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March 15,1999

Re: ENSC 370 ***Automated Windshield Wiper Control System*** *Design Specifications*

Dear Dr. Rawicz

The enclosed document, *Automated Windshield Wiper Control System Design Specifications*, outlines the design specifications for our project. Our project goal is to fully automate windshield wiper control through a sensor that will detect the amount of rainfall and control the wipers accordingly.

This document describes the components and design specifications of the overall system and of various components in the system. The components include the sensor, signal conditioning, and signal processing unit.

The members of RainWorks Innovations consist of four 3rd year Engineering Science students in the Electronics option. This four-member team includes Vincent Yen, Roger Stock, Dennis Lee and Kevin Kan. Should any questions arise, please contact Roger Stock at 945-5078 or by e-mail: rstock@sfu.ca.

Sincerely,

Roger Stock, Vincent Yen, Dennis Lee and Kevin Kan

Encl: *Automated Windshield Wiper Control Design Specifications*

Automated Windshield Wiper Control System
Design Specifications

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Executive Summary

The AWWCS (Automated Windshield Wiper Control System) is the product currently being developed by RainWorks Innovations. It will automate automobile windshield wiping depending on the amount of rainfall on the windshield.

The rainsensor consists of variable resistance and variable capacitance circuits to detect various types of rainfall. It provides input to a microcontroller through an ADC and signal conditioning unit to meet the required input parameters. After the microcontroller determines how to control the wipers according to the sensed rainfall, it sends controlling signals to the actuator interface which manipulates the existing wiper control system to initiate a wipe. A manual override from the user will return control to the cars original wiping system.

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1 Introduction

Automobile windshield wiper systems on the current market are completely dependent on user input. Existing windshield wiper systems require user control for different rain conditions, as well as system activation and deactivation. Given various rain conditions that might occur within a short period of time, windshield wiper control may pose a cumbersome task for the driver as well as a dangerous distraction. An inexpensive automated windshield wiper control system, which activates, deactivates and varies the wiper rate depending on rain conditions presents an viable alternative to existing wiper control systems. In addition, the utilization of non-intrusive sensors, inexpensive and customizable microcontrollers and easy installation procedures will make this product an attractive option for car manufacturers or as a car kit for modification enthusiasts. Currently this product is only available in luxury and prototype vehicles, making our inexpensive car kit an accessible alternative for the general public. This document outlines the design specifications for this concept. The implementation of each functional unit of the system is described.

2 System Overview

The AWWCS receives both rain and user input. The data is processed and a decision is made to actuate a windshield wipe. Figure 1 gives an overview of the main system units shown by block diagrams.

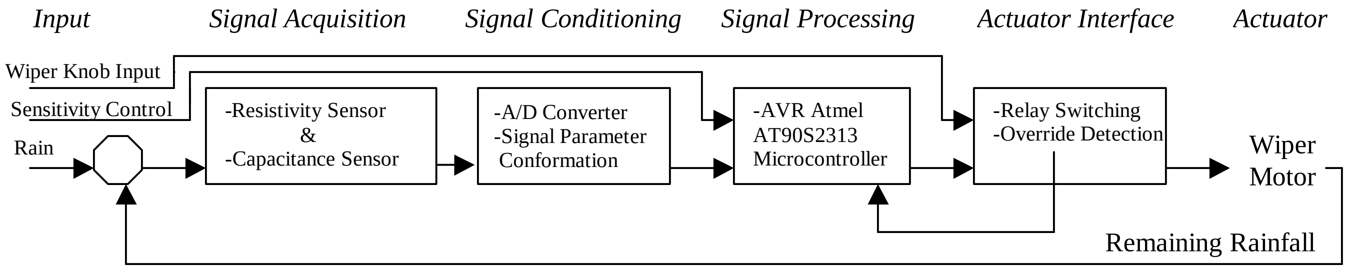

Figure 1: AWWCS System Block Diagram

Our custom rain sensor first senses rain as input; the sensor uses variable resistance and variable capacitance functionality to detect rain. Through the signal conditioning block, the inputs from both types of sensors pass through voltage converters, amplifiers, and analog-to-digital converters to be processed correctly by the microcontroller. The microcontroller analyses the conditioned signal inputs and determines if wiping is necessary. The actuator interface allows the microcontroller output signals to control the wipers through a relay switching network. The interface works together with the cars' existing wiper control system; a manual override initiated by the wiper control knob will return wiper control to the cars existing system.

3 Signal Acquisition

Wiper actuation will be dependent on the input signal. Figure 2 shows the signal acquisition stage relative to the AWWCS.

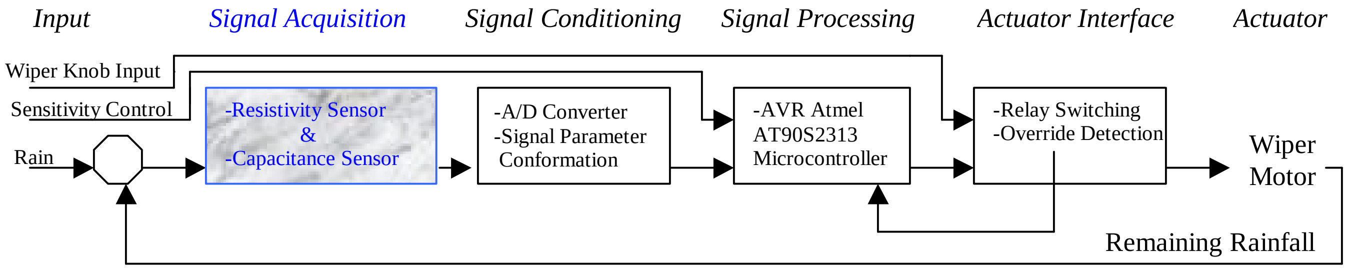

Figure 2: Signal Acquisition Stage in AWWCS

The amount of rain on the windshield will be measured and processed by the AWWCS. AWWCS will then decide to actuate the wiper to clean the windshield. The rain amount detection on the windshield will be determined by a combination of custom designed sensors: two variable resistance sensors and a capacitance sensor.

3.1 Variable Resistance Sensor

3.1.1 Discussion

The variable resistance sensor is composed of two parallel strips of conductive material placed on the windshield. During normal operation (e.g. no rain) there will be an open circuit in between the parallel conductive strips. Raindrops that lie between the two parallel strips will complete the circuit and appear as a resistor connecting the two strips. The presence of additional raindrops on the sensor will appear as additional parallel resistors. Therefore, the presence of additional raindrops on the sensor will result in decreasing resistance seen in between the two strips relative to one raindrop.

The physics behind the variable resistance sensor is simple. A raindrop in between the conductive strips will have resistivity described by formula 2.

$$R = r\frac{L}{A} \tag{1}$$

Where L is the distance between the two conductive strips and A is the cross section area of the raindrop orthogonal to L. Since the distance in between the parallel strips is fixed, the variable L will remain constant. However, additional raindrops on the conductive strips will result in an increase of A, resulting in a greater conduit for the electrons to pass between the two conductive strips; resistance seen between the two strips will subsequently decrease.

3.1.2 Variable Resistance Sensor Description

The variable resistance sensor is composed of two parallel strips, each 15cm long. The distance in between the parallel strips is 4mm. The strip thickness will not affect sensor operation. Figure 3 is the variable resistance sensor layout.

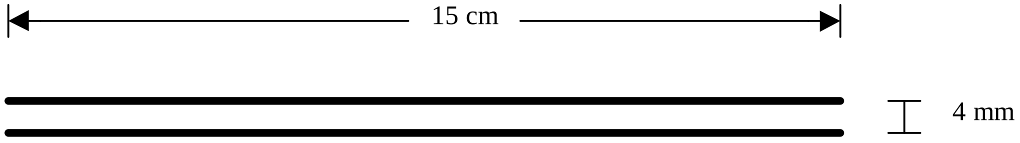

Figure 3: Variable Resistance Sensor

A non-conducting material will be placed in between the two parallel strips; presenting an even surface for a wipe. Through experimentation we discovered that water remained in the groove between the two strips after a wipe; a non-conductive layer is required to fill the groove. For a further discussion of the limitation of the variable resistor sensor, see 3.1.4 *variable resistor sensor limitations*.

