Design of a Sensor Based Smart Sprinkler System

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ABSTRACT

For many states in the U.S., particularly southern states, droughts are a frequent
reality. Cities have vested interests to conserve their sparse water supplies, especially
in areas where natural bodies of water are virtually non-existent. The *Smart Sprinkler
System* will reduce the amount of water wasted through irrigation by utilizing sensor

inputs rather than time-controlled watering schedules. Field trials of our prototype showed that water conservation is achievable. Additionally, the *Smart Sprinkler System* avoids damage to lawn and flowers due to over-watering and under-watering. This type of damage is common in time-controlled irrigation systems.

INTRODUCTION

The University of North Texas at Denton is the third largest, single-campus university in Texas. The Department of Engineering Technology is one of the founding departments of the newly established College of Engineering. The department is ABET accredited and is one of 25 in the nation that offer undergraduate and graduate programs in Engineering Technology. The senior design projects class serves as the setting for the final, capstone project. Students work in teams (of 4 or 5 students) to propose, design, implement and successfully demonstrate the working of their project. Final presentations are made to an audience comprising faculty members and invited industry personnel from the area (numbering 20-25). Students are graded individually and in teams for technical content, demonstration and presentation skills.

Convenience is a major factor in driving technological innovations. Many of the products we use make our lives easier and we appreciate them for just that purpose. In fact, many of us are willing to spend much of our income on purchasing products that help us gain a little extra time to pursue personal interests. For many states in the U.S., particularly southern states, droughts are a frequent reality. Cities have vested interests to conserve their sparse water supplies, especially in areas where natural bodies of water are virtually non-existent. During times of water scarcity, regulations are often placed onto residential homes to reduce water usage. One of the first areas forced to cut water usage is usually irrigation of lawns and flowers [1]. Lawn and flower irrigation contributes to approximately thirty-five percent of water consumed in residential homes [2]. As one of the "thirsty" sources for water, cities continually ask citizens to use smarter irrigation systems that water when necessary using appropriate amounts [3]. The National Wildlife Federation states that adjusting ones irrigation controller "once a month to account for changes in the weather" is one of the easiest ways to conserve water.

In order to address the problem of 'smart irrigation' we formed a company called 'Smart Water Solutions' as a requirement for the senior design projects class. As fulfillment of the capstone project requirements, we took upon the task of designing a sensor based *Smart Sprinkler System.* The *Smart Sprinkler System* will fulfill the desire of people to automate tasks and to increase their level of convenience. The *Smart Sprinkler System* will give customers a similar convenience by enabling them to efficiently control their irrigation system via computer software. However, the *Smart Sprinkler System* goes one step further -- offering the most efficient way to irrigate, adjusting the amount of water used for irrigation every time the system operates.

POTENTIAL CUSTOMERS

The main groups of customers for the *Smart Sprinkler System* are homeowners, home builders, and small business and government institutions who consume considerable amounts of water for irrigation. Each customer group will benefit from the convenience the *Smart Sprinkler System* offers, while the entire community will benefit from conserving our water supply.

Homeowners will want to buy the *Smart Sprinkler System* to add high-technology and convenience to their outdated systems. Running sprinklers solely on timers is inefficient and arcane. In the *Smart Sprinkler* System, sensory inputs will determine how much water should be used to effectively irrigate. Customers will enjoy an easy-to-use computer interface to conveniently set watering schedules to specific zones, while conserving water and saving a few extra dollars. Customers are willing to pay a little extra for improved; perhaps even luxury systems Recently, *Nokia* highlighted this trend by introducing the 8800 model luxury mobile phone. Despite the lack of impressive technological features, to date, over one million customers in Europe purchased the 8800, which comes with a price tag of approximately €1,000 ($ 1,190) [4].

Homebuilders will be able to install the *Smart Sprinkler System* in the subdivisions where it is required to use the provided system for irrigation, or to simply make the home more attractive to buyers. The system will conserve water and save money immediately and new home owners can use the system's convenience right away. The *Smart Sprinkler System* can be included into the mortgage of the house, similar to the way solar panels are sometimes included.

Small business owners with significantly higher irrigation needs than homeowners will buy the *Smart Sprinkler System* to save money. Customers will enjoy noticeably decreased water bills, while full automation and ease use will fulfill the desire to have a "set-it-and-forget-it" type system.

Additionally, the *Smart Sprinkler System* appeals to cities for installation in small parks and other public properties [5]. Cities have a vested interest to conserve water, but convenience and ease of use are also factors that will influence the buying decision. At the same time, we realize that the *Smart Sprinkler System* is not desirable for use in largely centralized, facility controlled environments, similar to that found at the University of North Texas. Their special demand for total integration and control is something the *Smart Sprinkler System* is unable to fulfill at this point in time.

METHODS

 The major components of the *Smart Sprinkler System* are a computer using *LabVIEW™*, a microcontroller, analog-to-digital converters, sensors, and the circuitry to open and close the solenoid sprinkler valves. Figure 1 shows the interconnections of these components. Figure 2 details the relay circuitry to control the solenoid valves, and Figure 3 shows the sensing circuit.

SERIAL PORT CONNECTING PC UNIT AND MICROCONTROLLER

PERSONAL COMPUTER WITH LabVIEW®

HC12 MICROCONTROLLER

10 BIT ADC ON MC, OR SEPERATE ADC BASED ON THE RESOLUTION REQUIRED

5V SIGNAL TO OPEN RELAY

5V SIGNAL TO OPEN RELAY

5V SIGNAL TO OPEN RELAY

10 BIT ADC

LOW AMP ANALOG OUTPUTS FROM DAQ

SENSORS

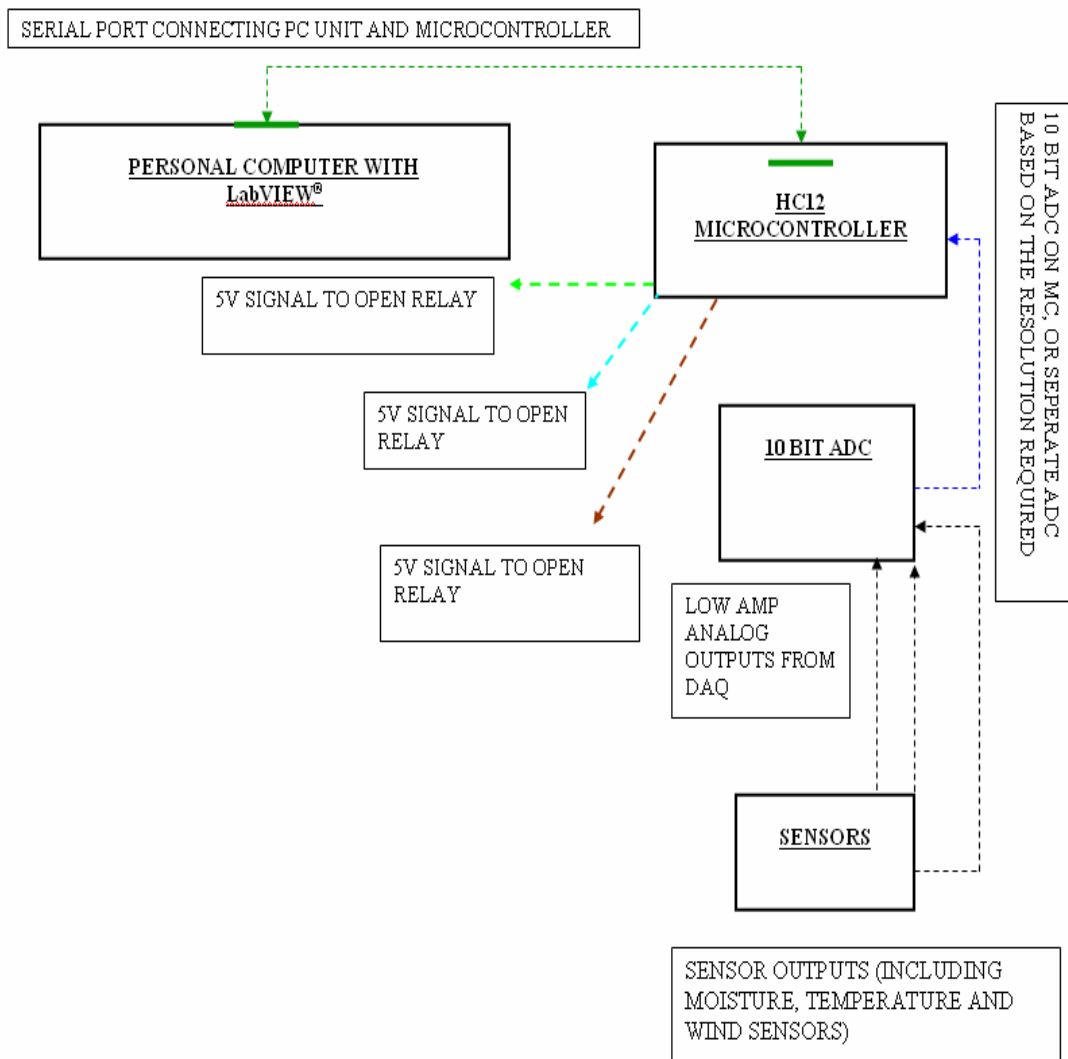SENSOR OUTPUTS (INCLUDING MOISTURE, TEMPERATURE AND WIND SENSORS)

