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March 16, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
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Re: ENSC 370 Project Windshield Anti-Fog System Design Specifications

Dear Dr. Rawicz,

The attached document, *Windshield Anti-Fog System Design Specifications*, epitomizes our system design. Our project is to design a safety device that will help avoid possible car accidents because of the foggy situation on windshield.

This document lists the required electronic components and includes the design specifications of the various units. These units include a signal acquisition unit, a signal conditioning unit, a signal processing unit, and an actuator interface.

ABEE Technologies Inc. consists of four motivated and innovative engineering students, including Edlic Yiu, Edwood Yiu, Angela Lee and Benjamin Lee. Please feel free to contact us via e-mail at ensc370-abee@sfu.ca should you have any questions on our document, or should you wish to comment on our project.

Sincerely,

Edlic Yiu, Team Leader
ABEE Technologies Inc.

Enclosure: *Windshield Anti-Fog System Design Specifications*

The **Windshield Anti-Fog System**

Design Specifications

Submitted by: *ABEE Technologies Inc.*
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Benjamin Lee
Edlic Yiu
Edwood Yiu

Submitted to: Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University

ABSTRACT

The WAFS is a device that detects the visibility of the windshield and actuates the blower when the moisture level exceeds a predefined threshold value. A laser beam is emitted on the surface of the windshield. Due to the scattering of the laser ray by the moisture on the windshield, the signal level of the reflected laser beam would diminish as the amount of moisture increases. Hence, by placing the photo-sensors on the dash, the moisture level on the windshield can be measured. The signals from the photo-sensors are then passed to the signal conditioning unit. An analog-to-digital converter samples these continuous signals, and the resulting digital data is acquired by the microcontroller. The microcontroller will then start the blower when the foggy windshield appears.

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1. Introduction

The invention of vehicle reduces the time for travelling. However, there are hazards that diminish the pleasure of driving, such as the foggy windshield. The Windshield Anti-Fog System (WAFS) comes to a rescue for the foggy situation. When fog appears on the front glass, the WAFS will start the blower automatically and air will be distributed to the windshield. As a result, fog will disappear gradually, which improves visibility for the driver. In other words, drivers can concentrate on controlling their vehicle without worrying the appearance of fog.

Towards achieving our goal and implementing this device, thorough considerations have to be made. This document provides the design specifications of various stages, and specifies all electronic components used in this project. These stages include the signal acquisition, signal conditioning, signal processing, and actuator interface. The audience for this work is Dr. Andrew Rawicz, Mr. Steve Whitmore, the design engineers of ABEE Technologies Inc., and external design consultants.

2. System Overview

The Windshield Anti-Fog System inputs a laser signal and outputs a voltage signal to turn on the air conditioning system. Figure 1 illustrates the different stages from how to sense the moisture level, condition them, processing them, and generating the necessary output.

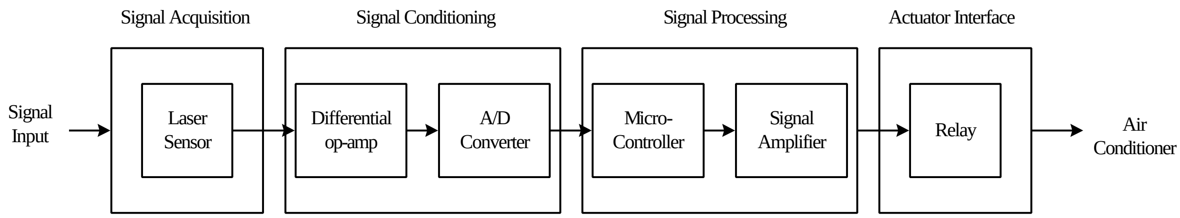

Figure 1. Detailed Windshield Anti-Fog System Block Diagram

First in the signal acquisition stage, a laser emitter projects a laser beam onto the windshield. The reflected signal, which may be weaken if there is fog on the glass, is detected by a laser sensor (Note: This sensor also receives other signal like sunlight). A second laser sensor is then used to detect only the sunlight, noise and other external signals. The sensors then passes the respective voltage signals to the signal conditioning stage where a differential op-amp is used to measure the difference in voltage of the two sensors. This process can filter out the reflected laser beam signal, which can be used to determine the moisture level on the windshield. The output from the differential op-amp is translated into digital data in signal conditioning stage by an A/D converter, and the result is acquired by the signal processing stage. In the signal processing stage, the microcontroller analyzes the input digital signal and determines if the air conditioning system should be turned on to eliminate fog. If the output of the signal processing unit is logical high, the actuator interface will switch power to the air conditioning system.

