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TRP: Waterproofing Technology for Embedded Devices

Section I: Introduction

Embedded devices, known for their convenience to prototype with, have relatively exposed elements on them that are water-sensitive. If not treated carefully, even a little exposure of water on these components can cause significant damage to the system, causing the system to crash, have forced reboots, lose data, or even permanent damage the hardware. Since our team project will expose our embedded systems to significant humidity or even direct exposure to water, making the system waterproof in a effective and efficient way is crucial to the reliability of the system. In this technical review paper, several waterproofing technology widely used for embedded devices will be discussed.

Section II: Constraints & Requirements

Although waterproofing is common for electrical devices, the nature of embedded devices put some constraints on our choices. First of all, the implementation of such technology should be cheap. There is no point to use some technique that costs 10, if not 100 times the cost of the devices themselves. Second of all, the technology should be easy to use and modular. This is because in rapid prototyping we want to quickly disarm/arm our devices repeatedly. Last but not least, the technology should comply with the hardware constraints of the devices (for example, a technology that gives waterproofing ability but causes heat dissipation problem would not be considered valid).

Section III: Waterproofing Technology for Embedded Devices

Candidate I: Waterproof Case with Heat Glue/ Other Additive Sealing Substance

There are a lot of waterproof cases for embedded devices on the market. Though all of them are mostly made in polymer (plastic), their external connectivity and sealing abilities differ. Some have built-in holes on the walls of the cases[1], while the others require one to drill holes on the walls and then seal the hole with heat glue, silicon or other materials[2]. A lot of embedded device hobbyists use this technique to protect their outdoor devices and these cases have been proven trustworthy. Most of the times the device is insulated from water, and even when a little water leaks in, the heat generated by the devices drives the water and vapor eventually out, keeping the inside of the case dry.

The effectiveness of these cases can usually be indicated by their IP ratings[3].

This collection of products are generally quite expensive, with prices ranging from $10 to $30 per case. Their waterproofing capabilities are decent, but don't match with their costs -

especially those that we need to modify with drills. These products are highly modular, as they are built and tethered towards makers' needs to access the internals frequently. Overall, this is an effective approach, but not the most economic one.

Candidate II: Potting Compound - Silicone and Epoxy

A lot of industry-level electronics products use this technique to give full protection to their water-sensitive or magnetic-sensitive parts[4]. This technique requires one to drown the device in a fixed-shaped pot filled with insulating liquid that hardens (called the potting compound), and one ends up with a solid brick of insulating material with the device enclosed inside. If any connectivity is required, the wires will poke outside the brick and be exposed. In which case waterproof connections will be required[5]

The most generally used materials for potting are silicon[6] and epoxy. Gels made of other materials are also available on the market[7]. What differentiates these materials from one another is not just insulation capabilities, but also their different melting points. And melting point is definitely a point of interest because insulating materials usually create completely enclosed space where heat can't be dissipated easily. For example, Urethane has a melting point of below 125 degrees Celsius and is therefore not ideal for embedded devices that can sometimes go up to 90 degrees Celsius on the processors. Epoxy lies above Urethane at about 180 degrees Celsius, and Silicone stands at 250 degrees Celsius, being the safest thermally among the three.

Although this is an extremely effective technique to give the device the ability to be fully soaked in water and still be functional, it carries little to no modularity. If we want to have access to the device inside, we have no choice but to break the entire coating apart and re-pot as we need. The cost of these materials vary, but are generally below $4/oz.

Candidate III: Tupperware

This technique is not an official solution to the problem but has grown a lot of popularity among the hobbyists due to its cost-efficiency and reliability[8][9]. Some even use this for their arduino/raspberry pi boat projects, which itself is a testament of this technique's effectiveness.

Compared to raspberry pi / arduino waterproof cases on the market, tupperwares are equally, if not more, effective in insulation. What's even better is that they are generally cheaper than those cases. They are also quite modular as well - one can lift and remove the covering insulating lid with rather ease. The drawbacks are that 1. we will need to manually drill holes and seal the holes and 2. the dimensions of tupperwares aren't tethered for embedded devices so one might need to find ways to mount the devices onto these tupperware.

Section IV: Conclusion

Though there are many ways to approach the waterproofing problem in embedded devices, a seemingly sketchy approach of using tupperware is gaining a lot of popularity due to its cost efficiency and overall effectiveness.

Appendix: References

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