3.1.3 Rain Resistance

Through experimentation, we have discovered that a raindrop measuring 4mm diameter will have a resistance of 300kΩ when measured directly between the two ends. Raindrops in diameter between 4mm and 10mm will have resistances slightly less than 300kΩ. For a further discussion on the resistivity of rainwater, see 3.6 *Rainwater Resistivity Discussion*.

When using the variable resistance sensor, the measured resistance of one 4-mm diameter raindrop between the two strips is 300kΩ. However, raindrop diameters between 4mm and 10mm will have a resistance much closer to 300kΩ than through direct tip to tip measurement. Examining the resistance equation, we noticed that L is constant using a variable resistance sensor; therefore different raindrop sizes will result in more constant resistances than tip to tip measurements.

3.1.4 Variable Resistor Sensor Limitations

H2O is a highly polar molecule; therefore there exists a great inter-molecular attraction, which manifests as capillary force. This force results in water’s tendency to cling to the edge of the sensor. Our experiments has determined that parallel conductivity strip distance less than 3mm will result in occasional “dirty” wipes, with water film developing between the strips. The presence of non-conducting filler between the strips will reduce the area for water to cling to and allow “clean” wipes, with complete removal of water on the sensor. However, for the sake of durability and accuracy, the parallel strip distance is 4mm. In addition, two variable rain sensors are used to enhance rain sampling on the windshield. The variable capacitance sensor will detect raindrops smaller than 4mm diameter.

3.2 Variable Capacitance Sensor

3.2.1 Discussion

The variable capacitance sensor is composed of a thin conductive strip on the external surface of the windshield and a conductive plate on the interior surface of the windshield. The strip and the conductive plate act as a capacitor with the windshield glass as the dielectric. Water at the external surface of the windshield acts as a conductor and increases the surface area of the variable capacitance sensor.

The variable capacitance sensor obeys the following physics formula.

$$C = e\frac{A}{D} \qquad (2)$$

Where *A* is the overlapping area between the two plates and *D* is the distance between the two plates. For our configuration of the variable resistance sensor, *D* is the thickness of the windshield and will remain constant. The presence of raindrops in contact with the conductive strip will increase the overlapping area of the capacitor, therefore increasing capacitance.

3.2.2 Variable Capacitance Sensor Description

The variable capacitance sensor is composed of a thin conductive strip on the external surface of the windshield and a conductive plate on the interior surface of the windshield. The thin conductive strip will be 15cm long and 1cm wide and centered with the conductive plate on the opposite side of the glass. The conductive plate on the interior surface of the windshield will be 15cm long and 4 cm wide. Figure 4 shows the variable capacitance sensor.

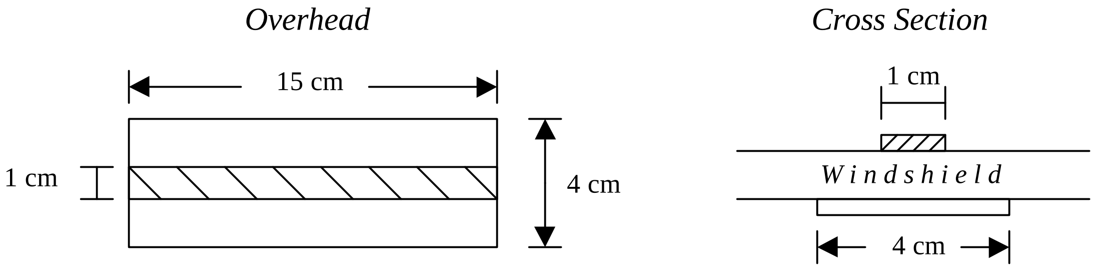

Figure 4: Variable Capacitance Sensor

The capacitance of this configuration is 20pF. The presence of moisture increases the capacitance, up to 60pF, at which saturation of the variable capacitance sensor is reached. Through experimentation, we have determined rain presence of 20% on the windshield to correspond approximately to capacitance value of 35pF. However, this value is accurate only for drizzle like rain, defined to have a rain drop diameter less than 4mm. For more on variable capacitance sensor limitations, please see 3.2.3 *Variable Capacitance Sensor Limitations.*

3.2.3 Variable Capacitance Sensor Limitations

The variable capacitance sensor is highly sensitive to drizzle or mist like rain, where rain drop diameter is below 4mm and rain rate exceed 4 raindrops per square cm. These rainfalls create an ideal even conductive film on the windshield surface and increase sensor capacitance. However raindrop diameter beyond 4mm on the windshield results in large amount of moisture on the windshield clumped at high water concentration in a relatively small area. The large drops often do not come in contact with the conductive strip and do not contribute to sensor capacitance increase.

3.3 Combination Sensor Configuration

The combination of variable resistance and capacitance sensors is used to enhance accuracy of the signal. Each sensor compensates for the short fall of the other sensor. The variable resistance sensor cannot be used to detect lower diameter raindrops due to the capillary action in between the conductive strips; therefore the variable capacitance sensor will be used to compensate for the lack of lower raindrop diameter detection.

3.4 Sensor Placement

The sensors will be placed on the windshield, within wiping range of the windshield wiper. In addition, the sensor will need to be non-intrusive and does not obstruct driver vision. The sensor will need to be placed near the perimeter of the windshield to reduce exposed wiring. The optimal sensor location that meets the above parameter is located at the lower corner of the passenger side of the windshield. There will be a 3-cm clearance between the windshield and the bottommost side of the sensor. There will be a 1-cm clearance between the end of the wiper range and the side of the sensor. Figure 5 is the sensor position relative to the windshield and wipers.

