's RF lab.

For the second question we were evaluating, our tests concluded that all of our shelves can hold the maximum weight of 50 ft of cable with no significant amount of twist on the cables (as over-bending can cause varying results in the experiment). The design was stable when the weight was placed on all the shelves, as we did not see the wood bending or moving from the weight of the cables. Also, when Prof. Spencer was working with the design, we told us he appreciated that the design was stable and solid. However, we noticed an inconvenience when Prof. Spencer was working with the design. He typically tends to make the coil of the cables very large, and this large diameter did not fit into the shelves, so he had to recoil the cables to be slightly smaller. Although this did not seem like a significant problem, to increase the ease of use, if we had more time, we would alter the dimensions of our prototype to make the surface area of the shelves larger to accommodate for the large diameter of the coil.

Figure 3. This image depicts us using a voltmeter to test whether or not our prototype was conductive.

For the third question we were evaluating, our tests concluded that our prototype was waterproof. When we put some water droplets on the surface of all the shelves, we took note that visually, the water droplets remained droplets. They did not get absorbed into the wood, so we were able to conclude that our prototype was waterproof and would not absorb moisture, as this could possibly alter the results of the lab. For the fourth question we were evaluating, our tests concluded that our prototype was nonconductive. As shown in Figure 3, when both sides of the wood were in contact with the probes, zero volts were recorded. Therefore, we were able to conclude that our prototype was non-conductive, which means that it won't interfere with the signals and results of the experiments performed in E157.

Figure 4. This image depicts the setup for testing the fifth question of stabilizing cable connections.

For the fifth question we were evaluating, our tests concluded that our prototype stabilized the connection points. When we simulated a bumpy environment by pushing and flicking the connectors, we noted that they were able to maintain the cable connections in place, as in the cables themselves did not become disconnected. We also noted that the signal in the oscilloscope, which looked like the signal shown in Figure 4, did not become disrupted when we simulated the bumpy environment. This allowed us to conclude that our prototype will stabilize the connection points and the signal when bumped or moved. Throughout the whole evaluation process, the connectors and cables stayed in place without being permanently attached to the prototype, and the prototype as a whole was stable. As shown in Figure 4, we also informally tested whether or not the cable connection points were functional. Connecting the cables in series, both through and not through the connection points, produced the same signal, allowing us to conclude that our cable connections were functioning properly.

Figure 5. This image depicts the TDR signal that was produced when using our prototype.

Based on the output signal shown by the oscilloscopes, which is shown above in Figure 5, Prof. Spencer concluded that the output did successfully improve the signal stability compared to the previous compiling methods of E157 students. The goal is to have the signals on an oscilloscope to display smooth step response without many bumps. The signal shown above also displays the correct pattern as the input impulse generator, which means that our cable connections were working properly. We saw two step responses in the blue line and one in the green line, which were the desired responses. We further tested how well our design could stabilize the signal by shaking the cables outside of the shelf that connected to the oscilloscopes and also cables on each layer of the shelf design. Due to the connection separation of BNC passthrough, the signal didn't change when Prof. Spencer shook the outside wires hanging from the shelf. However, the signal did shake a little bit when Prof. Spencer shook the cables on the third layer. There was also a slight overshoot in the green signal, which according to Prof. Spencer could be caused by the BNC pass throughs being loose. We later addressed this issue by further tightening the screw that mounted the BNC passthrough to the side wall. Overall, Prof. Spencer agreed that our design is solid in quality and would help E157 to get more accurate results during their TDR lab.

Based on the overall results from testing the prototype, we as a group feel confident that our design and final prototype meets the needs of our client, as it passed all the evaluation tests and meets all the necessary objectives, constraints, and functions.