The part list for Windshield Anti-Fog System can be found in the appendix.

3. Signal Acquisition Stage

At the beginning, the input signals are obtained by the signal acquisition stage. Figure 2 shows the context diagram of this stage.

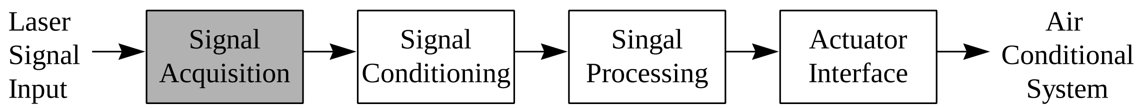

Figure 2: Context Diagram of the Signal Acquisition Stage

The Windshield Anti-Fog System (WAFS) detects the moisture on the inside of the windshield and turns on the air conditioning system to remove any fog on the windshield. A laser ray is emitted on the surface of the windshield. Due to the scattering of the laser beam by the moisture on the windshield, the signal level of the reflected laser ray would go down as the amount of moisture increases. Hence, by sensing the intensity of the reflected laser ray, we would be able to determine how foggy the windshield is.

3.1. Usage of Two Sensors

Two laser sensors will be used in this system. One of them is used for detecting the reflected laser signal from the windshield (Sensor 1). The other one is used to detect the signal mainly from the sunlight as well as other external light waves (Sensor 2).

Two sensors are used because sensor 1, which is intended to measure only the signal from the reflected laser ray on the windshield, also receives radiation signals from other sources with different wavelengths and intensities. Especially with the interference of sunlight which contains all kinds of light waves. This generates some unwanted signals that would affect the system to detect the real situation. For this reason, two sensors are employed and the difference between two sensor signals determines the exact signal for the reflected laser beam. This can be done by using a differential op-amp with the two inputs from the sensors. The resulting signal is then implemented and passed to the signal processing stage.

3.2. Laser Emitter and Sensor Placement

A laser emitter is placed on the back of the rear mirror where the driver cannot see; hence the emitter won't interfere with the driver. Figure 3 shows the placement of the laser emitter and sensors.

Two sensors are placed on the signal board about 6 cm from the windshield. A separation of 2 cm between the two sensors is required to make sure that the compensation sensor (Sensor 2) does not receive any signal from the reflected laser.

Either an infrared or a visible red laser would be used in this project.

