Don't Crack Under Pressure: Creating a Pressure-Tolerant Circuit Board

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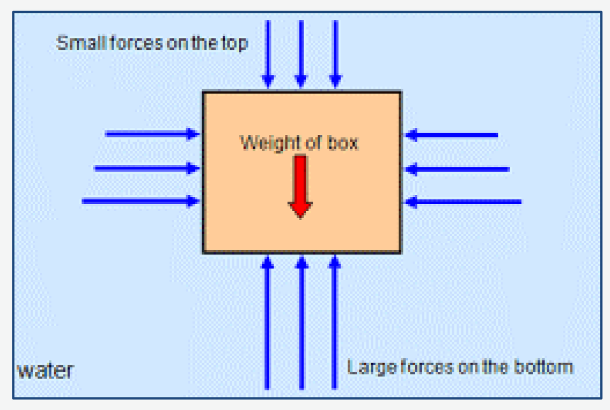
Introduction

The U.S. Navy utilizes many underwater electronics such as communication cables that are laid underwater at great ocean depths. In the ocean, the farther you go underwater, the pressure exerted on an object will increase. As a result, the electronics in these cables must be protected from all the external pressure. The current technology that the Navy utilizes is to place the electronics inside metal canister pressure vessels. The problem is that the canisters are designed to withstand specific pressures. Therefore, the farther down an electronic has to go, the larger the canister it requires despite how small the electronics inside may be. This way of housing electronics is inefficient and can very costly because transporting 100 canisters to lay communication cables underwater costs a lot in fuel given their heavy weight .



Compressive forces exerted on an object increase as water depth increases

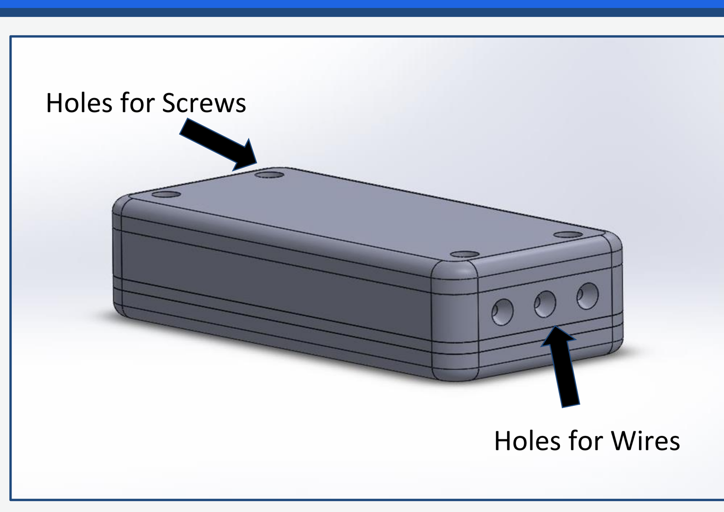

Metal Canister
Length: 11 in. Diameter: 4 in.
Weight: 20 lbs. Rating: 2,000 ft.

Approach

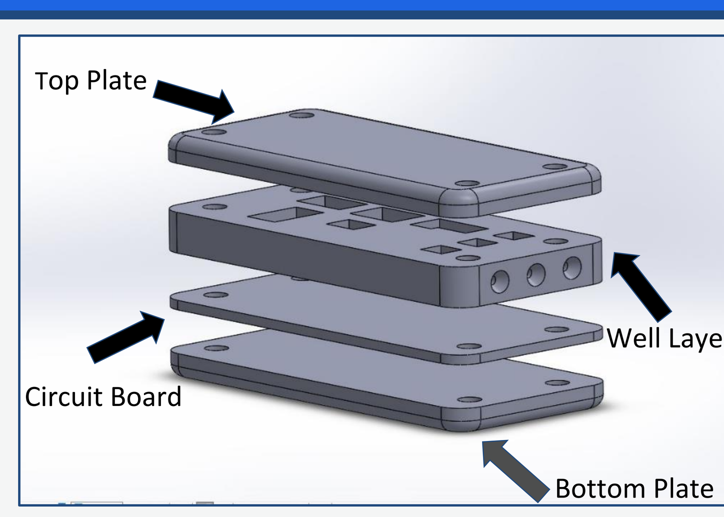
Goal:
Find a new innovative way to house circuit boards to replace bulky canisters.