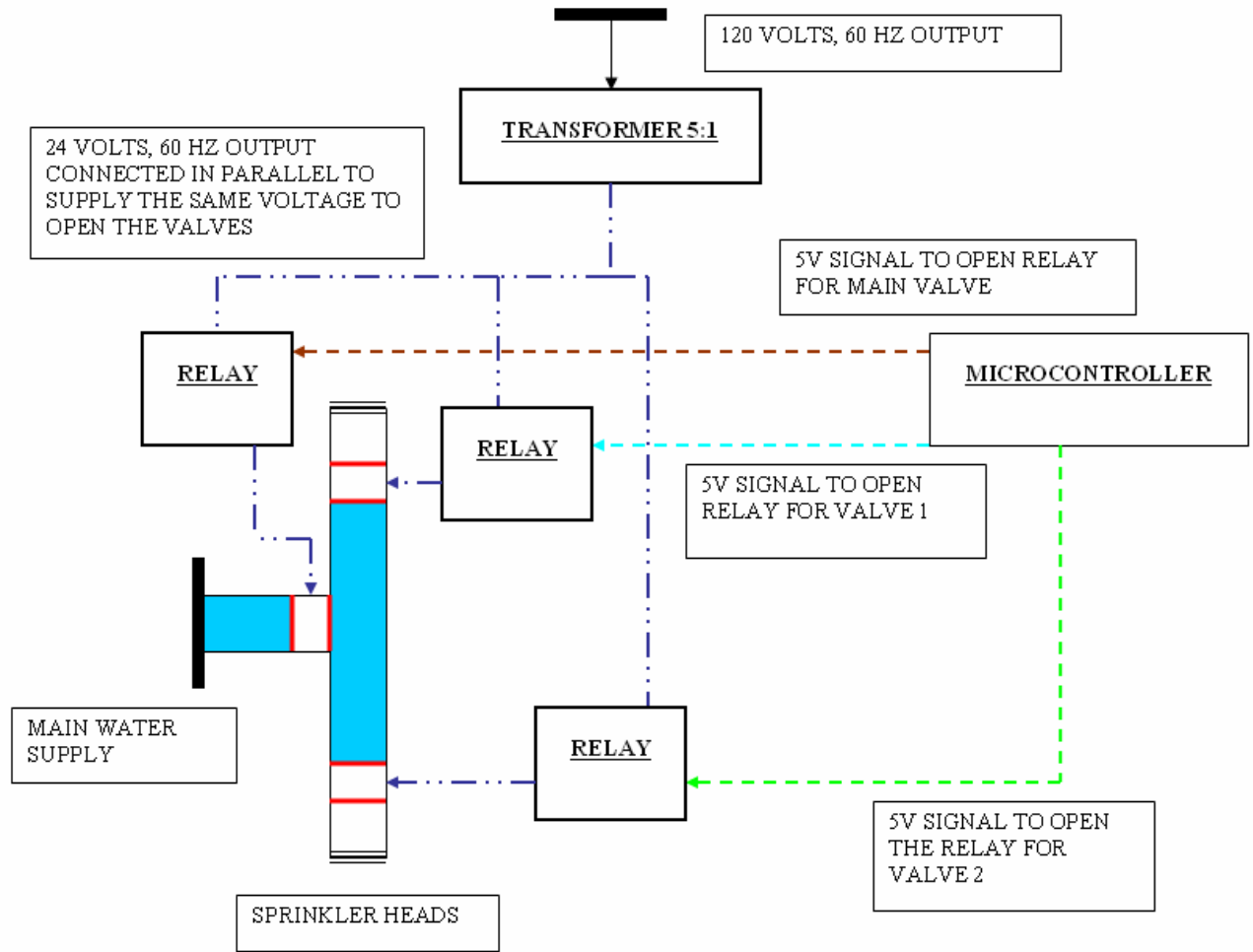Figure 1: Block diagram of the *Smart Sprinkler System*

Figure 2: Block diagram of relay circuitry to control valves

It is our desire to utilize 120 VAC/60 Hz household standard power available to run the *Smart Sprinkler System*. The solenoid valves require 24 VAC/60 Hz to properly open and close. We will incorporate a step-down transformer to convert the 120V to the required 24V (see Equation 1). Relays requiring 5V to open will be used to control the valves. Once the valves open, the system becomes primarily mechanical. The sprinkler heads will open due to the water pressure in the pipes. At that stage, sensing circuitry will determine how long to irrigate to reach the desired moisture level in the ground. Due to environmental situations, the desired moisture level might not always be reached. Hence, algorithms will be in place to account for these occurrences to ensure that irrigation is still effective.

The sensing devices that will be used are going to be analog with industry standard voltage ranges from 0 to 5 VDC. All sensors must be able to withstand outdoor environmental changes, including moisture, wind, dust, and temperature fluctuations. Because the moisture sensors are buried in the ground of each sprinkler zone, they must be specifically resistant to damage due to soil conditions. Further, cables routed

underground must have sufficient protective coating to prevent damage from natural forces and withering. One of the sensors identified will require the use of signal conditioning using the amplifier in Figure 3. The required gain for this amplifier is 3.289 (see Equation 2).

To implement the software portion of the project, we will utilize *LabVIEW*™ on the front-end, giving the user an intuitive interface to monitor and control the *Smart Sprinkler System*. *LabVIEW*™ will only be used for the prototyping stage, because it is undesirable to market to the end-user due to its price and lack of ease of use. Once the *Smart Sprinkler System* moves into the market, we will develop a software solution utilizing the *Java*™ platform. Because of its cross-platform compatibility, *Java*™ is the logical choice before introducing the product to the market. It ensures that we will reach a maximum amount of customers by not being limited solely to *Windows*™ users. We will outsource development of the market release front-end software portion once the electrical system is ready for production. A potential candidate firm with this job has yet to be identified.