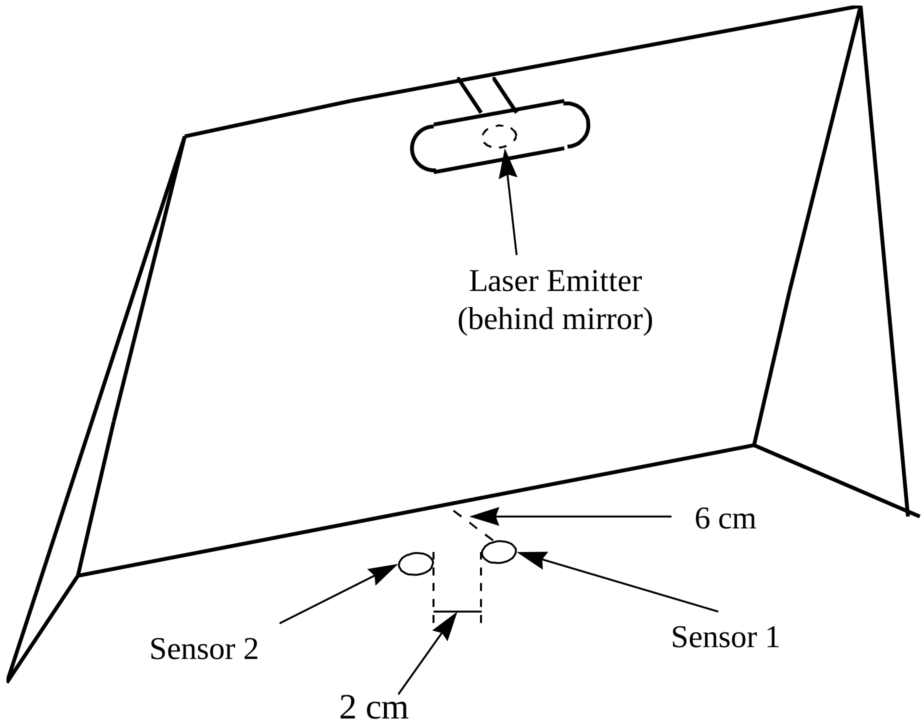

Figure 3: Physical design of the WAFS

3.3. Visible Red Laser Emitter

The visible red laser emitter has its advantage and disadvantage due to its visibility.

It is an advantage to use the visible red laser because the WAFS requires the laser beam to travel a long distance before it reaches the sensor. Putting the sensor at the correct position, where the invisible infrared laser reflected onto, is very hard to accomplish since the invisible laser dot is very small and hard to detect. But with the visible red laser, we can see the laser spot and put the sensor at the proper place. It is more accurate and saves a lot of time.

On the other hand, because the red laser is visible, it may affect the driver's vision and endanger the passengers in the car.

3.4. Infrared Laser Emitter

In contrast with the visible red laser, the infrared laser has its advantages and disadvantages due to its invisibility.

The disadvantage of the infrared laser is that the laser beam and the sensor are hard to be located. It may also cause damage to people's eyes, as they don't know where the laser projects.

However, there is a great advantage to use infrared as it won't disturb the driver because the laser beam is invisible.

3.5. Choice of Laser Emitter

Both the infrared and the visible red laser emitters would be tested to validate their performance on the project. The infrared laser emitter will be used if it works properly because it won't affect the driver's vision. The visible red laser would be used to test the system in the lab since it is much easier to experiment with.

3.6. Choice of Moisture Detecting Position

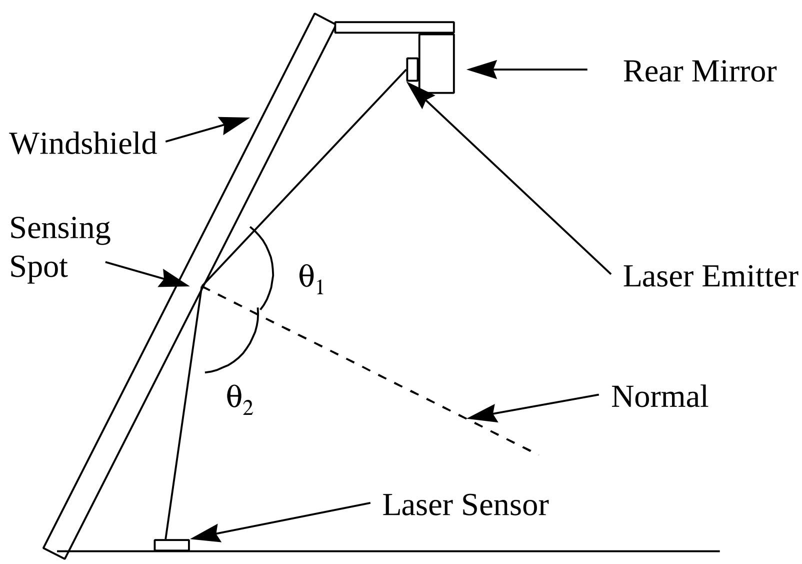

Figure 4: Side view of the system

3.7. Diodes

To produce visible red laser and infrared laser ray, diodes are the most efficient and low cost components. Diodes can be easily implemented without extra complex circuit. In addition, diode is a low power consumption device that is suitable for our design.

