Design Issues

ECE 480 - Team 10

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The requirement for our project was to develop a universal interface for current and future thermostats. A new thermostat is also being developed, but the interface plate is crucial. The aspects of Product Lifecycle Management (PLM), from design to disposal, must be considered for this project. Key factors, such as product lifetime and component choice, needed to be considered.

PRODUCT LIFESTYLE MANAGEMENT (PLM)

An important requirement, emphasized by our sponsor, is that our interface plate be functional for many years after installation. It is desired that our interface plate be usable for any future thermostat and allow for an easy upgrade to better technology in the future. To that end, we have designed our product with future usability in mind, both inside and out.

The physical structure of our interface plate is built for long-term use. First, we have designed our product to fit into a standard electrical box. This allows for our wall plate to be easily mounted to studs in new construction, or to be attached to drywall in existing homes. Using a standard size box makes it easy for contractors and installers to mount and wire the device, and assures that our product conforms with any construction codes. Also, standard plastic or metal electrical boxes are very inexpensive, but will last throughout the lifetime of a home.

The faceplate has also been designed for easy, lifetime usability. Utilizing a hard plastic and mounting screws, it will also feature an RJ-45 connector mounted in the middle which provides the connection to any future thermostat. An RJ-45 connector is the same as a standard network (Ethernet) jack, and can be plugged in and removed thousands of times without failure. This assures that old devices can be removed from the interface plate and new ones installed for life. Metal mounting lugs on the faceplate provide the connections to use the faceplate with current thermostats on the market. The faceplate is designed for durability, and should last as long as necessary.

Finally, the internal electronics of the wall plate interface were chosen to provide a lifetime of adaptability. There are technologies on the horizon which will put information on the power grid. These so called “smart grid” projects will encode data such as time of day pricing and load characteristics over power lines. These features are in development, but are not yet working. By utilizing a PIC microprocessor as the “brains” of the interface plate, we have provided an upgrade path using flash-based reprogramming. The PIC microprocessor can be reprogrammed via a USB interface. This will allow the device to be updated when the “smart grid” technologies become viable to increase energy conservation. The PIC also has a number of general purpose input/output (GPIO) ports. This assures that future data inputs and outputs will be available when technologies are changed or upgraded. The electronics of the universal wall plate interface will be adaptable, allowing the product to last decades into the future.

One area in which a design trade-off was made was in the use of standard coil relays. We originally wanted to use solid-state relays in our design, because they have no mechanical parts. Standard coil relays have moving parts, and could wear out after many on/off cycles over many years. However, they are much less expensive than solid-state relays while still providing reliable performance. The use of solid-state relays would have significantly increased the cost of our product to an unacceptable level. In the end, the choice was made to use standard relays over solid-state relays to contain costs while still providing functionality.

Recycling issuses have also been considered. Non-volatile memory was chosen to be used in our device to avoid the need to use batteries to maintain data during power loss. Not using a battery means that it does not have to be replaced or maintained, and that there is no issues with disposal of some of the more potentially dangerous chemicals and metals that are found in common batteries. Some batteries, such as lithium-ion batteries, could explode if overheated, so their use was avoided also.

We tried wherever available and when the space could be afforded to use DIP components. These types of components are friendlier towards the scavenger or hobbyist who typically salvages components off of old electronics boards to be used in everything from homebrew robotics to building radios. This offers a second life to some of our device if and when it was ever disposed of, offering less waste in the end of the products lifecycle. We also would use easily recyclable plastics which could be used in other products later. It is also important to us to use lead-free components, to keep hazardous lead out of landfills. These aspects help keep the cradle-to-grave philosophy active, and assure responsibility on the design engineer's and manufacturer's part.

SAFETY

One of the major concerns of our design is overall safety. A desired outcome of our project is that our device will eventually be installed in homes throughout the state and nation. A consequence of this is that the device must be thoroughly tested for safety before mass deployment. If not designed properly, our product could cause heating failures, house fires, or shock hazards.

The first aspect of safety comes from the power supply design. Our product gets its operational power from the 24 Vac furnace transformer. We have designed a power supply which converts the 24 Vac to +5 Vdc needed by the internal electronics and relays. The power supply needed to be stable with a significant load, while not getting too hot. Our switching supply was tested extensively, and produces steady voltage at nearly twice the current that should be needed during operation. The regulators and other components stayed cool to the touch while running for 2 hours under full load. We feel confident that the power supply is safe for use.

One negative aspect of using a switching power supply is that it creates EMI noise due to the switching circuits. This could be problematic because without more testing, it may be in violation of FCC emissions regulations. If the noise is significant enough, it could interfere with other electrical equipment in the home and beyond. Under the right conditions, the noise could even interfere with the device itself. Our design has not been tested for EMI radiation, but this is an issue that would need to be addressed before the product was mass produced.

Because our product is connected to a significant source of AC voltage, it is imperative that it is installed by knowledgeable people. While 24 Vac is not extremely high, it could hurt some people, especially those with certain conditions or illnesses. We have designed our box to take the 24 Vac lines in a safe manner, and to make sure that it is not possible for a user to come in contact with the high voltage. Even so, it is important that a professional install the device initially while making sure that the circuit breaker for the furnace is turned off. Once the plate is installed, the user can change the thermostat without help as simply as one connects or disconnects a telephone from a jack.

ADAPTABILITY

Adaptability is one area of focus where our project can be improved. While the wall plate is not very interactive, the thermostat is directly used and manipulated by the customer. What we have developed thus far is not very friendly in being useful to persons with some types of disability. Someone with bad eyesight might have difficulties reading the screen and making changes or adjustments. One possible way to address and fix this in the future is to offer larger text size, or make text size be adjustable to the end user. In addition, a completely blind person would have even greater difficulties. A solution to this would be to label buttons in braille, and to have an audible signal that would help the user know the current settings and options. Other possibilities that could be explored would be to have the device respond to spoken commands for someone who is not able to manipulate the controls. A sip and puff interface could also be integrated. Making the device disability-friendly, while not a main priority for our product at this stage, is important to think about in looking at the overall big picture.

ENVIRONMENTAL

Environmental needs play a large role in the development of our product. Michigan is currently the highest state in terms of fossil fuel usage for energy. The idea behind developing a thermostat that uses the ASHRAE comfort index standard is heat and cool a home more efficiently and frugally. The ASHRAE comfort index was composed of a complex study relating humidity and temperature to the comfort of the majority of people. It correlates temperature and humidity to a given comfort index, essentially a rating of how comfortable a person felt in that environment. The goal for our thermostat is to use less energy to maintain personal comfort, which in turn requires less usage of fossil fuels to provide the power to the HVAC system. Our responsibility when creating the software control for controlling the usage of heating and air conditioning was to use the ASHRAE comfort index to accurately determine a temperature, given the current humidity in the air, to keep a house at. Current thermostats only consider the temperature that the homeowner sets to request the proper HVAC services. This is quite inefficient, because depending on the moisture present in the air, that temperature can actually be much less comfortable than one that would require less heating or cooling to maintain. By considering this effect, we will control the HVAC system in a more conservative manner. When one considers the scope of this project, being applied to the entire residential population of the state of Michigan, the potential savings for this product are enormous financially, but more importantly, environmentally.

CONCLUSION

There have been numerous factors for our design team to consider during the development of this project. As future engineers, we cannot only consider the immediate, bottom-line impact of our products. Our duties and responsibilities implore us to make sure that safety, environmental, recycling, and accessibility factors are all part of the design process in order to create outstanding products.