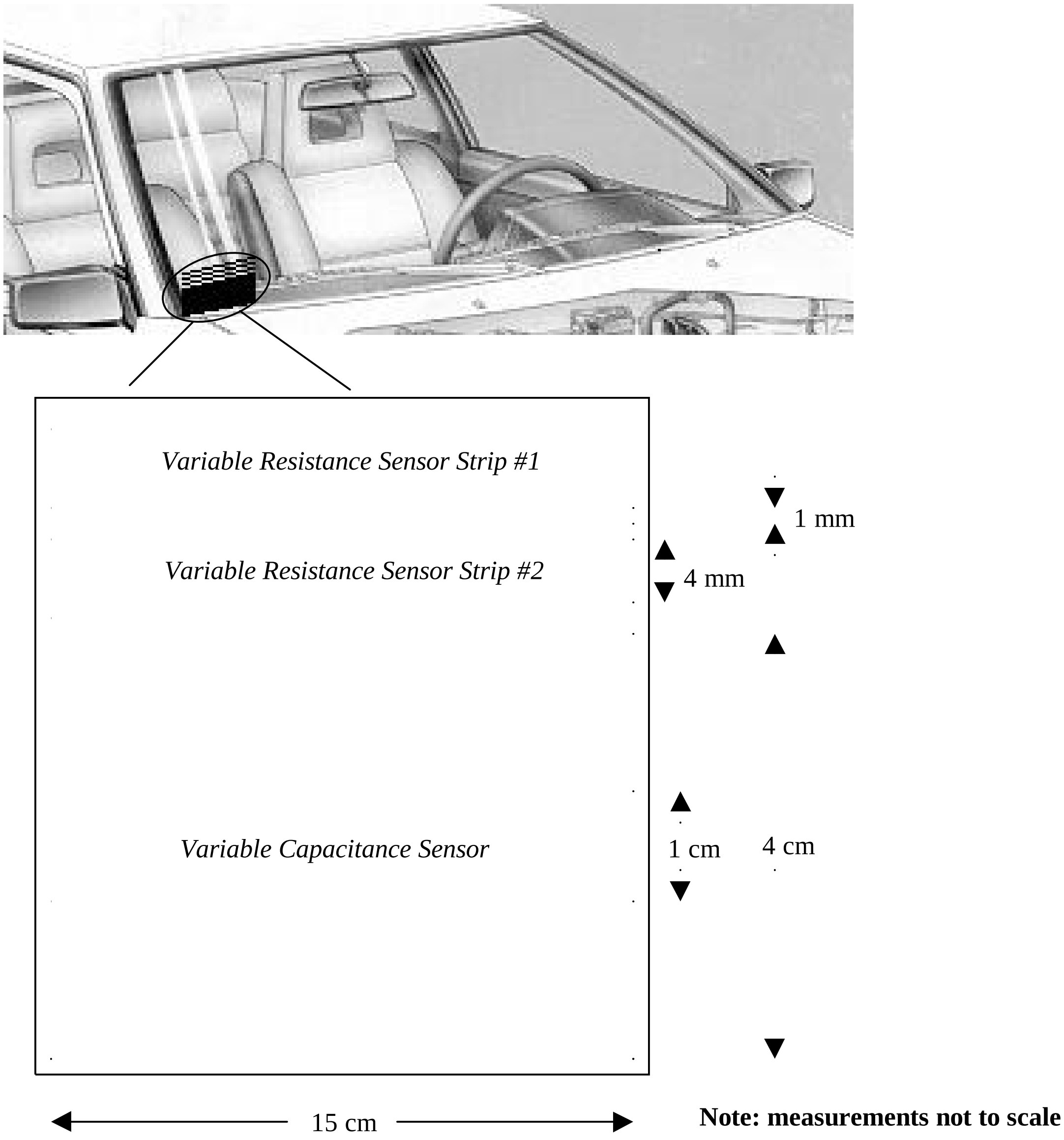

Figure 5: Variable Capacitance Sensor

As shown in figure 5, the variable capacitance sensor is placed below the variable resistance sensor. The variable capacitance sensor requires a conductive plate which may obstruct driver vision and is therefore placed in the least intrusive area, see 3.2.2 *Variable Capacitance Sensor Description*. In addition, the separation between sensors is 0.5 cm.

3.5 Sensor Materials

Sensor parts are placed on the windshield; therefore materials selected need to bond with windshield glass strongly, withstand repeated wiping, environmental exposure and potential vandalism. In addition, materials selected need to be cheap and easy to find. After research and experimentation, we have selected the following components for the sensors.

3.5.1 Aluminum Tape

This is typical aluminum tape used to patch surface automobile damage. We selected tape with thickness of 0.5mm and width of 5 cm. The aluminum tape has excellent conductivity and durability. However, for exterior windshield placements, the aluminum tape adhesive will require enhancement, see 3.5.3 *Rearview Mirror Adhesive*. The aluminum tape is used as the interior capacitance plate for the variable capacitance sensor. Using the aluminum tape, with the enhanced adhesive, as the exterior windshield sensor components are available as an option behind Copper Tape and Conductive Epoxy; see 3.5.2 *Copper* Tape and 3.5.4 *Conductive Epoxy*.

3.5.2 Copper Tape

3M copper tape is available in thickness of 0.3mm and width of 1cm. The copper tape is too narrow to be used as the interior capacitance plate of the variable capacitance sensor. However, the copper tape is much thinner than the aluminum tape, resulting in reduced capillary action of the water during wiper, see *Variable Resistor Sensor Limitations*. Adhesive enhancement is also required for the copper tape, see *Rearview Mirror Adhesive*. Wrings can also be directly soldered onto the tape. The copper tape is considered an option for the exterior windshield sensor component behind Conductive Epoxy, see *conductive epoxy*.

3.5.3 Rearview Mirror Adhesive

Rearview mirror adhesive is available to bond the metal pad of the rearview mirror with the windshield. This adhesive is ideal for permanent bonding of metallic tape to the windshield.

3.5.4 Conductive Epoxy

Epoxy with silver doping is available for making quick correction on PCBs and is highly conductive. Using the Chemtronics conductive epoxy, which has low viscosity, we were able to apply thin conductive strips on the windshield by creating tape masks. The epoxy strips, when cured, are extremely thin (<0.3mm) and are exceptionally durable; we were unable to remove the conductive strips. In addition, we have discovered that the capillary effect of water does not apply to the conductive epoxy, an advantage over the metallic tapes, see *Variable Resistor Sensor Limitations*. Currently, conductive epoxy is the primary option for the exterior windshield component.

3.6 Rainwater Resistivity Discussion

Pure water is not a good conductor. Rainwater conducts as a result of particulate and H+ ions within the water. Therefore, depending on geographical local, the conductivity of rainwater will vary.

An experiment was conducted to measure the varying conductivity of rainwater. Rain samples was collected over a one week period from different locations across lower mainland: Coquitlam, Burnaby, Richmond and Burnaby Mountain. Measuring resistivity using the variable resistor sensor, we observed resistivity fluctuation of ±15% of the 300kΩ value mentioned previously (see 3.1.3 *Rain Resistance)*. We attribute this fluctuation to experimental error, since we cannot accurate produce raindrops of equal size. In addition, ±15% error is acceptable given our functional specification of sensor accuracy to within 20% of the actual state.

4 Signal Conditioning Overview

Signal conditioning is required to take the analog signals provided by the sensors into the digital domain suitable for processing by the microcontroller. Figure 6 shows the signal conditioning stage relative to the AWWCS.

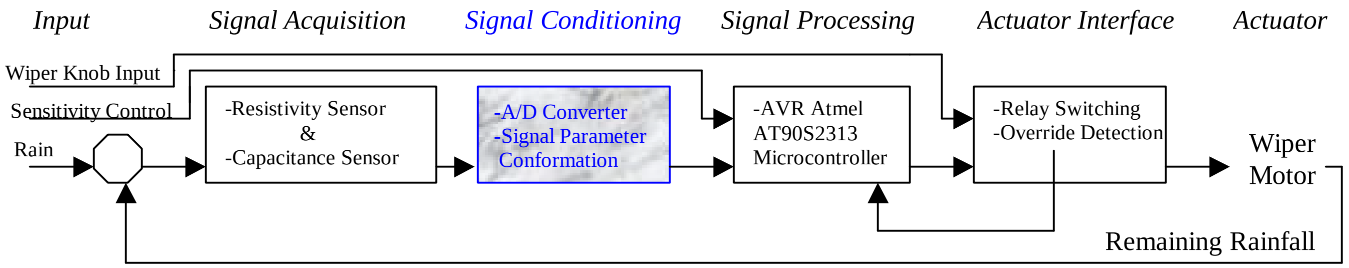

Figure 6: Signal Conditioning Stage in AWWCS

Figure 7 provides a closer examination of the signal conditioning stage.

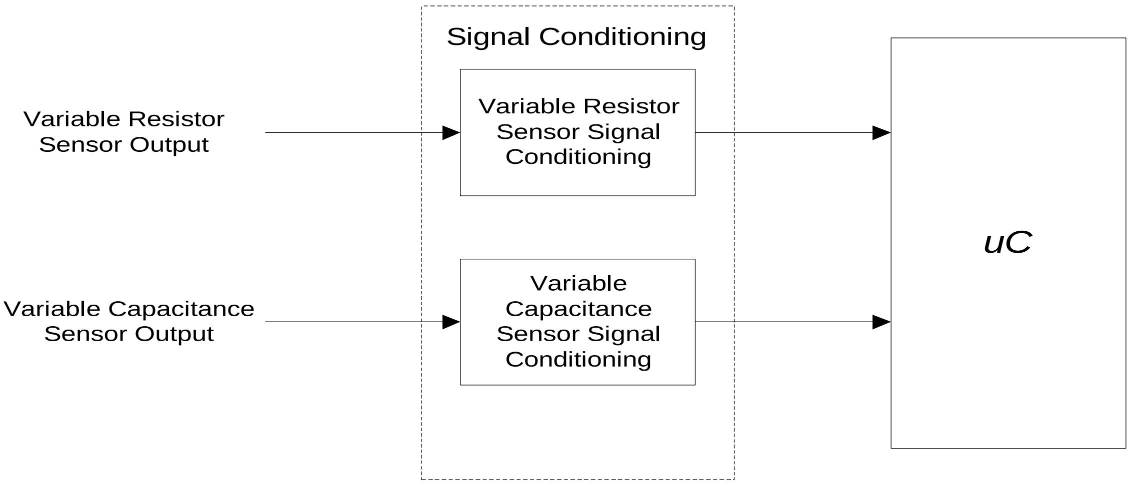

Figure 7: Detailed Block Diagram of Signal Conditioning Stage

4.1 Variable Resistance Sensor Output Signal Conditioning

The detailed block diagram of the variable resistor signal conditioning block is shown in figure 8.