ANALOG OUTPUT: 8mV PER 1MPH FOR 0-144MPH

WIND SENSOR

ANALOG OUTPUT: 0-1.152V FOR 0-144MPH

ZONE 1

AMPLIFIER

SIGNAL AMPLIFIED FROM RANGE 0-1.152V TO RANGE 0-5V WITH AN AMP GAIN OF 4.34

MOISURE SENSORS
ANALOG OUTPUT: 0-5V DC FOR 0-100% MOISTURE LEVEL LINEARLY

ADC

10 BIT ADC; RESOLUTION OF .0049V, OR SEPERATE ADC BASED ON RESOLUTION REQUIRED

ZONE 2

TEMP SENSOR

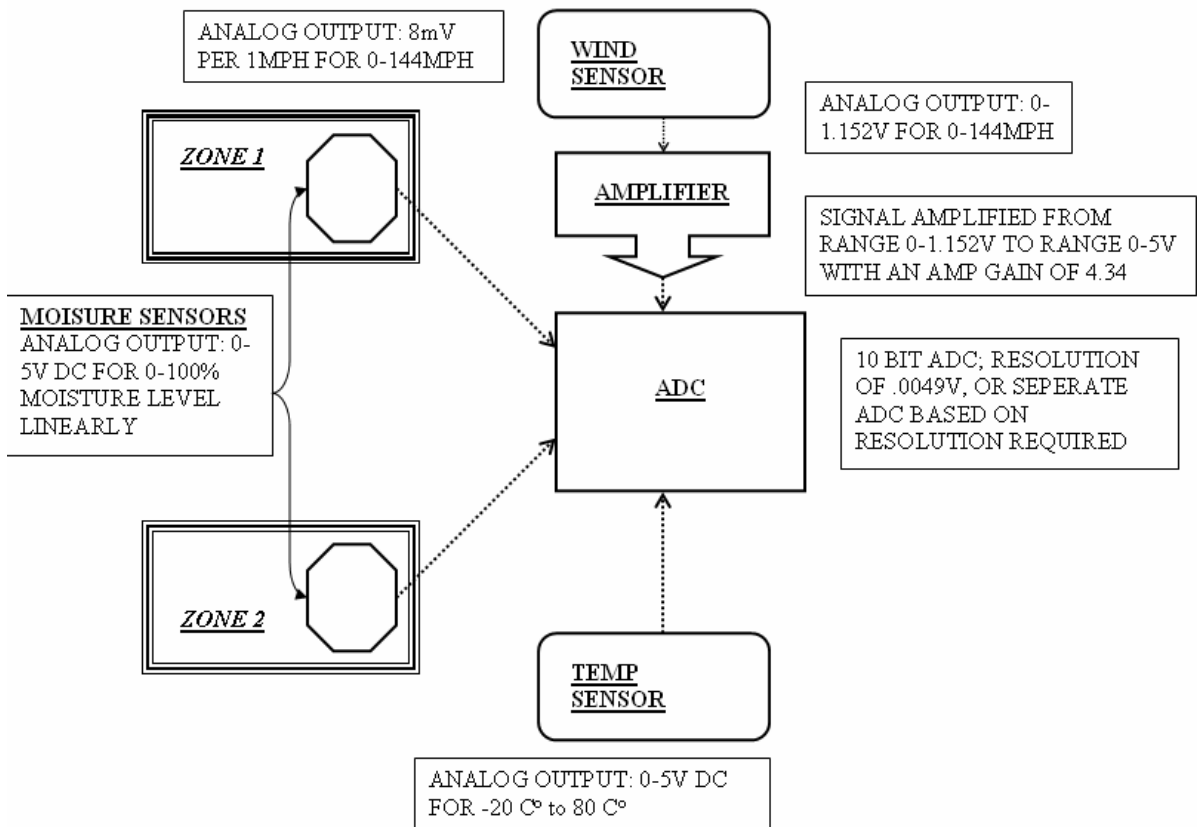ANALOG OUTPUT: 0-5V DC FOR -20 C° to 80 C°

Figure 3: Block diagram of sensing circuitry for temperature, wind, and moisture

On the software-side back-end of the *Smart Sprinkler System*, the HC12 microcontroller will monitor and drive the logical portions. We are strongly considering microcontrollers that have built in analog-to-digital conversion for increased system stability. Because the system requires a resolution of at least 8-bits (see Equations 3 through 5), the microcontroller should at least have an 8-bit data bus and registers. We may use 10-bits for the analog-to-digital conversion if it is financially feasible, as it will greatly improve sensing accuracy -- the 8-bits represent the minimal required resolution. We will program the microcontroller using assembly language or C/C++, depending on the complexity of the control mechanism. During the preliminary design stage we concluded that we should program using C/C++, as it gives us more flexibility in writing code.

The described design is preliminary and may change after the publication of the proposal.
We will keep detailed records of any changes and document why the change was necessary. This ensures transparency to parties that having a vested interest in seeing the *Smart Sprinkler System* succeed.

Design Calculations

Transformer Ratio
$$\frac{V_S}{V_P} = \frac{N_S}{N_P} \Rightarrow N_S = \frac{V_S}{V_P} \cdot N_P = \frac{120V_{AC}}{24V_{AC}} \cdot 1 = 5 \Rightarrow \frac{N_S}{N_P} = \frac{1}{5} \qquad \text{(Equation 1)}$$

Amplifier Circuit Gain Considerations for Signal Conditioning
$$A = \frac{V_{Desired}}{V_{Actual}} = \frac{5V}{1.52V} = 3.289 \Rightarrow R_{Ratio} = \frac{R_f}{R} = \frac{2.289}{1} (non-inverting) \qquad \text{(Equation 2)}$$

Analog-to-Digital Conversion Considerations
$$Q_{Moisture} = \frac{V_{Range}}{2^{bits}} = \frac{5V}{2^8} = 0.02V \Rightarrow Accuracy = \frac{Range_{measured}}{2^{bits}} = \frac{100\%}{2^8} = 0.4\% \qquad \text{(Equation 3)}$$

$$Q_{Wind} = \frac{V_{Range}}{2^{bits}} = \frac{5V}{2^8} = 0.02V \Rightarrow Accuracy = \frac{Range_{measured}}{2^{bits}} = \frac{144}{2^8} = 0.56mph \qquad \text{(Equation 4)}$$

$$Q_{Temp} = \frac{V_{Range}}{2^{bits}} = \frac{5V}{2^8} = 0.02V \Rightarrow Accuracy = \frac{Range_{measured}}{2^{bits}} = \frac{100}{2^8} = 0.4^o C \qquad \text{(Equation 5)}$$

Power Supply

The valves used in the *Smart Sprinkler System* require 24 VAC to open and an initial inrush current of 300 mA. Once the valve is open, 200 mA of current are required to

keep the valve in an open state. We used a 5:1 step down transformer (120 VAC to 24 VAC @ 60 Hz, 450 mA) to power the circuit and tested the output with a multimeter when the transformer was connected to a regular household outlet. The output voltage of the transformer was between 28 and 29 VAC, providing approximately 440 mA of current. The transformer satisfies system requirements, because it reaches the 24 VAC needed to excite the valves. Because the valves are able to withstand AC voltages well beyond 24 VAC, the transformer's 28-29 VAC output is not a concern.

The current the transformer provides was not enough to operate the solenoid valves. The system requires enough current to keep two valves open at any instant in time. It is not necessary to open more than two valves at a time, since only the main valve and the valve in the zone that is currently irrigated will be open at the same time. Because the valves we chose need 300 mA inrush and 200 mA holding current each, the transformer's 450 mA maximum output is not enough. Amplification (see Equation 6) is necessary to raise the transformer's output current to at least 600 mA. The system requires the following current gain:

$$Gain = \frac{I_{out}}{I_{in}} = \frac{600mA}{450mA} = 1.333$$

(Equation 6)

To achieve the required current value, a transistor that provides a current gain between 1.4 and 1.5 outputting approximately 630 mA to ensure proper valve operation. Overall, the design of the power supply is complete, aside from implementing the transistor current amplification.

