Wireless Sensing System for Intelligent Concrete Curing

Design Issues Paper

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Section 1: Product Lifecycle Management

Product Lifecycle Management (PLM) is a process of planning the whole lifetime of a product from the initial conceptual stages of development, through the design and manufacturing, use of product and to the time of retirement. Our design team has broken the PLM down into following stages: design and development, production and retirement. Each of the stage was considered carefully to maximize the efficiency of the PLM.

1.1 Design and Development

In the preliminary stage of design and development process, the needs of customer are carefully assessed. In our case, the customer, Texas Instrument (TI) is looking for a wireless system that integrated TI components to collect and display data that would indicate the health of curing concrete. To meet this goal, a sensor board was designed with all TI analog components such as Op-amp and DC-DC converter, interfaced with TI uMAVRK module, sample the signal and transmit through the RF module and finally display the signal on the GUI designed in LabView.

1.2 Production

Cost of production is always a concern for the customer and since this product is intended for single use only, the cost needs to be reduced as low as possible. There is not any cost on the developed GUI or from the software on TI uMAVRK module. The main cost will occur from the hardware components and physical production. Mass production will drastically reduce manufacturing expenses. Another production focus for the customer is the time period of actual manufacturing of the product. The total manufacturing process generally takes about two to four weeks for a small production amount which will affect the whole project timeline. These time constraints need to be considered in the early design phase to produce a quality product without delay the project timeline.

1.3 Retirement

The product is intended for single use to monitor the health status of concrete curing. The item has been designed to be incorporated into the concrete that is curing and remain buried into the concrete structure. There will not be any product disposal concerns to address upon it’s retirement. Expected life for this current version of the product is about twelve months, but could be nearly unlimited. Several RF energy scavenging technologies are available to utilize and should be considered for inclusion into the future modification of this product design. Using such technologies would easily support the potential of an infinite lifetime without having to change the general framework.
Section 2: Universal Design Features

2.1 Ease of Use

The present sensor system has a number of aspects which make it accessible for most users. There are also several features which can be improved or added to broaden the usability of the product. Following universal design, the sensor system is simple, intuitive, flexible, and requires little effort to use. Anyone who is able to mix and pour concrete is more than able to apply our product. Simplicity is achieved by implementing a physical system which only needs to be turned on and submerged into freshly poured concrete. The software and information portion is simplified by being contained within a plug-and-play USB package. The wireless connection between the components eliminates any confusion with wiring. The goal of the product is achieved with two major components and requires no additional effort such as drilling into a concrete structure. The robust, protective enclosure and method of obtaining moisture and temperature readings gives the product flexibility to be used outside of the intended purpose of concrete curing. The user interface provides a good first step in providing information, using thermometers and speedometer-style graphics which are large and clear to display the data from the sensor. These features of the Design Day demo follow universal design principles well.

2.2 Potential Improvements

The commercial application has ample room for improvement in the physical design and programming features to make the system even more accessible to a variety of users. The presented data is currently not particularly equitable for domestic use. If a homeowner wants to use the product to make a conclusion on whether or not his or her new driveway has cured, they would have to make decisions about the data readings that are more suited to a civil engineer. To allow all users to understand results from the system, algorithms for various types of concrete would have to be developed and programmed into the software which clearly interpret the signals to state that the concrete has cured based on the data gathered by the sensor. The demo design has little tolerance for error. Presently there is no ability to detect the level of the battery power and in lacking such detection one might use the system when it is on the verge of being powerless. If the battery dies while the system is in use, the status of the concrete can be incorrectly judged resulting in failure of the product’s goal.
Section 3: Energy Use Considerations

3.1 Accuracy

There are power consumption issues that are evident with the present design. To supply relevant information to the microprocessor of the μMAVRK, amplification and filtering are needed and the integrated circuits (IC) need to meet proper accuracy and minimal power consumption requirements. Due to a steady decline in supply voltage from the power module (2 AAA batteries) being used, a voltage regulator is necessary.