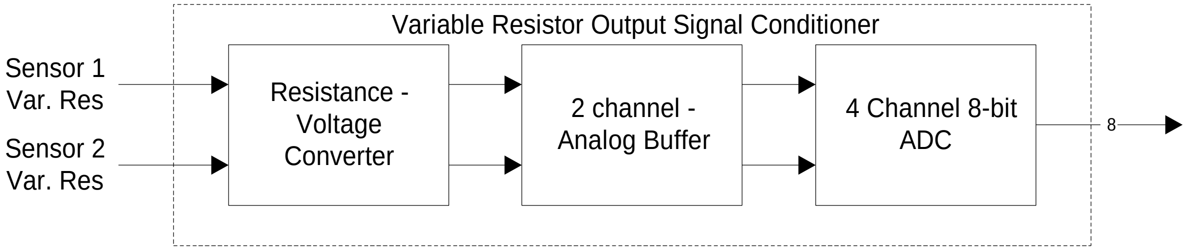

Figure 8: Detailed Block Diagram of Variable Resistor Output Signal Conditioner

The output signal from the rain sensor is not directly coupled to the ADC, but rather to an op-amp first and then into the ADC. This is done for two reasons:

- to scale the output to the proper voltage swing required by the ADC (i.e. 0 to 5 V)
- to increase the input resistance of the stage immediately after sensor

The ADC that we are using has a fairly low input resistance and this will provide significant loading on our sensor. In addition the maximum allowable voltage swing of input signal that is fed into the ADC is 0 to 5V. Currently the voltage swing of sensor output is from 0 to 4 V and as such needs to be scaled up to 5 V.

4.1.1 Resistance – Voltage Converter

In order for us to detect the changes in resistance in our sensor, we employ a voltage dividing, resistor network, as shown in figure 9.

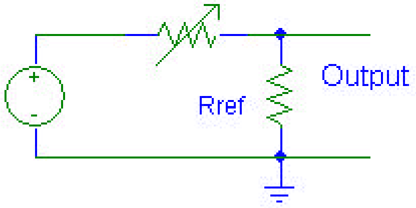

Figure 9: Schematic of Resistance – Voltage Converter

From this we can determine the output voltage to be:

$$Vout = \frac{R_{ref}}{R_{ref} + R_{sensor}} Vin \qquad (3)$$

The value of the reference resistor is not yet determined, but initial tests have shown 100kOhms as a candidate (it gives somewhat linear response to the number of raindrops). The output voltage as a function of the number of raindrops (equal size) seems to be:

$$Vout = \frac{R_{ref} \cdot n}{R_{1drop} + R_{ref} \cdot n} Vin \qquad (4)$$

4.1.2 Amplifier/Buffer

The amplifier circuit is an op-amp in non-inverting feedback configuration with a decoupling capacitor at the non-inverting input, as shown in figure 10.

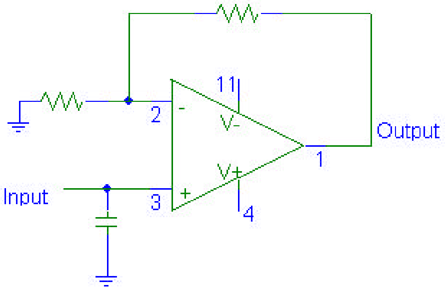

Figure 10: Non-Inverting Amplifier

A gain of 1.25 is required to increase the voltage swing of 0 - 4V to 0 - 5V. Using the gain formula for non-inverting amplifiers:

$$A = 1 + \frac{R_1}{R_2} \qquad (5)$$

results in $R_1/R_2 = 0.25$. To realize this circuit, National’s LM2902 (digikey $0.87) is being used. This op-amp operates on a single power supply and is available at a very low cost. In addition it offers the high input resistance need to minimize the loading effect.

Table 1: LM2902 data

Supply current	1200 uA
Input bias currents	500 nA
Single Ended Supply Voltage	3 to 32 V
Temperature Operating Range	-40C to 85C
Output Current Source (min): Sink (min):	 10 mA 05 mA

4.1.3 Analog to Digital Converter

An ADC from National is used to transform the analog signals into the digital domain. ADC0844 provides 4 channels for analog inputs and then outputs in 8 bits in parallel.

Table 2: ADC0844 data

Power Consumption	15mW
Single Ended Supply Voltage	5V
Conversion Time	40us
Temperature Operating Range	-40C to 85C
Accuracy:	+/- 0.5 LSB

Channels 1 and 2 will be used for the resistance based rain sensors, with the other two reserved for other sensors.

4.2 Variable Capacitance Sensor Output Signal Conditioning

The detailed block diagram of the variable capacitor signal conditioner is shown in figure 11.

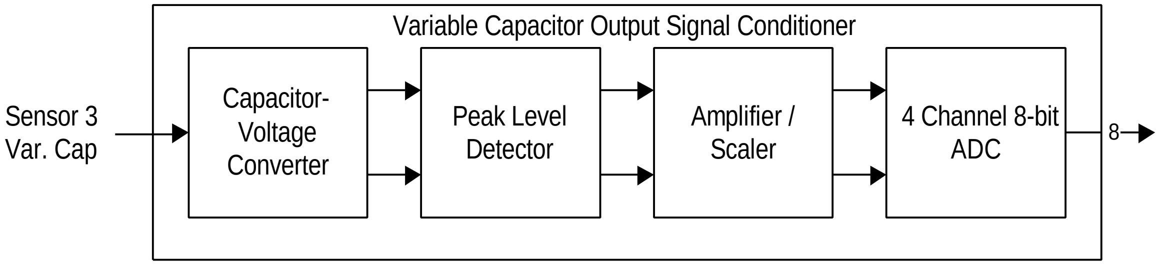

Figure 11: Detailed Block Diagram for Variable Capacitor Output Signal Conditioner

4.2.1 Capacitance to Voltage Converter

Figure 12 shows the design of the capacitance to voltage transfer function.

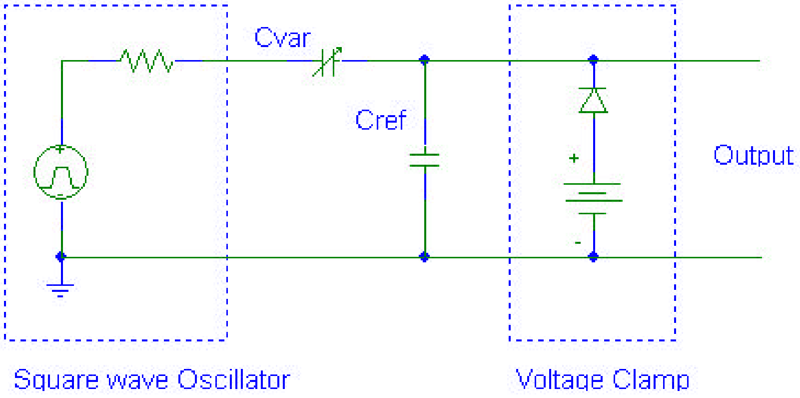

Figure 12: Schematic of Capacitance to Voltage Converter

The capacitance of the sensor is measured using a capacitive voltage divider. With a square wave oscillating around 20kHz being fed into the system, the amplitude of the output signal varies as a function of the capacitance of the sensor.

$$V_{out} = \frac{C_{\mathrm{var}}}{C_{\mathrm{var}} + C_{ref}} V_{in} \tag{6}$$

We can see that if the reference capacitor is much larger than the variable capacitor the output voltage will be directly proportional to the capacitance of sensor. The input to the single sourced op-amp terminals must be clamped circuit at –0.3V. For added security, our clamping circuit is set at 0.3 V, using a buffer set to 1V. The square waves are created using a square-wave relaxation oscillator as shown below.

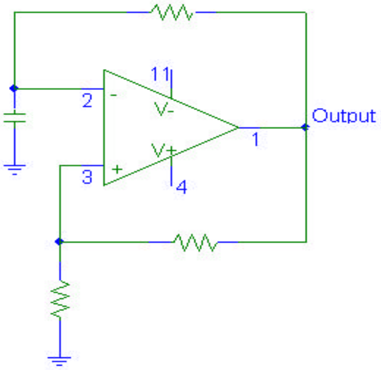

Figure 12: Square Wave Relaxation Oscillator

The frequency of oscillation can be controlled by the resistors and capacitors, while the output voltage oscillates between the rails.