Requirements:
- Pressure tolerant to 2,500 psi (5,000 ft.)
- 80% weight reduction from canisters
- Design, manufacture, and test in-house

Design and Materials

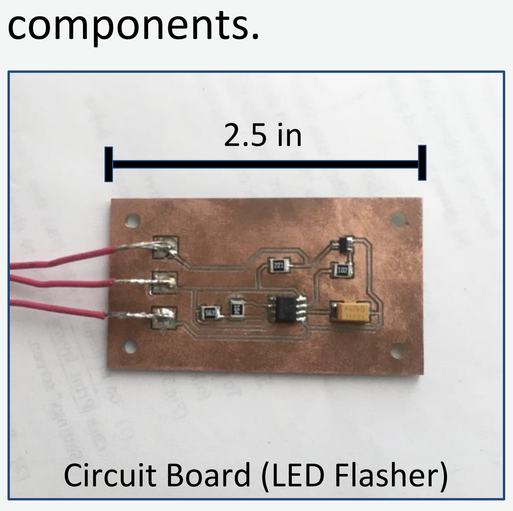


Collapsed View



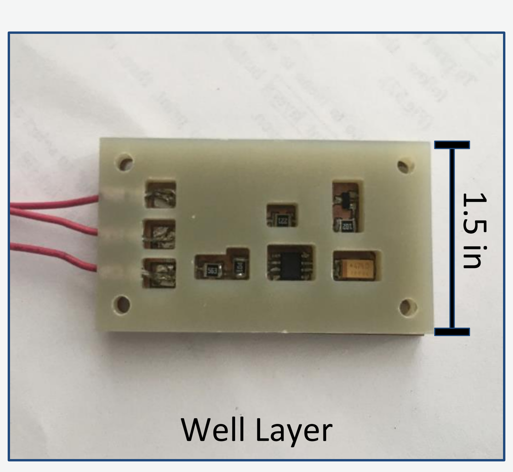
Exploded View

We designed a compact case made up of 4 layers. Two layers made up the top and bottom plate, one layer was the circuit board itself while the other was a well layer. The circuit board layer was going to be a LED flasher composed of surface mount components.



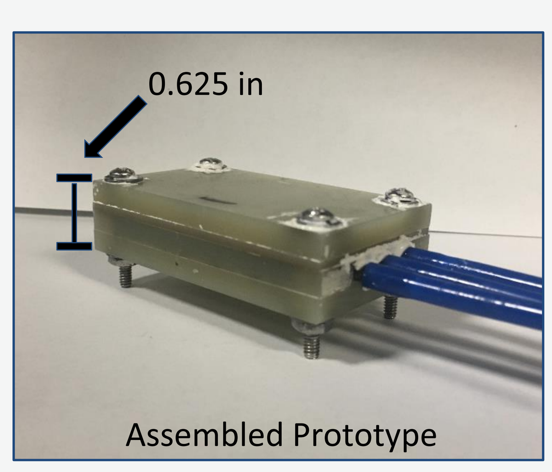
Circuit Board (LED Flasher)

LED flasher served as simple circuit that we would able to design in-house. It would also be a convenient way to test our case in the Deep Oceans Lab.



Well Layer

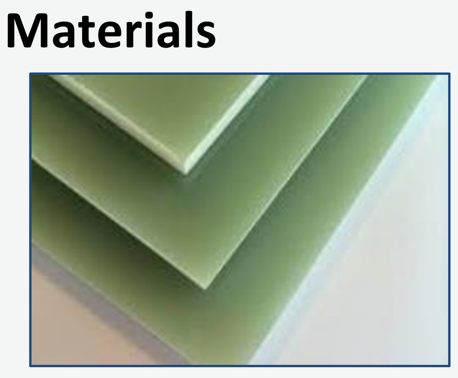
The wells act as a barrier if top plate were to deform due to compressive forces. This ensures that electronic components are not crushed.



Assembled Prototype

Screws were placed to prevent any shear between plates and to hold JB Weld Epoxy strong between the plates. The case was then dipped in Dichtol to seal any gaps or capillaries.

Materials



Garolite Fiberglass (G10)
- Fiberglass
- Low moisture absorption
- High electrical insulation
- Compressive strength: 35,000-68,000 psi
- Tensile strength: 32,000-40,000 psi

J-B Marine Weld
- Pressure-Tolerant epoxy
- High strength
- Waterproof
- Designed for marine applications
- Tensile strength: 3,200 psi

Dichtol WFT 1532
- Capillary sealant
- High strength
- Compressive strength: 5,000 psi

Testing and Results

Testing was conducted in the Deep Oceans Lab (DOL) in the Port Hueneme Naval Base. The 72 inch pressure chamber is able to recreate pressure of up to 5,500 psi, which is approximately 11,000 ft. underwater. We tested our design up to 4,500 psi even though our requirement was to only test to 2,500 psi. We inserted two prototype cases at the same time with their own LED light to monitor two at a time. One was set up to be flashing, while the other one had constant light.