Valve Control Circuit

There are three major components that comprise the valve control circuit shown in Figure 4.
These parts are:
- Sensing Circuit
- Power Supply Circuit
- Valve and Relay Circuit

To control the solenoid valves, the system will use the provided 24VAC at 450mA output from the power supply. The current is amplified to 630 mA using a current amplifier. There are two valves open at any one time when the sprinkler system is running. The valves draw a combined current of approximately 600mA. The output from the current amplifier is applied in parallel to three relays that in turn are connected to the valves. The amplifier output is connected to pin 4 of the relay as shown in Figure 4. When the valve is to be opened, the HC12 microcontroller sends a 5V signal to the relays. This signal is amplified because it does not provide enough current to activate the relays. The relays require 70mA at 5V to open. We confirmed through testing that the 2N4401 transistor that is connected in series between the

microcontroller and the relays provides enough amplification of the signal for the relays to operate properly.

The 1N4148 diodes shown in Figure 4 are connected between the AC power supply of the transformer and the microcontroller to provide isolation and prevent any AC signal to damage the HC12 microcontroller. The HC12 retrieves the soil moisture and temperature levels from the sensors and compares them to the parameters set by the user for the system to start. When the relay receives the 5V and 70 mA, the induced magnetic field closes the normal open (NO) switch and lets the 24VAC from the transformer pass to the valves through pin 2 as shown in Figure 4. Water is supplied to the sprinkler heads in the specific zone when the main valve and the valve for the specific zone are open.

This design completes the valve control circuit.

Figure 4: Valve Control Circuit

Sensors

Smart Water Solutions will implement two types of measurements via sensors – moisture and temperature. We were unable to use the wind sensor described in the preliminary design, due to its tremendous cost. To keep the system competitively priced, we will use a wind controlled switch instead, which is not connected to the microcontroller. The moisture sensor we chose is the NovaLYNX 250-124. This moisture sensor gives a linear DC output voltage depending upon soil saturation from 0% to 100%. The output dc voltage range of the sensor is 0VDC to 5VDC which occupies the entire range of the HC12 microcontroller's analog-to-digital converter

(ADC). This entails that it will be unnecessary to condition the signal and the digitized signal will be accurate.

The temperature sensor used in the *Smart Sprinkler System* is the AD594. This sensor is capable of measuring -55 to +125 degrees centigrade. The AD594 has a positive and negative source power input. In order to receive a temperature range from 0 to +125 degrees centigrade, we will ground the negative input pin. The AD594 gives a linear DC output voltage in the range of 0 VDC to 1.25 VDC. Hence, signal conditioning is required to make use of the full range of the HC12's ADC. The maximum analog input voltage to the ADC can be 5 VDC and the maximum output of the AD594 is only 1.25 V. With this, we arrive at the following required gain:

$$G = \frac{ADC_{max}}{AD594_{max}} = \frac{5}{1.25} = 4$$

(Equation 7)

Using the result from equation 7 and a non-inverting amplifier, we can compute the following required resistor ratio R_f to R_{in}:

$$\frac{R_f}{R_{in}} = \frac{G}{V_{in}} - 1 = \frac{4}{1.25} - 1 = \frac{3}{1}$$

(Equation 8)

The 10-bit ADC proposed in the preliminary design will be replaced by the HC12 internal 8-bit ADC. We already proved in the preliminary design that using 8-bits yields enough accuracy for the system, and using the internal HC12 ADC will provide more stability to the system.

LabVIEW™ Graphical User Interface

Smart Water Solutions has completed the design of the Graphical User Interface (GUI) for the *Smart Sprinkler System* prototype. The design was done using *LabVIEW™* as no members of the start-up team have enough knowledge to generate such an interface using a high-level programming language. The GUI enables users to set moisture options and time to water for two zones. The user can also access pre-determined values of moisture levels and time to water for three soil types and specific soil content. The pre-determined values can further be set for the two zones available. The GUI also allows the user to set upper and lower temperature values and time intervals during which the system will operate for complete irrigation control. The serial communication interface has also been developed to transfer the user-defined values to the microcontroller. These values are compared to the values obtained from the sensors and the controller sends a signal to open the valves for the zones if appropriate conditions are satisfied. The GUI's main window is shown in Figure 5.
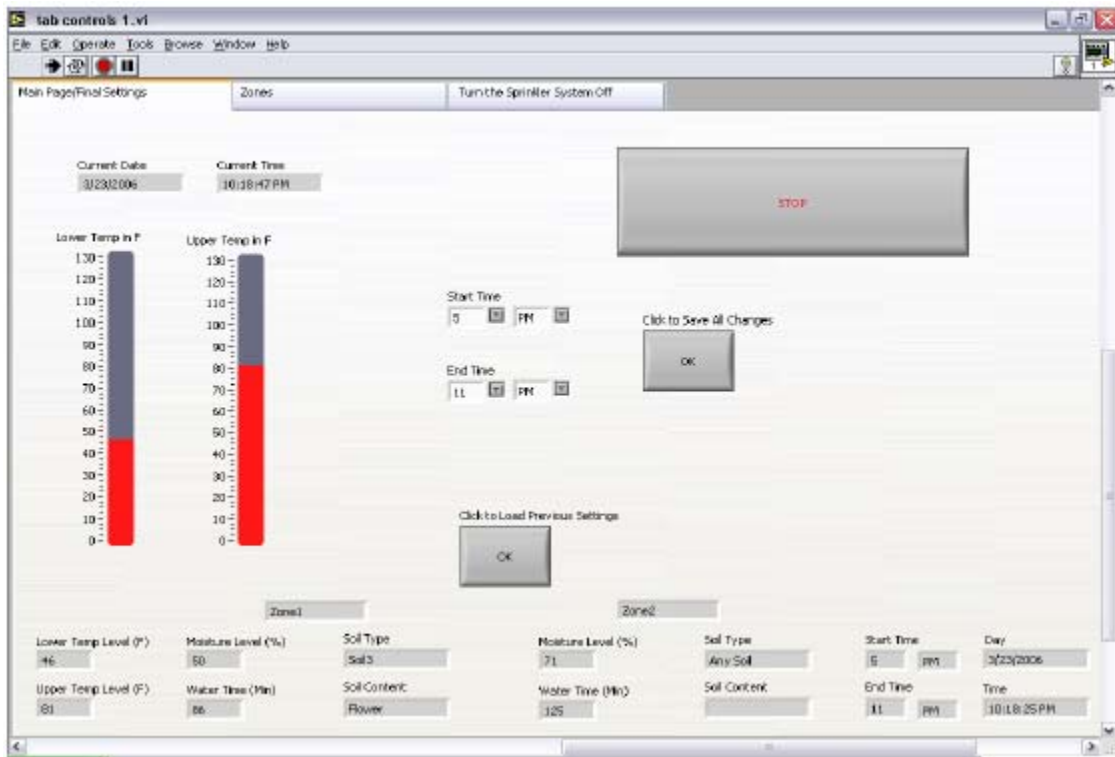
Figure 5: LabVIEW Graphical User Interface (GUI) main window

When the user starts the program it shows the current time and date, sliders to set the upper and lower temperature values for the sprinkler system to operate, and the option to set the start and end time to form the time-window of irrigation. It also gives the user an option to access the previously set configurations. The moisture and time to water values for both zones are loaded on the screen in addition to the soil type and content. The user can also look at the time and date on which the last values were saved. In the final design the main window will also include a button to pass the information to the microcontroller of the sprinkler system through serial communication after the user successfully saves the new values. When the user selects the **Zones** tab in the GUI, a window, such as that shown in Figure 6, opens.