4.2.2 Peak Level Detector

The analog voltage coming out of the capacitance-voltage converter (CVC) will need to be converted into a digital signal via the ADC. Between the CVC and the ADC there needs to be additional signal conditioning, namely transforming the AC output into a DC input. This can be done by using a peak level detector which holds any signal at its peak point, as shown in figure 24.

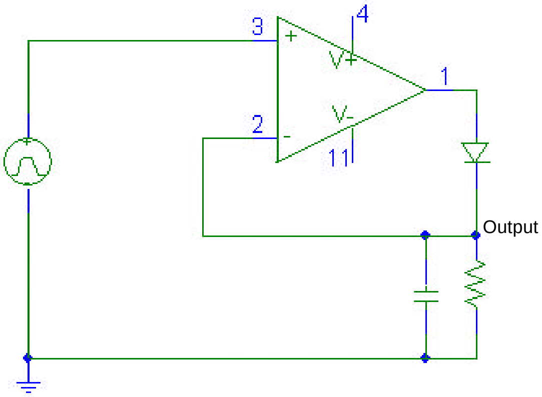

Figure 13: Peak Level Detector

In order to increase the response time to the capacitance changes of the variable capacitance sensor, the basic peak detector circuit is modified at the sacrifice of having increased fluctuation at the output. This increased fluctuation, however, does not pose significant problems since the ADC resolution needed is quite small (less than four bits.)

4.2.3 Amplifier

In order to get full advantage of the ADC, the full scale swing should be around 5V. For this we employ an op-amp in non-inverting configuration. The actual gain has not yet been determined, but will be as more testing is done.

4.2.4 Analog-Digital Converter

The ADC for the variable capacitance signal conditioning is the same as the one used for its variable resistance counterparts. Channel 3 is used for the capacitance based sensors.

5 User Interface

User interface provides sensitivity and off mode control; the UI is composed of a sensitivity knob and two state LEDs. Figure 15 shows the location of the sensitivity knob with respect to the dashboard and a magnified view of the sensitivity knob with LED indicators. There are two levels of sensitivity available to the user, as well as the off state.

1. **Off**: By turning the sensitivity knob to “Off”, the user disables the AWWCS. Under this state, no automated wiping action will be taken.

2. **Normal**: This sensitivity level is the default sensitivity level built in the AWWCS. See 9.1.1 *Sensitivity Knob*

3. **High**: By turning the sensitivity knob to “High”, the user can request the AWWCS to take wiping actions under lighter rain condition than the default sensitivity level built in the AWWCS. See 9.1.1 *Sensitivity Knob*

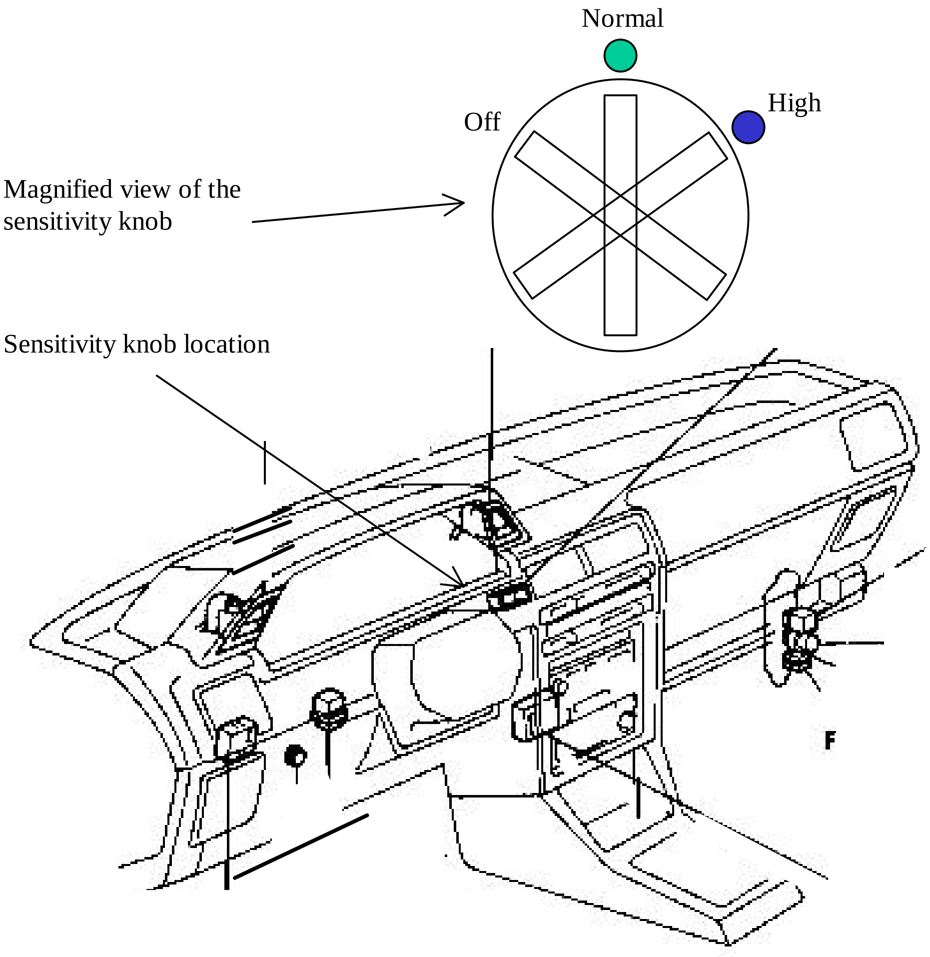

Figure 14: User Interface and UI Location

5.1 User Interface Circuitry

Figure 16 shows the schematic of the sensitivity knob circuitry. The sensitivity knob is connected to the +5V out of the voltage regulator. When the sensitivity knob is set to Normal state, the input pin of the microcontroller, I_n, receives a high signal. When the sensitivity knob is set to High state, the input pin of the microcontroller, I_h, receives a High signal. In the off state, both I_n and I_h are pulled to low.

During the Normal or High state, their respective LED will be activated by a 25mA current determined by the 200Ω resistors.

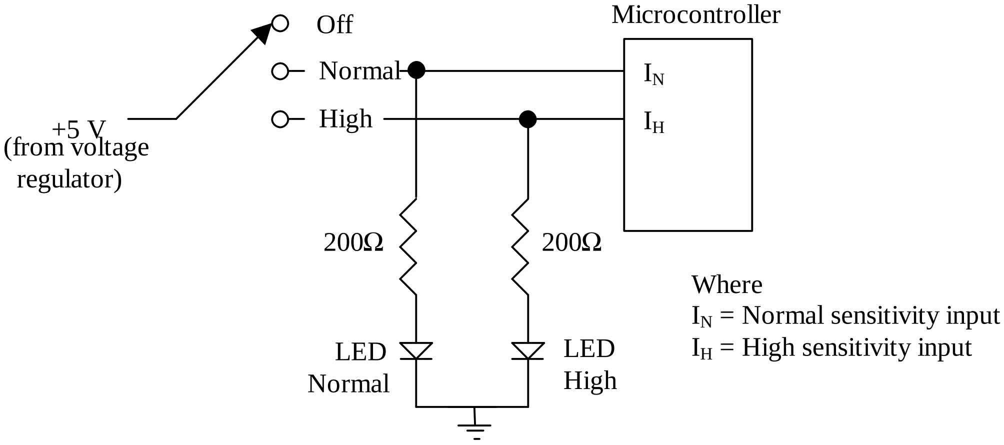

Figure 15: Sensitivity knob circuitry

5.2 User Interface Output

Table 3 gives the user interface output to the microcontroller, given the switch states.

Table 3: Microcontrollers' detection on sensitivity

I_N	I_H	States
0	0	Off
0	1	High
1	0	Normal

6 Signal Processing

Figure 17 is the signal processing block relative to the AWWCS.