Pressure vessel sealed with the prototypes inside

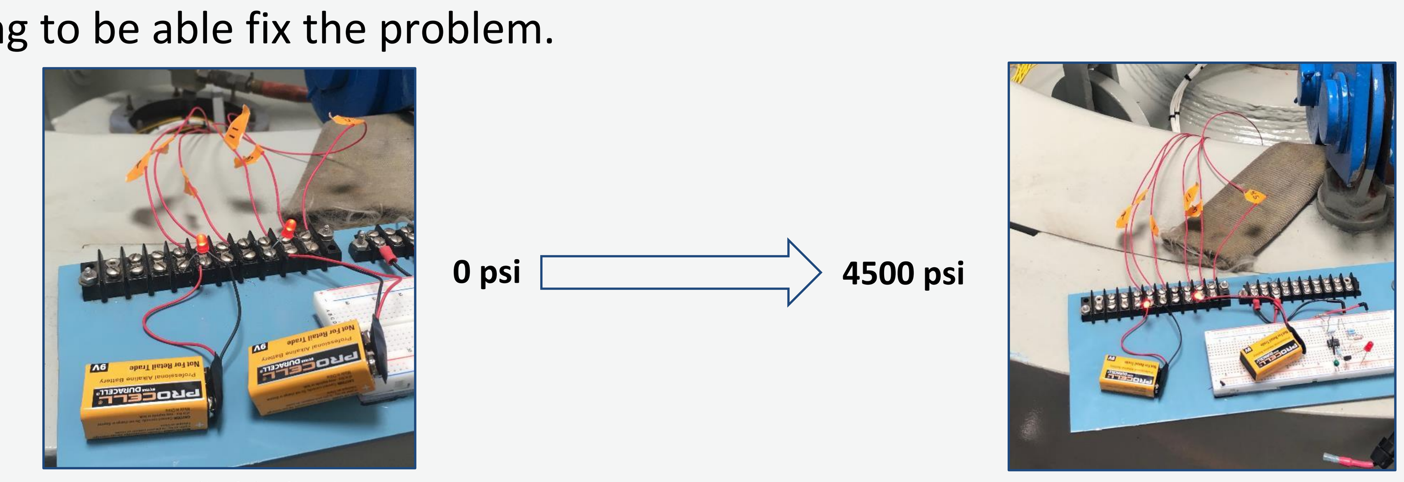

Cases were placed inside bags in case they shattered or failed

Testing Procedure

1. Set up chamber with our 2 LED lights.
2. Increase pressure in intervals of 500 psi at a time.
3. Wait 5 minutes of dwell time between each interval to settle down
4. Decompress in intervals of 1000 psi at a time.

Results

Our constant LED light successfully stayed on all the way to 4,500 psi. Our flashing LED light kept flashing until the increase in pressure from 2,000-2,500 psi. The flashing stopped, but the LED remained on to 4,500 psi. During the decompression interval of 1,500 psi, the LED started to flash again. We are trying to investigate why this happened since the light did not actually go off. When removed from the pressure chamber, there were no noticeable cracks or deformation on the casing. This is why our initial thought was that one of the wires had a bad connection. Especially because before the testing started, the LED stopped flashing but was fixed when the wire was tightened slightly. To make sure, we are investigating everything that could have gone wrong to be able fix the problem.



Circuit 1 (left): flashing
Circuit 2 (right): constant

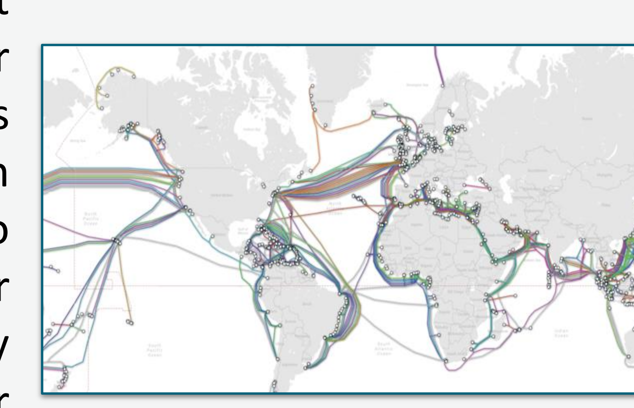
Circuit 1 (left): constant
Circuit 2 (right): constant

Future Work

Future work includes testing the prototype again to see if the same issue arises and making any changes necessary to ensure the electronic components are not affected by the increasing pressure. Once the design is set, tested thoroughly, and has proven to not fail, this approach can be used to incorporate fiber optic cables and more complicated circuit boards that may be more practical for the Navy's needs.

Conclusion

Our results were favorable as we were able to at 4,500 psi, which was significantly higher than our 2,500 psi requirement. Our whole case weighed less than 2 pounds achieving a 90% weight reduction in comparison to the 2,000 ft metal canister and go more than 3 times deeper. It is worth doing further research in pressure tolerant electronics as the Navy continuing to expand their underwater communication cables. Our approach can save the Navy a lot of weight and space on ships when deploying these cables around the world.


Map of Naval Undersea Fiber-Optic Cables 2015

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