3.7.1. Red Laser Emitter Diode

Two brands of the red laser emitter diodes we considered were from Sharp and NVG. Since our design requires low power laser, the smallest optical power output of red laser emitter diode, 5mW, was chosen. Although both companies have laser emitter diodes with 5 mW optical power output, we chose NVG primarily because it is 3 times lower cost than Sharp. The following is the characteristics of our chosen visible red laser emitter diode, NVG D6605I.

Table 1. The Characteristic of NVG D6605I

Operating voltage (V)	2.7
Operating Current (mA)	40-60
Laser wavelength (nm)	660±5
Optical power output (mW)	5
LD reverse voltage (V)	2
PD Reverse voltage (V)	30
Operating temperature (°C)	-10:+40

The following figure is the diagram for NVG 6605I. Pin 2 is connected to ground, and pin 3 is connected to 5V power supply with a 50 Ω resistor. The 50 Ω resistor limits the current into the laser emitter.

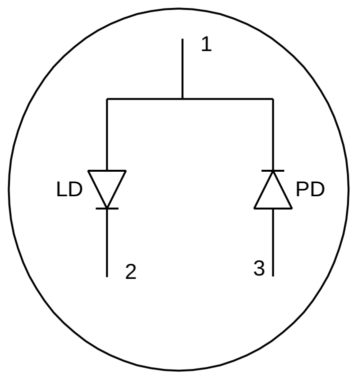

Figure 5. Pin Diagram for NVG D6605I

3.7.2. Infrared Laser Emitter Diode

The selection criteria for the infrared laser emitter diode are similar to the criteria for the visible red laser emitter diode. The only difference between infrared laser emitter diode and visible red laser emitter diode is the laser wavelength. The laser wavelength for infrared laser emitter diode should be approximately 810 nm.

Since SFU Engineering Lab Store carries the infrared laser emitter diode, which is suitable for our design, we will use the one provided from school.

3.8. Monolithic Photodiode (Light Sensor)

The OPT101 monolithic photodiode from the Burr-Brown Corporation was selected to measure the intensity of laser beam. This integrated circuit allows a wide range of operating voltage, which is ideal for battery operated environment like vehicle. In addition, the linearity of output voltage with respect to light intensity and the on-chip transimpedance amplifier can significantly simplify the design of the Windshield Anti-Fog System. Besides, most photodiodes in the market offer current as the output, which requires an op-amp or a resister for current-to-voltage conversion. Thus, non-linearity from an op-amp or a resister may prevent the proper identification of the actuator's set point. Therefore, the characteristics of the OPT101, along with its relatively low cost, offer an excellent choice for detecting laser intensity. Table 2 quantifies these characteristics and Figure 6 shows the connections of the OPT101 to be used in this project.

Table 2. OPT101 Characteristics

PARAMETER	OPT101
Operating Voltage Range	+2.7 to +36V
Dark Error (Offset Output Voltage)	7.5mV
Responsivity of Voltage Output	0.45V/µW @ 650nm
Output Voltage Range	0 to V_s