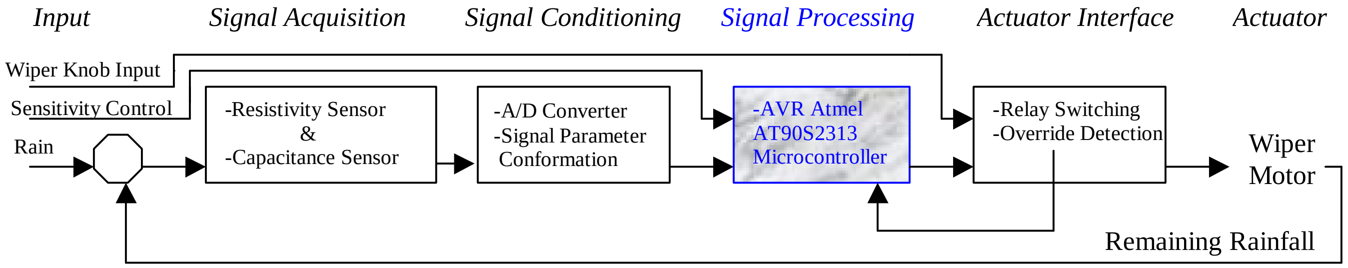

Figure 16: Signal Processing Block relative to the AWWCS

6.1 Algorithm

6.1.1 Sensitivity Knob

The following is the algorithm used to set the system to the sensitivity levels that the user inputs.

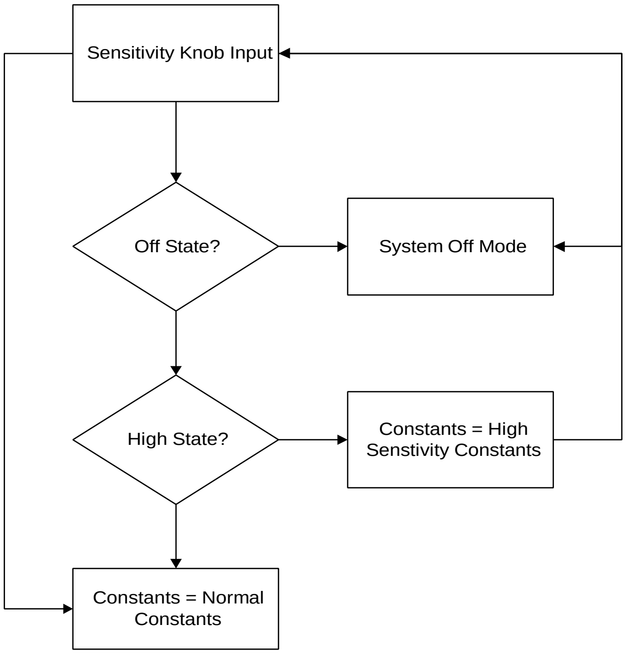

Figure 17: Sensitivity Knob Control Algorithm

6.1.2 Wiper Actuation Decision

If the input is in the “off “state, the system will disable any actuation control. If the input is in the “High” state, the system will use a set of constants as threshold for high sensitvity wiper actuation. If the input is neither “off” or “High” state, the system would be assumed to be in normal operation; all input wiping thresholds would be set to the normal. The following is the algorithm used to process the sensor inputs and determine wiper actuation.

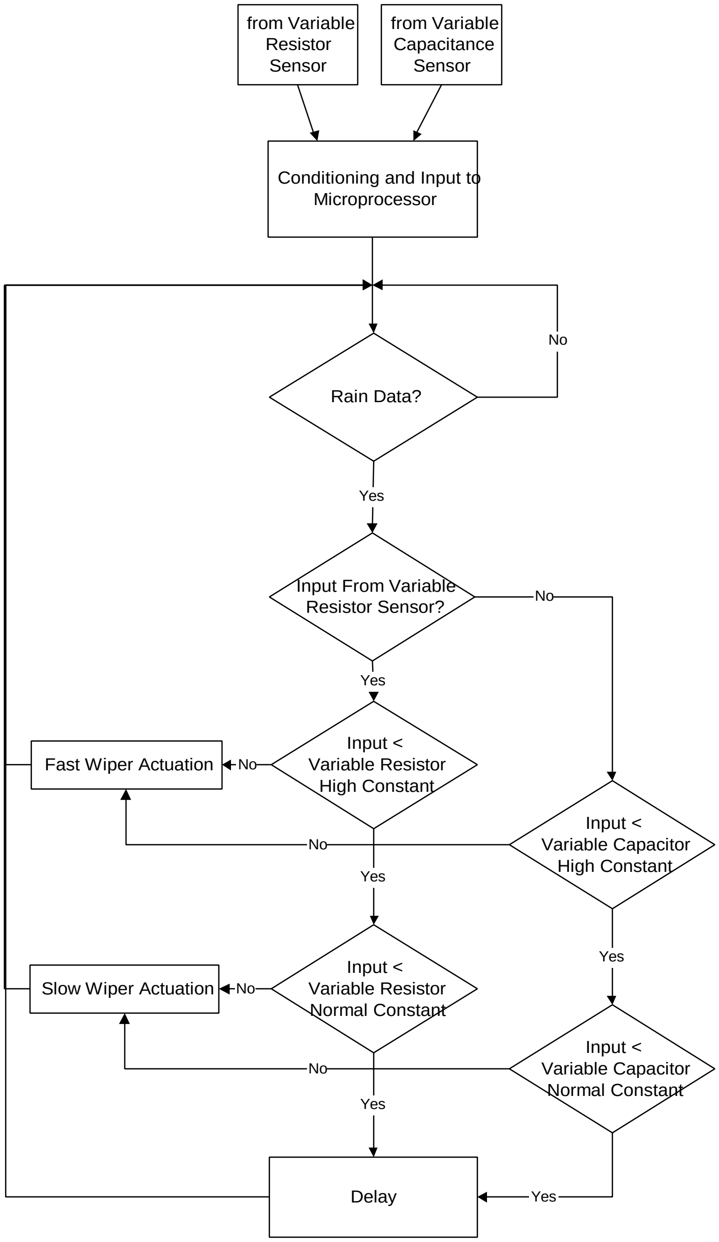

Figure 18: Actuation Decision Algorithm

The variable resistance sensor input will have higher priority then the variable capacitance input. In addition, a delay is implemented to ensure time for rain to accumulate to detectable levels.

6.2 Microcontroller

Our group decided on using the Atmel AVR for signal processing. The AT90S2313 was particularly suitable for our requirements. The 2313 is inexpensive and easy to find; the microcontroller uses 8-bit RISC architecture, which we believe to be simpler to program then the motrola MCH11. In addition, substantial resource and tools are available on the internet for this device.

7 Actuator Interface

The output signals from the microcontroller need to ultimately control wiper movement. The signals will not directly drive the wiper motor though; the microcontroller will control an actuator interface unit that will in effect control the wiper motor. Figure 20 shows the actuator interface relative to the AWWCS.

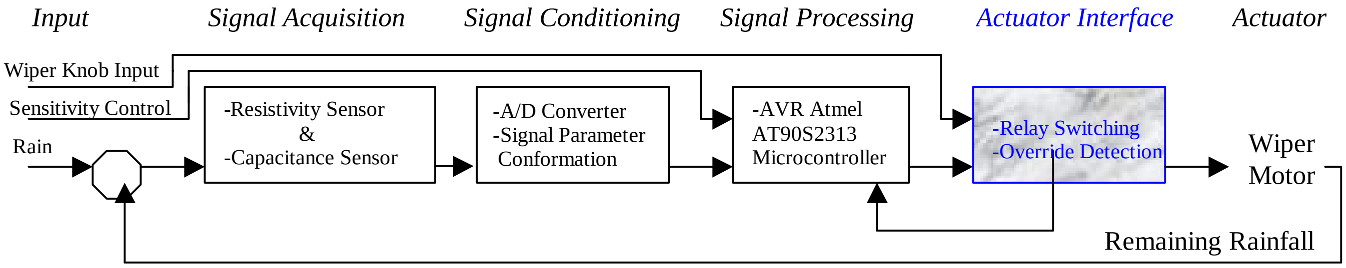

Figure 19: Actuator Interface Relative to the AWWCS

Figure 21 is a closer examination of the actuator interface system block that we will use.