The example in Figure 6 gives an option to access either of the zones with the predetermined values for moisture and time to water. The zones have an **Any Soil** option, giving the user the opportunity to set all options manually. The three provided soil templates in the program already have the moisture levels determined through our extensive research of watering schedules for different soil types. When the user selects the **Soil** option under any zone, three more options regarding the soil content become available. The **Anything** option will give the user an opportunity to set the time to water value with the moisture indicator that shows the appropriate moisture level for that soil. The **Grass** and **Flower Bed** options have the time to water values

pre-determined and the user will be able to see those values before deciding to use them. This ensures that the user always has total control over the system.
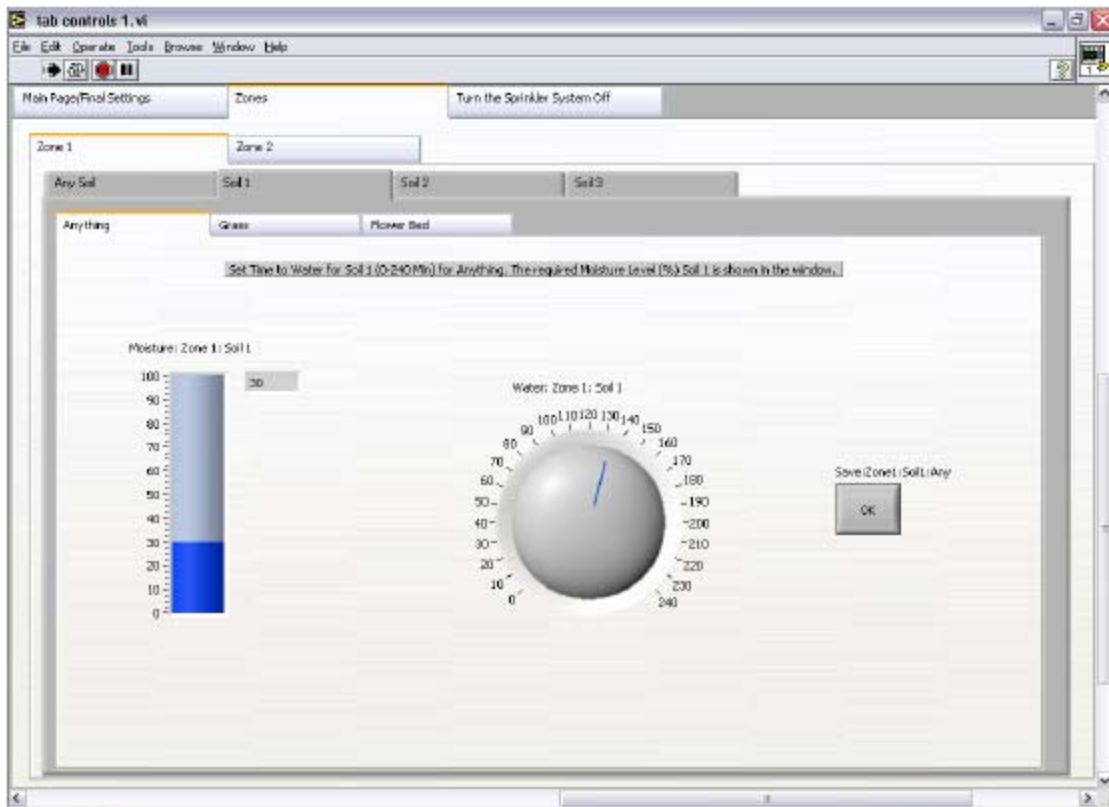

Figure 6: Graphical User Interface (GUI) individual zone options

Figure 7 is an example of the VI used by the program to save the values in both zones with different soil and soil content options. Due to the tremendous complexity of the overall Virtual Instrument (VI) connections, it is impossible to display the entire program in one single figure.
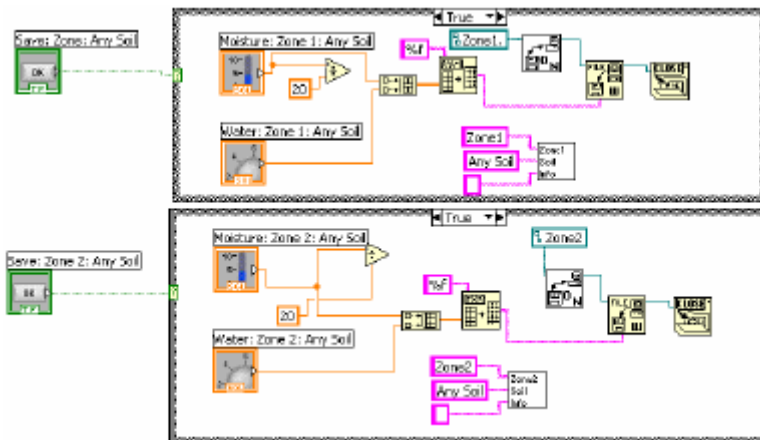
Figure 7: VI to save individual user soil type settings

Figure 8a shows how the moisture and time to water values for the zones are saved in an external file on the user's computer. Once the information is passed to the VI, it ultimately stores the values in the file. The program uses fourteen different sub-VIs. Once the user defines the values from the two zones and clicks the save button in individual zones, s/he needs to go to the main page to save all changes made. When the button is clicked to save the changes, the program goes through the process shown in Figure 8a to ensure that all data is kept in the appropriate place. All saved values, except current date and time, are passed through VIs that test to see if they meet certain specifications. When temperature values of zero are encountered or no changes to zones are made by the user, a prompt such as that shown in Figure 8b will appear.
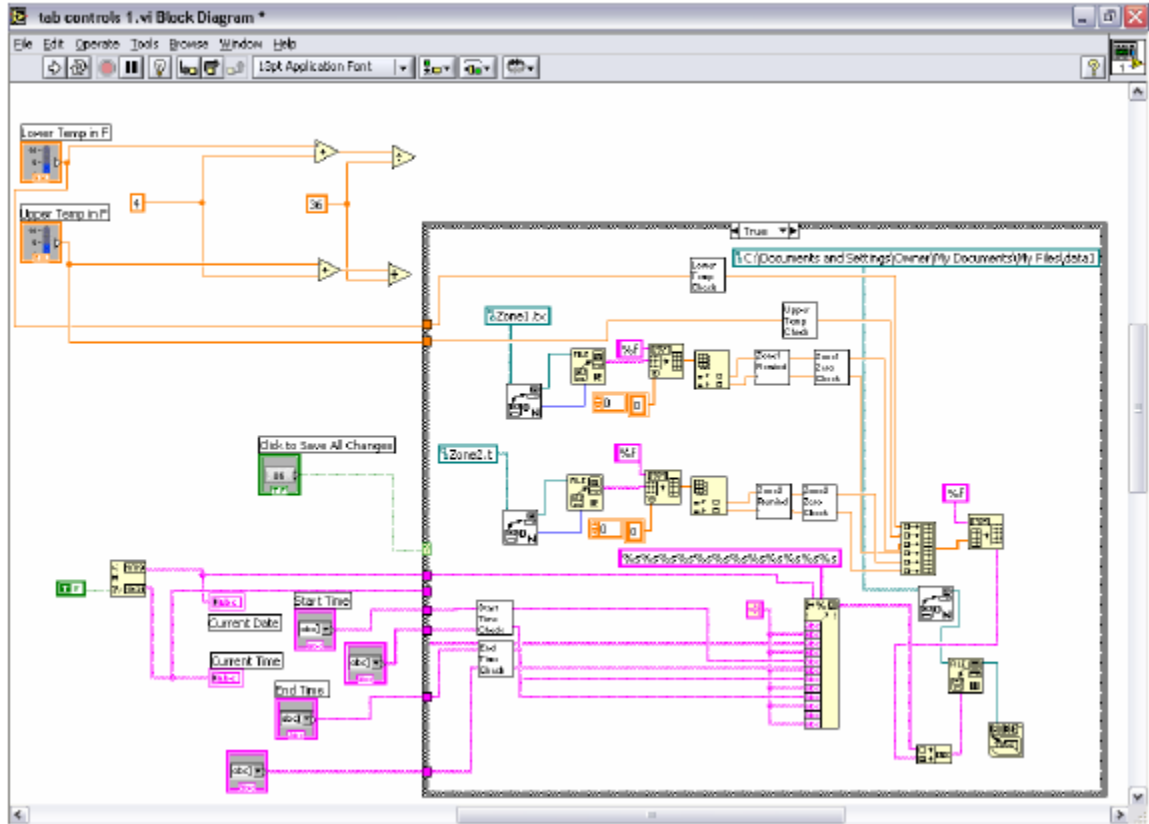
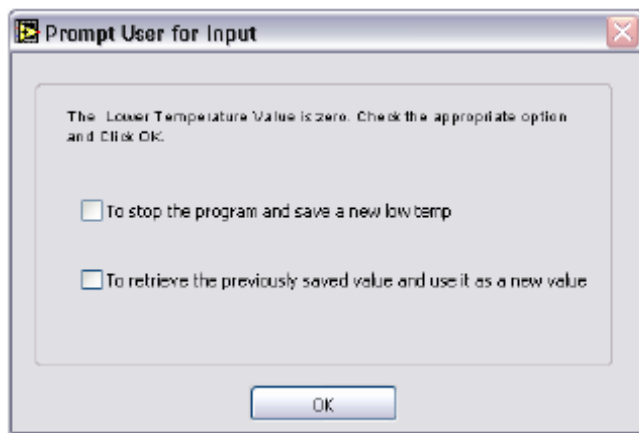Figure 8a – Process used to save user information to a separate file for later retrieval

