

Wireless Sensing System for Intelligent Concrete Curing

Sponsor: Texas Instruments

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Introduction:

Concrete work, whether residential or commercial, is a costly investment that can impede on one's business or personal convenience during the curing process. Construction companies give an arbitrary duration of time for people to be able to drive on the concrete. This recommended time is a generalization that does not consider variable temperatures and humidity levels. Since concrete has varying set-up times, it would be very beneficial to be able to know the exact time the concrete is cured to optimize business production.

Texas Instruments has taken interest in designing a system that would relay information of two important parameters, temperature and humidity, to a customer to inform them when they could begin driving or walking on their new slab of concrete. The desired specifications for this particular project, unlike any other product, are wireless communication from the sensors that have been sprinkled into the freshly poured concrete, to a centralized unit. The most imperative constraints for optimizing the designed system are power, accuracy and range.

Background:

This idea has received plenty of attention over the past 15 years. Research papers such as, "Feasibility of Embedded Wireless Sensors for Monitoring of Concrete Curing and Structural Health," by B. Quinn and G. Kelly, have concluded that these sensing units are very achievable. Currently, there are a multitude of companies, such as Engius who developed IntelliRock systems that have released similar sensing units with varying amenities. However, all the products currently on the market are not wireless. The basis of these units require one to drill holes (around 5" by 1" diameter) in the hardened concrete in numerous areas, placing sensors in the holes that connect to a unit that receives information on the temperature and humidity. Texas Instruments are taking a new approach by making a wireless transmitting system, that when completed has a great potential of generating strong revenue.

Design Specifications:

For this project, we must design to and deliver end results in accordance with the specifications given below:

- Research, design, test, document and demonstrate a solution that will effectively measure the temperature and humidity inside a medium similar to concrete.
- The Design will consist of two main components, the μ MAVRK and the MAVRK. These platforms will be provided by the Texas Instruments. The μ MAVRK will then be divided into three sub-components, a Sensor Module, Power Module and the Radio Module.

- The MAVRK, Power Module and Radio Module will be utilized without altering the circuitry. The Sensor module will need to be re-engineered in order to meet customer requirements and specifications.
- Sensor module with μ MAVRK must be enclosed by non-metal material in order to prevent damage due to pressure and humidity. Sensor should be exposed out of enclosure to achieve accurate condition of concrete.
- Test environment for demonstrating the performance of sensor module must be made.

Customer Requirements:

The MAVRK, Power Module and Radio Module will be utilized without altering the circuitry. The Sensor module will need to be re-engineered in order to meet customer requirements and specifications. Due to the devices' unattainability once placed into the concrete, the μ MAVRK platform should consume a very small amount of power. Another option is to enable re-chargeable capabilities on to this platform. Customer has requested to merge power supply, sensor module and μ MAVRK into one single proto board as non-critical criterion. Lifespan of module needs to be at least longer than 3 weeks, considering experimental time needed for full solidification of concrete was 2 weeks. Module will be submerged into concrete. Sensor modules are specified to be one-time use device. Cost of module should be within range of reasonability. Criterion of defining solidification of data received is not objective of this project. Analysis of data received from sensor module will be performed by other team.

Proposed Design Solution:

i. Sensor module

In early stage of project, focus is on sensor module embedded with power source. Conceptual schematics provided below. Each sensor will be powered by P3.0/GPO1_0 (Pin 11 - 18 of μ MAVRK Analog Interface). Output will be amplified by LM774 (Operation Amplifier) and fed Analog Channel 1 - 5 (pin 21-26). CC430F5133 (MPS on μ MAVRK) will be programmed to convert analog input to digital output. Digital output will be then sent through M62071Q (RF antenna) to MAVRK for analysis.

Parts needed:

μ MAVRK (remote MPS430 processor)

LM34 (temperature Sensor)

ADC0804 (8-bit Compatible A/D Converter)

HIS100 (humidity sensor)

DF-40C-40DS-0.4V (40pin μ EVM connector interface)

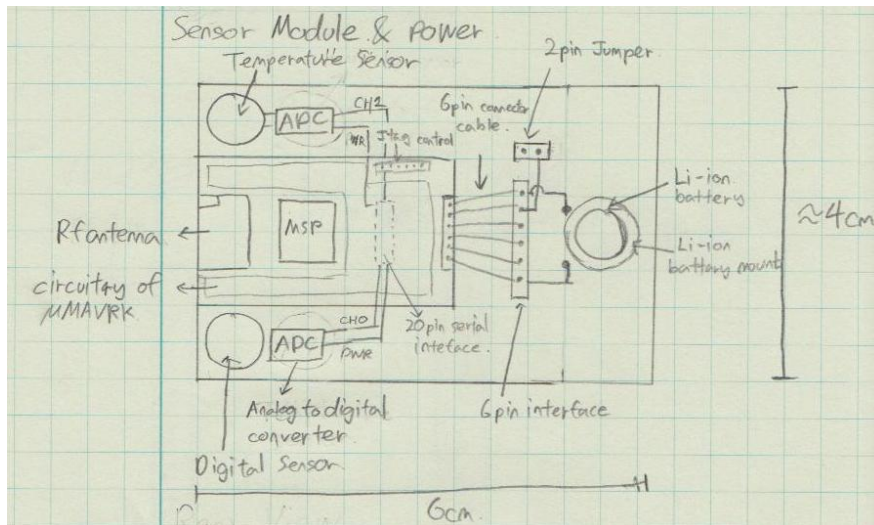
1060KTR-ND (Coin Cell battery holder)

LM774 (OP_AMP, to amplify output from sensors)