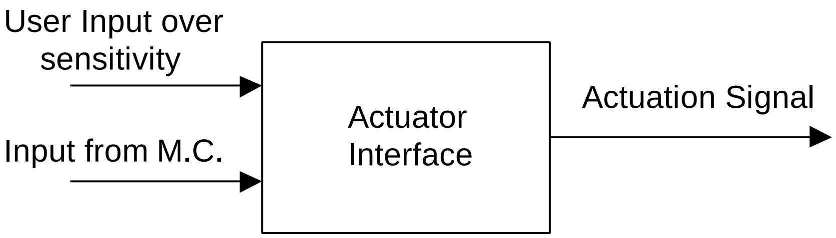

Figure 20: Actuator Interface System Block

7.1 Native Wiper Discussion

Figure 22 shows the cars' existing wiper control system. The main block of interest is the switching unit. The wiper knob mechanically controls a switching unit that manipulates 3 lines at the output carrying the actuating signals of interest. The motor operates in different wiping modes when a 12V signal (not shown) passing through the switching unit has its' pathway connection to the 3 different actuating signal lines switched. The mechanical control from the control knob controls the switching to direct the 12V signal to the correct actuating output lines.

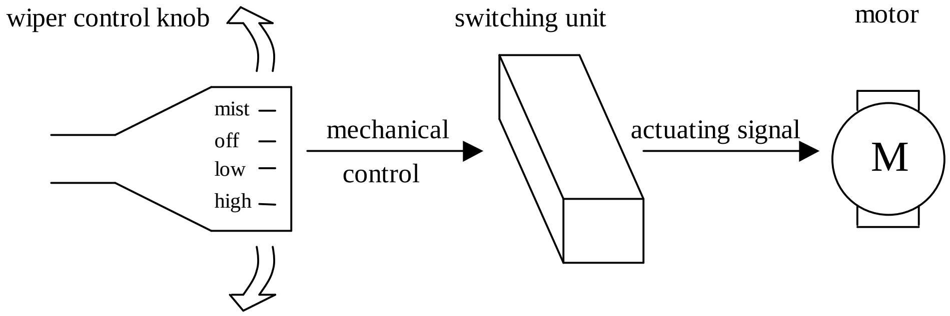

Figure 21: Existing Tercel Wiper Control System

Figure 23 shows the function table of the switching unit. The line segments represent short circuit connections between the vertical signals passing through the table. There are four modes of wiper operation that interest us; mist is a manual wipe mode where mist input causes a single wipe event. Other wiper functions such as washer fluid control which are unrelated to are system are not shown but do exist. The mechanical control from the wiper knob will direct the 12 V signal to the output lines that control the motor as well as the other unrelated functions. The '1' vertical column creates signals for a low speed wipe; the '2' column is the fast wipe signal. One can see that the only the 2 rightmost output lines (1&2) must be manipulated for wipe actuation; the left line (S) is needed only in the off state where the Vcc signal is not redirected to the output.

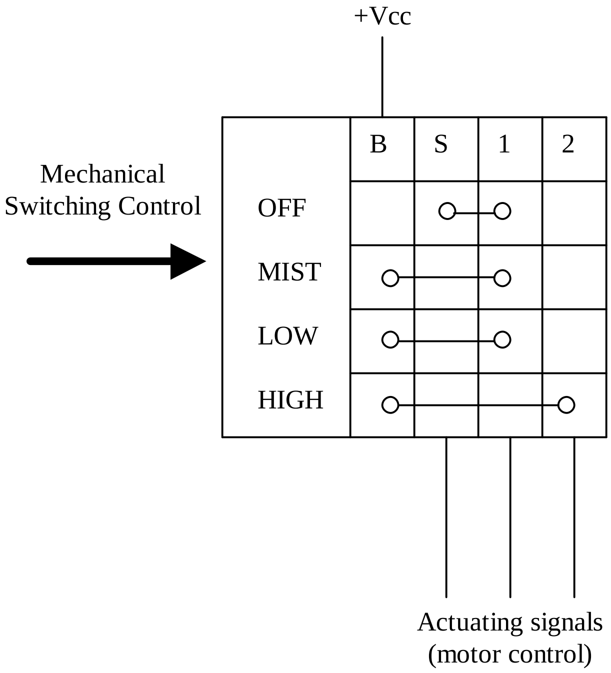

Figure 22: Switching Unit Function Table

7.2 Actuation Interface Modification

The AWWCS controls the wipers. The system also detects manual override and returns native wiper control to the user. The actuator interface will be implemented with switching relays and OR gate logic. Figure 24 shows the high level implementation of the interface using the simplified relay switching and OR gate models. We will use Siemens V23042 PCB Sensitive Non-latching Type (#V23042A2601B101) Relays whenever needed.

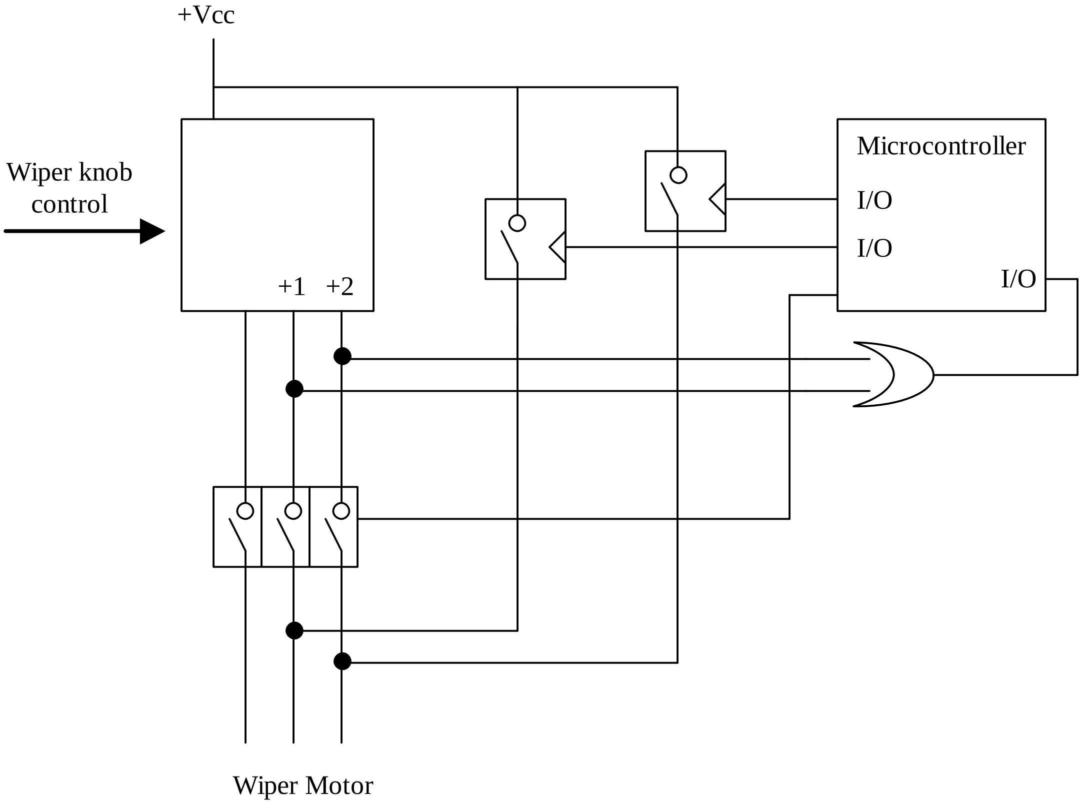

Figure 23: Actuation Interface Modification to Native Wiper Control

The above system will operate in various states; the two states of interest are:

1. AWWCS system enabled: The wiper knob is set to off and the wipers are taking command from the microcontroller.
2. Manual Override: The wiper knob is set to any wiper state (not off) and the microcontroller output is not controlling.

For the Microcontroller to know which state the wiper knob is in, an OR logic circuit (with details to follow) will compare the voltages from the +1 and +2 actuating lines. According to the function table of Figure 23, the lines will be connected to ground voltage when the knob is off and when the knob is in a wipe mode, one of the two lines will carry a voltage high. Therefrom the input into I1 from the amplifier provides microcontroller with the wiper knob state. The OR gate will be *a FairChild Quad 2-input OR gate* (Digikey #: DM74ALS86N-ND); Figure 25 shows the resistor configuration to provide approximately 5V inputs to the OR gate (with approximately 12V on the +1/+2 lines).