Figure 8b – Prompt to warn users if values entered do not meet specifications

This kind of control allows the user to either stop the program and save new values or retrieve the previously saved values and use them as new values. The moisture and time to water values for both zones will go through the same process and if either one of the values is zero, a similar prompt such as that in Figure 8b will appear. The GUI will also remind the user if the previously set moisture and time to water values are similar to the newly set values.

There is a possibility that the user might decide to select a certain soil and soil content option, but forgets to click the save button to permanently keep the options. To alert the user of this scenario, a reminder prompt similar to the one shown earlier will appear. It enables the user to go back and click the save button for the new moisture and time to water values to take effect.

The main window of the GUI also gives the user an option to access previously saved information. Figure 9 shows the process of how the system retrieves those values for the user. The VI's in this loop are responsible for obtaining the soil and soil content values for both zones.
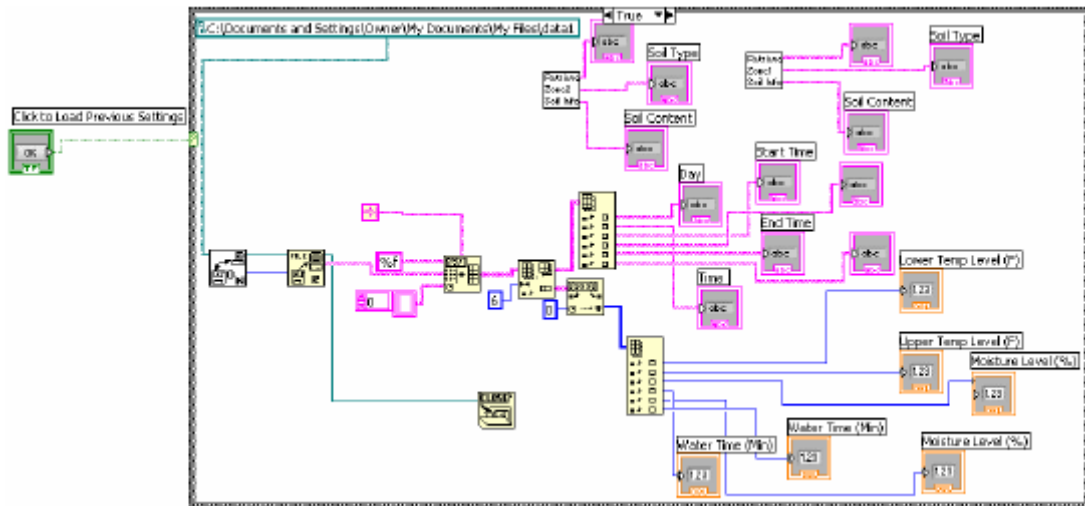

Figure 9 – VI to retrieve previously saved user data from the main window

In the final design the user will have to click an additional button after s/he saves the values to pass the new values to the microcontroller. The program is connected to the controller through serial communication, and the parameters for serial communication are shown in Figure 10. These values will be pre-defined to ensure a secure serial communications link. Users will be unable to change this configuration in the final product, as it may render the serial communication link in a non-working condition.

Figure 10: Serial communications parameters in *LabVIEW™*

The parameters in Figure 10 are connected to an already existing VI in *LabVIEW*™ to establish serial communication. Figure 11 shows the required connections to pass the parameters on and also shows the VI being connected to the serial connection VI shown in Figure 12. The VI in Figure 12 is responsible for passing a string through the serial port to the microcontroller. This string contains the user-defined values for the operation of the sprinkler system. Once these values arrive at the microcontroller, they are saved for use in the sprinkler system.
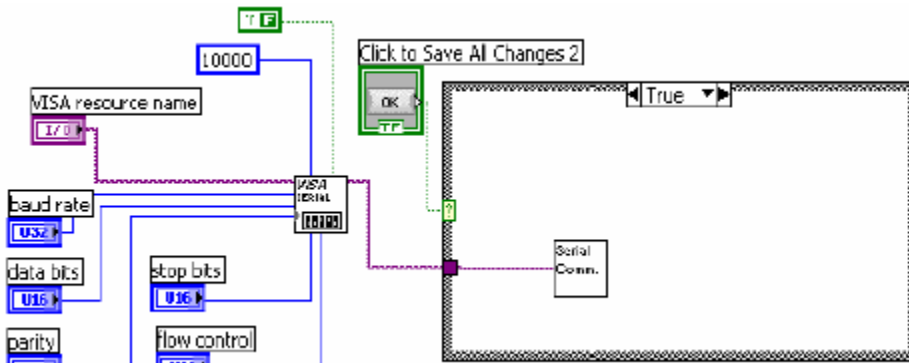

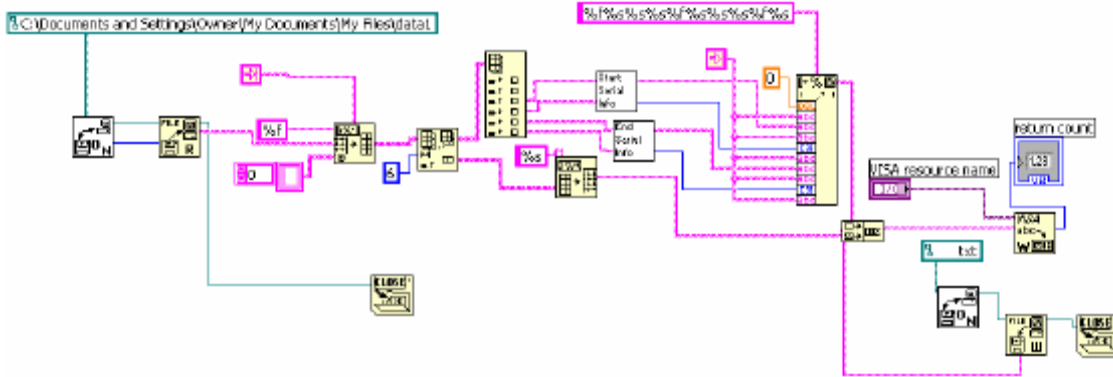Figure 11 – VI to set up serial communication parameters defined in Figure 10

Figure 12 – VI to pass user values to HC12 microcontroller

The overall generation of the GUI for the prototype is completed at this point.