3.2 Extending Battery Life

The sensing node consists of a sensor board, a μMAVRK, and a power module. Since the entire sensing node is going to be buried under the concrete during the period of construction, the entire sensing node must be energy-efficient. The time period for concrete to become fully cured has been estimated to be three weeks. The energy efficiency of our sensing node is assumed to support continual sensing process and data transmission for at least three weeks without changing the AAA batteries. The typical capacity of a Li-FeS2 AAA battery is around 1200mAh. The present design has two AAA batteries in parallel, giving a total capacity of power of about 2400mAh. Based on the simulation and actual test of the current consumption for each of ICs on the sensor board, the total current of the active sensor board plus the moisture sensor is about 2.43mA+7mA=9.43mA. The current pulled by the μMAVRK is about 8mA when it’s sending out the data through RF. The result of total current consumption is about 17.43mA for signal conditioning and data transmission. A simple calculation for the battery life indicates 2400mAh ÷ 17.43mA = 137.7h ≈ 5.73 days. Five days is not long enough to monitor concrete which can take twenty-one days to be fully mature. In order to meet the requirement of the three weeks, it is necessary to find ways to save the battery power. Lowering the sample frequency could be an option to consider. The present sample frequency utilized is approximately 1Hz, but may be reduced from taking one sample every second to taking one sample every ten minutes. Another possible modification to extend the power life would be to shut off the whole system and set the microcontroller into sleep mode, between the 10 minute time frame. This would significantly extend the battery life of the transmitter, adding to the reliability of the product and preventing poor assessment of cured concrete. Improperly cured concrete is weak and can lead to structural dangers that set the stage for accidents, injury and possible disaster.
Section 4: Regulations, Environment and Liability

4.1 Regulations

The main target of our product is the construction industry. In such a dangerous field environment, it is imperative to have strict safety practices in order to ensure the protection of the construction workers as well as end users. When designing any electronic device, it is important to keep in mind the emission regulations. These regulations ensure that your device is not susceptible to being interfered with and/or interfering with other devices in its working environment. As with all their commercial products, Texas Instruments goes through all the necessary procedures to obtain certifications to prove their devices fall within safe emission levels of the CISPR regulations system. The modular MAVRK development system falls under the same scrutiny and has passed emissions testing in a study done at Nemko Labs. Limited information is available with regards to our non-TI based components including our own fabricated PCB board. Prior to manufacturing this prototype for commercially available, the entire prototype would need to undergo regulatory testing to certify the product is working within CISPR regulations.

4.2 Environmental Considerations

Texas Instruments also aims to design products that have minimal impact on the environment. The majority of their products are under “Restriction of Hazardous Substance Directive” or RoHS compliance. The MAVRK development boards we employ in our project are marked with “Pb Free” logos which indicates that they satisfy TI’s “RoHS Material Declaration Certificate” which acknowledges that minimal to no harmful materials are used in the fabrication of their product.

4.3 Liability Issues

Construction projects that fail, whether finished or under completion, can have devastating effects on anyone unfortunate enough to be caught in harm’s way. Auspiciously, the industry has a fairly good grasp on determining the strength of their structural projects. The number of structures that collapse must be relatively low or the industry wouldn’t continue to produce the large structural masterpieces throughout the world today. Our product only aims to give a better estimate on the status of curing concrete these building scenarios. The data made available to our product user serves as a mere estimate. The product makes no attempt at acknowledging the concrete structural integrity. The sensing system can only provide characteristics of the drying concrete which can better aid in judging the status of the curing process. Reiterating; knowledge of the curing characteristics should be regarded as an estimate. Should the product become commercially available, the necessary steps would be taken in order to ensure that the user is aware of this in the form of disclaimer. This would ensure that should a construction project result in a disaster, none of the liability will be placed on our product.