Miscellaneous circuit elements (RLC, diodes)

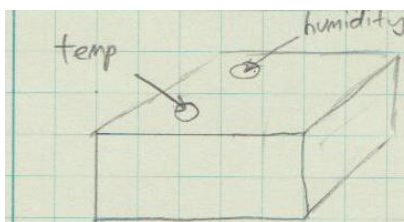
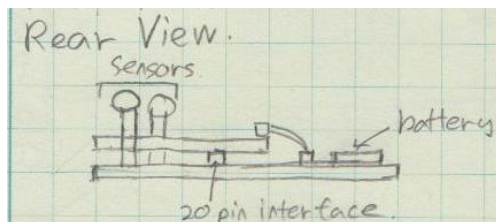
CM-74(plastic enclosure)

Conceptual schematics (top view)



Rear View

With Enclosure



ii. Test environment

Due to time constraints, testing the design while embedded in concrete is not applicable. In order to simulate this action, we propose two possible approaches. The first approach involves placing the μ MAVRK platform into a fish bowl filled with sand. To simulate the temperature changes found in concrete, a heat lamp will be placed near the bowl. Also to achieve the humidity simulation that occurs in concrete, the sand will be dampened with water. The second approach involves the same method of simulation; however crushed up limestone will be used instead of sand.

iii. MPS programing requirements

- Powering module on and off in specific time interval to increase battery lifespan.
- Changing analog input from sensors to digital
- Sending data through RF antenna provided on μ MAVRK

Risk Analysis:

Malfunctioning of development tool

- μ MAVRK and MAVRK is not a development tool in mass production state. There can be error within the development tool that cannot be fixed.

Life span of module

- Module must be in active state for minimum of two weeks. Using battery with large capacitance will solve the problem, but will increase the unit cost of module.

Field test

- Field tests are not likely to occur considering short time span of project. There can be issues which is not apparent on test environment level. Possible issues are :
 - o protection of module (pressure, temperature, humidity at practical environment might damage the circuit)
 - o frequency disturbance (due to low power nature of module, low frequency data transfer between μ MAVRK and MAVRK is likely to occur. Low frequencies are more likely to get distortion. Might limit signal range.

Project Management:

To optimize our project's duration of time we assigned individual roles to our team. These roles are designed to cover all aspects of the project that need a great deal of attention to meet our specifications in a timely manner. While our professor allocated non-technical roles to us, we took it upon ourselves to assign technical areas which best utilize each of our strengths.

Non-Technical Roles:

Kevin Yeh – Manager

Kyle Schultz – Website Preparation.

Jordan Bennett – Document Preparation and Lab Coordinator

Min-Jae – Presentation

Technical Roles:

These roles have been assigned in an attempt to cut down on time wasted. While we have split research and development of the areas pertaining our project, we will collaborate as a group to each aspect to assure proper design has been met.

Kevin - Although it is not clear if we have any software roles at this time, Kevin will most likely work on the MSP software when the issue comes up. Otherwise, he will focus on the other hardware

components like the band pass filter and Antenna with the other members of the group. More importantly Kevin will need to learn how Cadence Orcad works to lead the way in actual PCB Layout.

Minjae- Has expressed an interest in the RF technology including signal conditioning and wireless signal circuits.

Kyle – Research power constraints of modules to find optimal power levels based on robustness and range.

Jordan – Exploration in to hardware applications such as temperature and humidity sensors and their compatibility to μ MAVRK.

As a whole our group will accomplish the design and finally the demonstration of our project goals. To start off, we will begin the research of each individual component of the design. In research, we begin to analyze two things. First, each component must have input and output compatible with the rest of the design. Secondly, we must make sure it meets the design specifications of our sponsor such as low power, accuracy, range of signal, and robustness. For our research, we will look at data sheets, forums, and contact the company producing the parts we need. The final goal of the research phase is to finalize the required parts of our design. We will also buy the correct parts.

While the design phase is coinciding with the research phase, much of the work will also be done once we finish buying parts. We will begin using our theoretical designs and assembling our parts on the protoboard. As we assemble, we will continue to test as we progress, to avoid later issues. Testing as we go will ensure the functionality of our individual circuits, but it will not tell us whether we have met the design requirements of the system.

Although, we will test as we go, we will deploy a final sequence of test cases in our design. We will be testing the required specifications like the range/accuracy of our signal. Simulations through various software programs such as, PSPICE, will give us a better understanding of the conditions of which the product will be used. Although concrete may be a hard environment to produce, we can mimic the conditions with sands of many temperatures.

Our faculty member, Dr. Strangas, will be meeting with us every Wednesday at 8:30 in the morning. Working with him will help us move the project in the right direction. He will mainly be our point of contact in our questions about logistics. He will also provide suggestions on project management and how to allocate roles and resources.

- Project Schedule Time line – To be finished in Proposal
- Gant Chart – To be finished in Proposal

Cost:

Fortunately, TI has provided all of the expensive components involved in this particular project. The compatible software, the centralized unit (MAVRK), the debugging module and the μ MAVRK sensing module has all been given to us. Since we already have these units, the components needed to meet design specifications are at a very minute cost. Also, TI has a library of parts that can be obtained for free on their website, with restrictions to the quantity. We do not anticipate needing a large amount of TI available parts, which will not restrict our design process. The remaining parts not covered by TI will be humidity sensors, operational amplifiers and printed circuit boards. All of these parts we have looked into and cost no more than \$10 per quantity. We estimate our costs at a very pessimistic approach at \$100. This figure is well below our allocated \$500 budget, leaving us no doubt those additional funds will be needed for request.