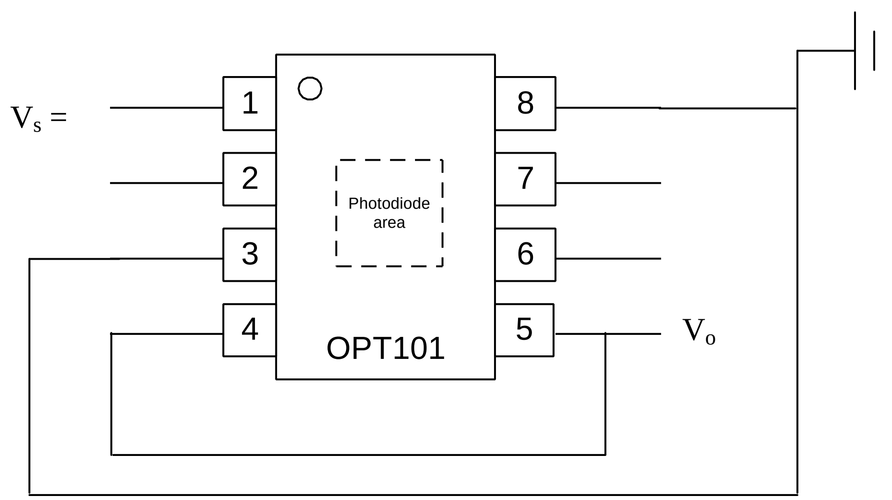

Figure 6: The Connections of the Monolithic Photodiode

In this configuration, pin 2, 6, and 7 are not used. The operating voltage is 5V so that the output voltage will satisfy the requirement in the signal conditioning stage. The output is 7.5mV with no light and rises linearly with increasing illumination till 5V.

4. Signal Conditioning Stage

After the signal acquisition stage, the inputs are manipulated by signal conditioning stage. Figure 7 shows the context diagram of this stage.

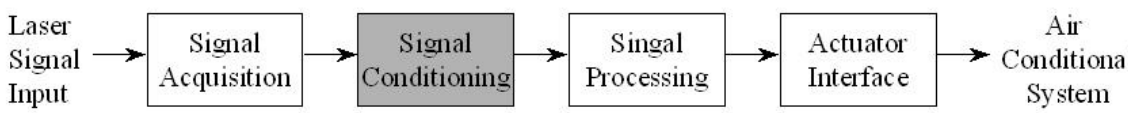

Figure 7. Context Diagram of the Signal Conditioning Stage

In the signal conditioning stage, the differentiation of the two signals from the photodiodes is taken in order to obtain the exact signal for the reflected laser beam. This signal is then fed into the Analog-to-Digital Converter, which results in a straight binary number used in the signal processing stage. Through the research of various A/D converters in the market, a single AD670 electronic component from Analog Device was selected to accomplish all required tasks in this stage.

4.1. AD670 Signal Conditioning 8-bit ADC

An AD670 integrated circuit from Analog Device provides many features, such as 5V-supply operation, differential inputs and 8-bit A/D conversion. These characteristics are ideal for the signal conditioning stage in this project. Although there are other similar products, such as AD7820 and LTC1406, in the market, the AD670 is the most attractive component due to its parallel interface, simple control logic, and relatively low cost. Table 3 gives the characteristics of the AD670.

Table 3. The Characteristics of the AD670

PARAMETER	AD670
Operating Voltage Range	+5V
Power Dissipation	450mW
Resolution	8 Bit
Conversion Time	10µs
Differential Input Range ($-V_{IN}$ to $+V_{IN}$)	0 to +2.55V (10mV/LSB)
Absolute Input Range	-1.50 to V_{cc}
Relative Accuracy	±1/2 LSB
Interface	Parallel