Microcontroller Code Development

Smart Water Solutions has decided to use assembly code to program the HC12 microcontroller. Since the preliminary design, we have evaluated options to use C, C++, and the free-of-charge programming environment SBasic. However, none of these products yielded the flexibility, stability, and programmability that direct assembler coding offers. We believed that this approach will aid us in developing the prototype in a timely fashion with the features our customers seek. The flow cart for the code used to irrigate the zones is shown in Figure 13.
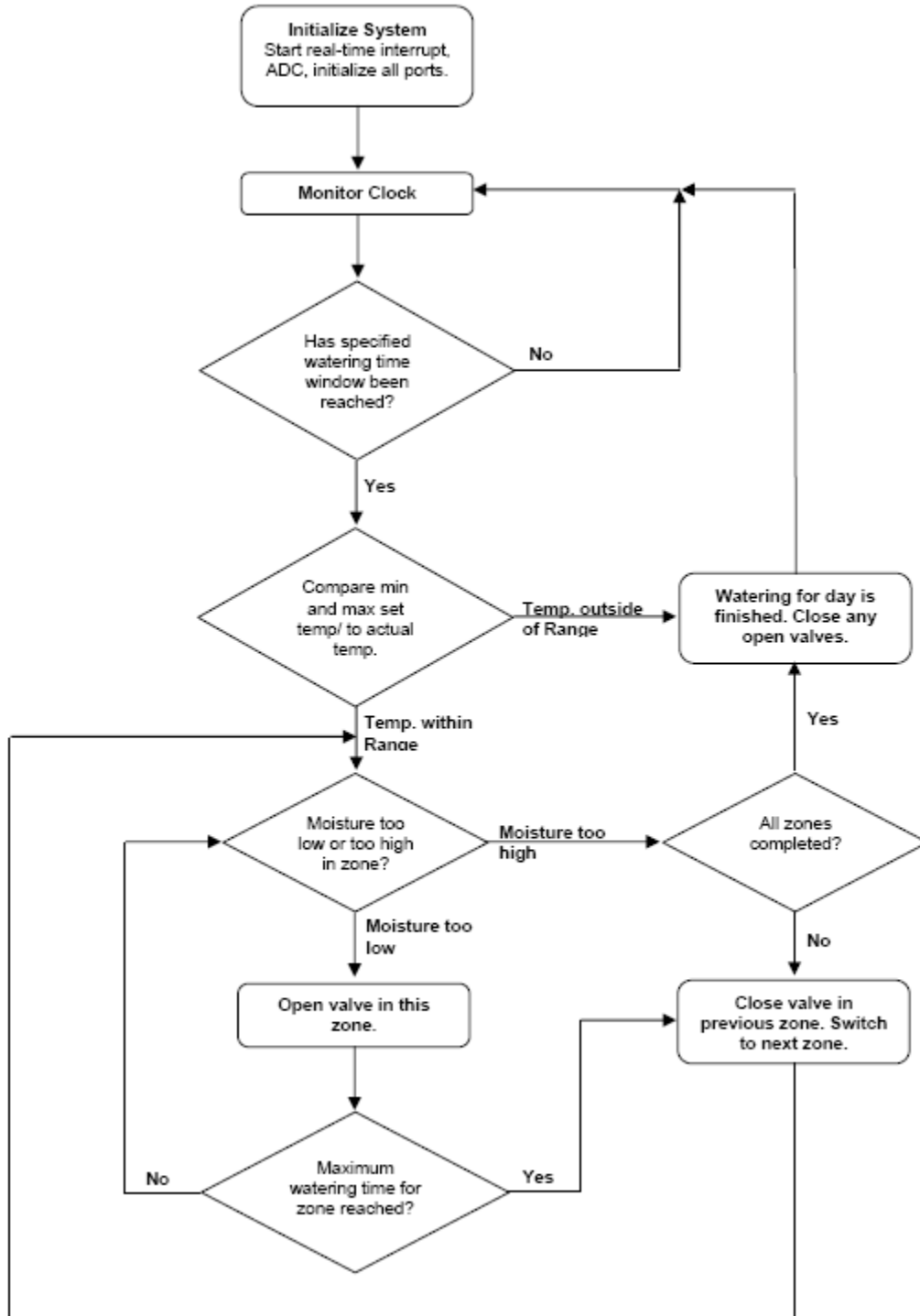
Figure 13: Code flow diagram to irrigate all sprinkler **zones**

Prototype Design

The *Smart Sprinkler System* prototype is contained within three enclosures. The first enclosure holds the microcontroller (Figure 14). A plastic box provides port connections to other system modules and protects the microcontroller. Connections are secured via terminal screws and labels provide accurate information about the required connections.
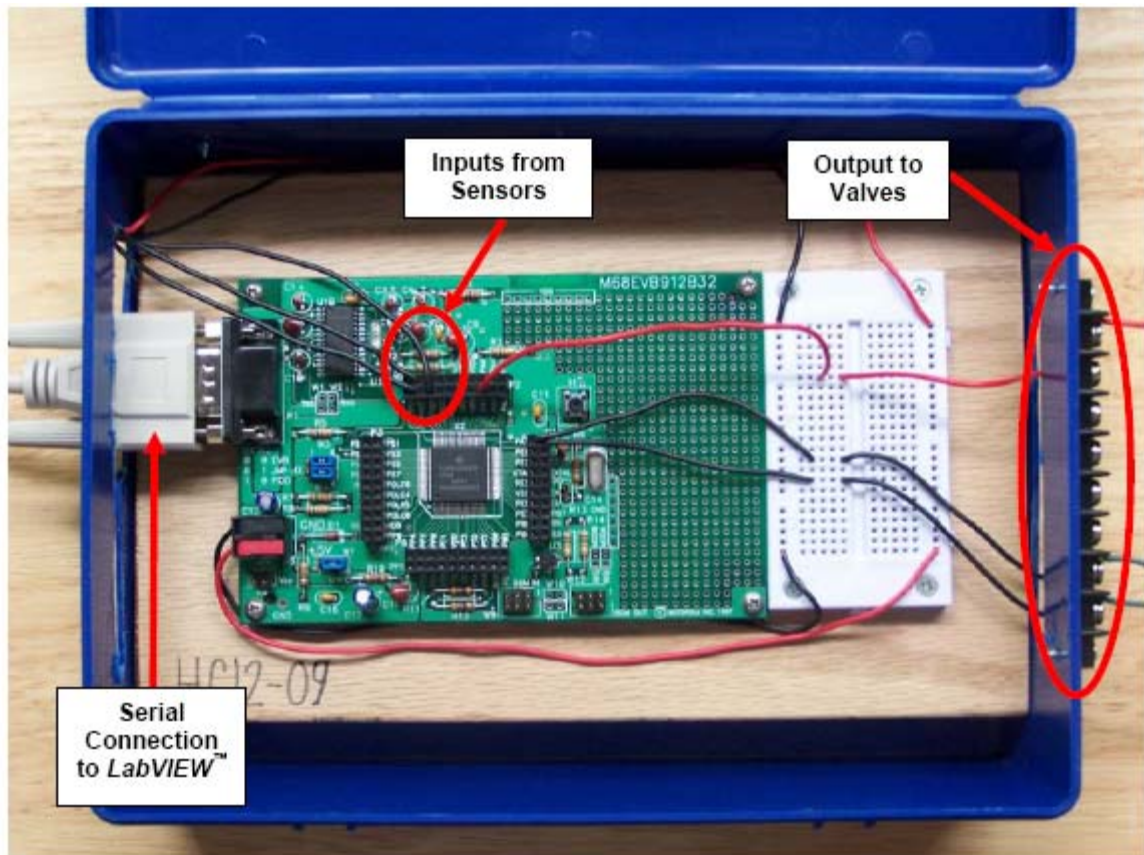