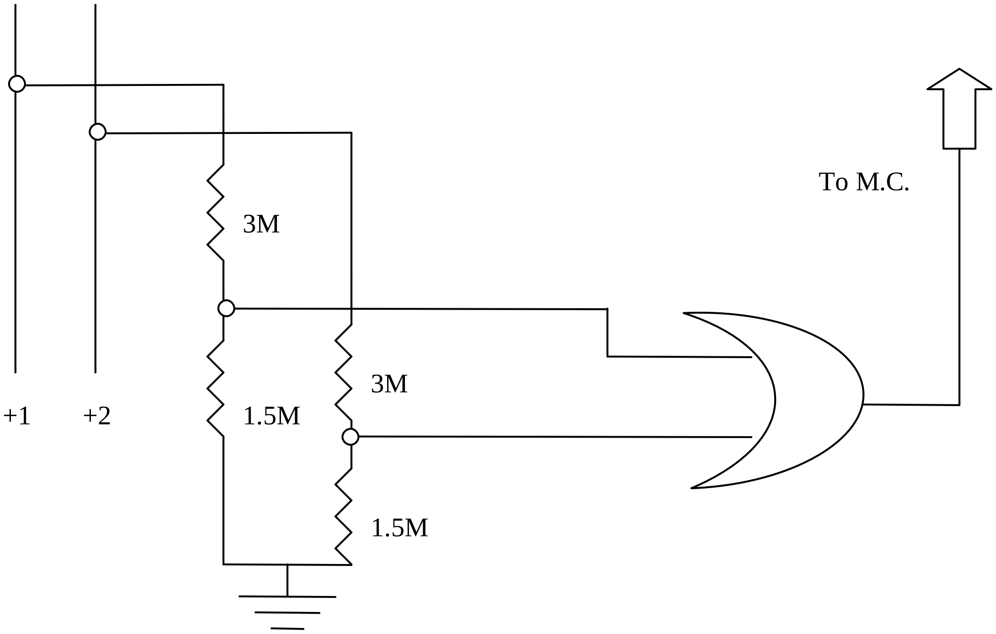

Figure 24: Manual Override Detection Circuit

When the wiper knob is detected to be off, the microcontroller will control the wiper motor. O3 will open the three relays on the actuation lines to isolate control to the MC. Then O1 and O2 will open and close the relays appropriately to give the correct actuating signal as commanded by the sensor input. An O1/O2 output of logic 0/1 will actuate a low speed wipe and an output logic of 1/0 will actuate.

When the wiper knob is detected to be in any of the wipe modes, the user has entered manual override mode and the cars' existing wiper system controls the wipers. O3 will close the three actuation line relays to accept native control from the wiper knob. O1 and O2 will force their two related relays open to prevent MC control.

7.2.1 Actuator Interface Installation

The area of modification and installment is located beneath the main plastic panel under the steering column in the Tercel. Upon inspection, the 3 actuating lines are easily accessible with general room available for the actuator interface. The OR gate, resistors and relay pair will be encased in a custom enclosure. This enclosure has the inputs/outputs listed in Table 4. The enclosure can be securely mounted by various means.

Table 4: Actuator Interface Enclosure I/O

Inputs	Outputs
Vcc	Vcc Relay #1
+1 (Blue/White stripe)	Vcc Relay #2
+2 (Blue/Black stripe)	Fairchild Quad 2-input OR gate
2 Atmel Output Ports	

Note that from Figure 23 that the +1/+2 inputs are taken *before* the 3 parallel actuating line relays and the two relay outputs meet the actuating lines *after* the relays.

Aside from the enclosure, the three parallel relays taking a common input from a single MC port must be fitted. The connections being made to the 3 actuating lines will require a physical cut to the lines to insert the relays and make the necessary connections.

8 Testing

Extensive testing is required for the AWWCS for system bugs, as well as to fine tune the system for optimal performance. Initial testing is best done with smaller components and in labs. Final testing will be performed in actual driving conditions.

8.1 Signal Acquisition Testing

The following is the test procedure for the variable resistance sensor

1. Connect variable resistor sensor to 5V DC voltage source
2. Examine resistance of the variable resistance sensor; it should be an open circuit
3. Place a drop of water such that the raindrop is in contact with both conductive strips
4. Examine the resistance of the variable resistance sensor, the value should be around 300kΩ

If the value of drop of water differs from 300kΩ by several order of magnitude, the conductive strip seperation is too close or too far.

The following is the test procedure for the variable capacitance sensor

1. Connect the variable capacitance sensor with an capacitance bridge
2. Measure the capacitance of the variable capacitance sensor, the capacitance should be around 20pF
3. Using a spray gun, spray a fine mist on the sensor
4. Measure the capacitance of the variable capacitance sensor

The capacitance of the variable capacitance sensor should increase. Additional mist spray will eventually result in a final steady capacitance of 60pF.

8.2 Signal Conditioning Testing

The following is the test procedure for the signal conditioning circuit of the variable resistance sensor.

1. Connect the variable resistance conditioning circuit to a 5V DC voltage source, replace variable resistance sensor with a 300kΩ resistor
2. Examine the output voltage across any resistor of the conditioning circuit

The voltage drop across any resistor should be around 2.5V

The following is the test procedure for the signal conditioning circuit of the variable capacitance sensor.

1. Connect the variable capacitance conditioning circuit to a 5V DC voltage source, replace variable capacitance sensor with a 20pF capacitor
2. Examine the pulse generator with an oscilloscope, a 5V 20kHz square should be observed
3. Examine the output of the variable capacitance sensor conditioning circuit

The output waveform should be close to square wave. The peak to peak wave voltage should be close to 2.5V.

8.3 User Interface

The following is the test procedure for the signal processing unit.

1. Connect the UI to a 5 voltage source
2. Turn the knob to off, no UI LED should be on
3. Turn the knob to “normal”, only normal LED should be on
4. Turn the knob to “fast”, only fast LED should be on

8.4 Signal Processing

The following is the test procedure for the signal processing unit.

1. Place the AT90S2313 into the STK300 Atmel test board
2. Connect the STK300 to a PC
3. Connect the 5V DC adapter to the STK300, activate the board
4. Run AtmelProg in the PC
5. The AtmelProg should be able to detect the STK300, as well as detect the AT90S2313, otherwise, there is a problem with the STK300 or the AT90S2313
6. Run AVR debug, input dummy test vectors simulating sensor conditioning circuit input

The output from the debugger is examined. Actuation should occur when input test vector reaches threshold level

8.5 Actuation Interface Testing

The following is the test procedure for the actuation interface.

5. Connect the actuation interface relays with a 12V voltage source
6. Place a 10Meg resistor load with each relay, simulating motor
7. Connect selected input with a 5V voltage source
8. Measure voltage across corresponding load resistor

Voltage drop across corresponding to selected input should change from 0 to 12V.

8.6 System Testing

The following is the test procedure for the AWWCS.

1. Connect 5V voltage source to AWWCS
2. Connect the actuation interface relays with a 12V voltage source
3. Place a 10M resistor load with each relay, simulating motor
4. Spray a fine mist over the combinational sensor
5. Examine actuation interface, the voltage across resistor load corresponding normal wipe should be 12V
6. Place a drop of water such that the raindrop is in contact with both conductive strips of the variable resistance sensor
7. Examine actuation interface, the voltage across resistor load corresponding normal wipe should be 12V
8. Place 6 drops of water such that all 6 raindrops are in contact with both conductive strips of the variable resistance sensor
9. Examine actuation interface, the voltage across resistor load corresponding fast wipe should be 12V

9 Reference

[1] Kip, Arthur F. *Fundamentals of Electricity & Magnetism,* 2nd ed. McGraw-Hill, New York: 1969.

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[3] Mano, M. Morris. *Computer System Architecture*, 3rd ed. Prentice-Hall, New Jersey: 1993.

[4] Atmel AVR, AT90S2313 Complete Data Sheet, 1998.