Figure 14– Microcontroller Box with interconnects

Last, the temperature sensor is mounted in a separate box together with the non-inverting amplifier providing a gain of four (see Figure 15). The gain ensures that the temperature sensor output to the microcontroller is between 0 V and 5 V. Connections between all boxes are provided by wires that are secured to the associated terminals. The final product will likely include only two boxes, as the microcontroller and relay control circuitry will reside on the same circuit board. The temperature sensor, on the other hand, will require its own box, because it is mounted outside the user's home.
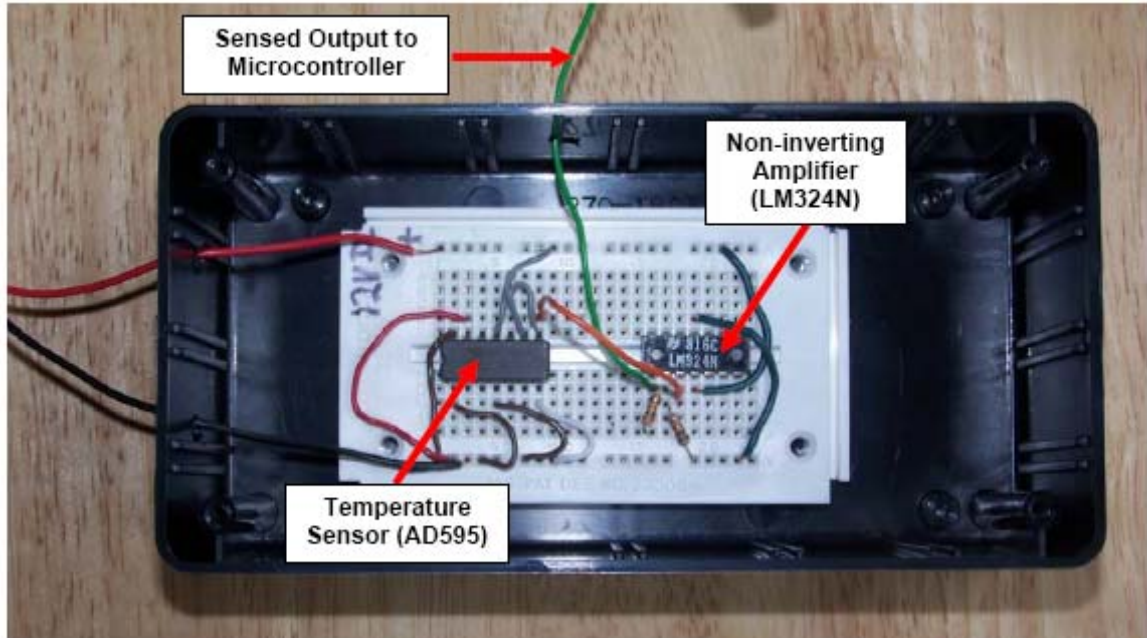
Figure 15: Temperature Sensor Box

RESULTS

We limited the amount of zones for the prototype to two. We felt that this was representative, even though most homes will require more zones. On the other hand, the average home likely will only require two moisture sensors, depending on the yard size and the complexity of the landscaping. The *Smart Sprinkler System* can service up to seven zones, and each zone can have its individual moisture sensor. This setup accounts for one output to the main valve for immediate shut-off during high-wind conditions and undesirable temperatures. It also enables the user to simply shut the system off, when desired.

The field trial of the prototype system was documented in a video presented at the senior design final presentation. It includes three trial runs that present three different scenarios for the system. In the first scenario, both zones require watering. Zone 1 is set to a relatively small value for the desired moisture content, while Zone 2 is set to a desired moisture content of 100 percent. When Zone 1 activates, the supplied moisture was enough to shut off Zone 1 in a few seconds and the system switches to Zone 2. However, Zone 2 remains running for the entire one-minute interval, because the 100 percent desired moisture content is never achieved.

In a second trial run, Zone 1 does not activate anymore, because the moisture content in the soil is still high enough from the previously supplied amount of water. Zone 2 activates immediately and again remains active for the entire time, because it is virtually impossible to reach 100 percent soil moisture content.

In the last trial run, the system simply stays shut off, because we set the temperature cutoff limits very tightly between 95F and 100F. The system will only activate if the temperature is between these two values. Because it was approximately 90F outside during the trial run, the system did not irrigate either zone. This illustrates shut-off for the system during undesirable temperature conditions, particularly freezing conditions.

Overall, we consider prototype verification a success.

Verification Field Trial Test Plan

The objective of field testing the *Smart Sprinkler System* prototype is to validate the performance of the system in the actual usage location. The following test plan outlines criteria and procedures used during the field test trial run.

Performance Criteria

The following criteria help us to validate the performance of the system:
1. All units including temperature sensor circuitry, moisture sensors, microcontroller, relay circuitry, valves, pipes and sprinklers function as expected after the system is built.
2. System switching from Zone 1 to Zone 2 and system turning off at correct times (i.e. when desired soil moisture content is reached).

Testing Site

We put the system on the lawn of a consumer's house. The system was not buried, as this would be undesirable in case troubleshoot is necessary.

Testing Procedure

1. Install the pipes, valves and sprinklers.
2. Connect wires between the microcontroller, relay circuitry and the valves.
3. Secure the wire connection with tape to avoid water interference with the components.
4. Run the program on the microcontroller to start running sprinklers.

Observations

After a few adjustments to the valves and troubleshooting, the system switched from Zone 1 to Zone 2 and turned off as expected. The following figures show the system and its performance:

Figure 16: Prototype System Connections

Figure 17 – Zone 1 running (left), Zone 2 running (right)

Capstone Project as an Assessment tool

The design was completed and implemented as part of a senior design project. The project enabled students to work in teams; apply their knowledge gained from the curriculum (technical and mathematical); demonstrate a working model and make a professional presentation to their peers and others. In doing so, the students and the program fulfilled program and departmental objectives and satisfied ABET criteria for assessment.

Particular assignment methodology is used in the Senior Projects/Capstone course due to the requirement that students enroll in this course, just prior to graduation. Thus, they have experienced the complete range of courses, faculty and facilities in the curriculum. The Senior Projects/Capstone course can be a rich source of information related to outcomes criteria, department and college goals and program objectives. The following assessment methods were incorporated in to the Senior Projects/Capstone course: 1) graduating seniors one on one exit interviews, 2) graduation surveys and 3) evaluations by semester, and typically involves teams of two, who develop a project proposal, plan and track the project using project management software, make several oral presentations on their progress, and submit regular status reports and interim and final reports.[1] The final week of the class

includes oral presentations on the projects before an audience of faculty, students, advisory board members, family members and other guests from the community.

CONCLUSIONS

The *Smart Sprinkler System* will be a product that changes the way we look at residential irrigation. Especially in southern United States, wasting water is unacceptable. Cities in the Dallas-Fort Worth area, such as Plano and Richardson are realizing that residential irrigation control is essential in conserving the scarce water supply of such areas. However, few residents have systems that control irrigation according to vegetation needs and weather conditions. Cities must continually ask for sprinkler systems to be shut off for a set amount of time to conserve water. The *Smart Sprinkler System* will mark the next generation of irrigation control.

It was our goal to develop a quality product as part of senior design course that will satisfy our customers. We performed verification, validation, and field trial tests to guarantee the fit, form, and function of the *Smart Sprinkler System*. Design verification and validation testing assures that design outputs meet the requirements our customers demand. Field trial testing guarantees that our product functions within the performance expectations. Using state of the art sensors, a microcontroller, and computer software we delivered a system that irrigates most efficiently and is easy to control and maintain. Customers will embrace this technology due to its features and the added convenience.

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Bibliography