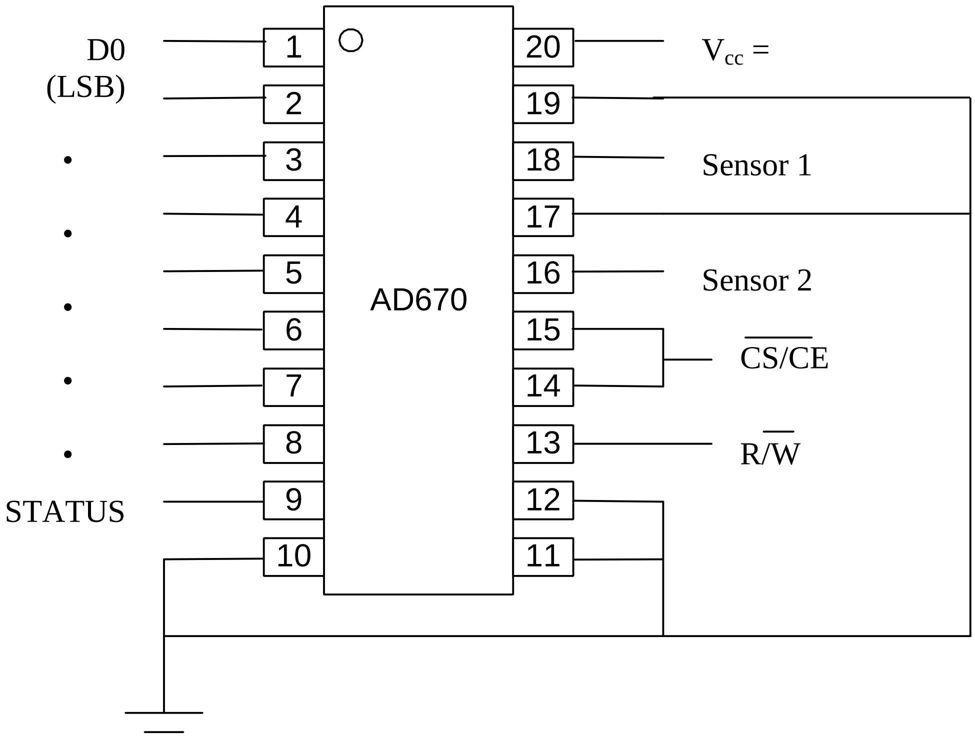

Figure 8. The Connections of the AD670

Figure 8 shows the connections of the AD670 to be used in the WAFS project. Pin 1 to 8 represent the straight binary number that will be acquired by the signal processing stage. Pin 11 and 12 are connected to ground in order to specify unipolar input signals and straight binary output format respectively. Pin 16 is connected to the OPT101 photodiode, which is used to measure the intensity of sunlight. Likewise, Pin 18 is linked to the other OPT101 photodiode, which is used to measure the combination of the sunlight and laser beam intensity. The voltage supply is 5V, and is connected through Pin 20. Pin 9, 13, 14, and 15 are used to control the read and write process of the A/D converter. Figure 9 shows a timing diagram for the single conversion/single read cycle.

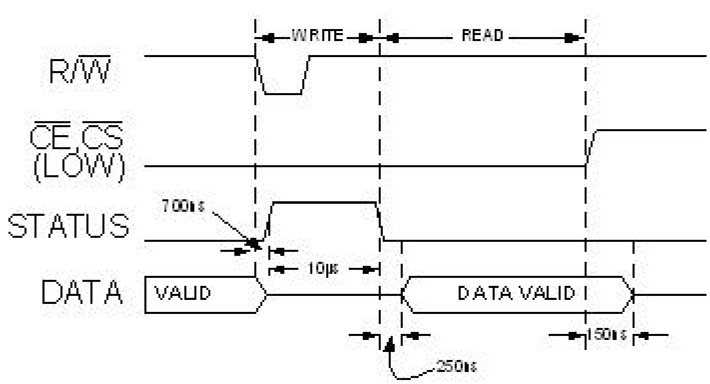

Figure 9. Single Conversion/Single Read Cycle

5. Signal Processing Unit

The signal processing unit is the brain of the system, which controls each operation within the WAFS. Figure 10 below shows the context diagram of this stage.

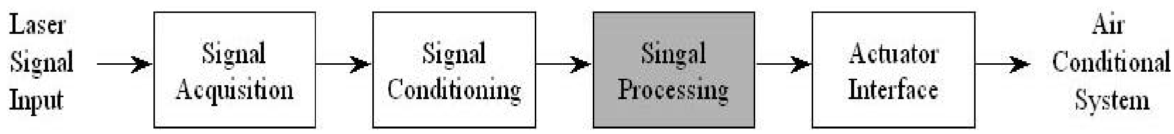

Figure 10. The Stage of Signal Processing Unit

The signal processing unit is responsible for analyzing the signal and commanding the actuator interface. Giving a logical high to actuator interface means turning on the blower.

5.1. The Algorithm

The signal processing unit is responsible for signal analysis and output generation. The following figure demonstrates the algorithm.

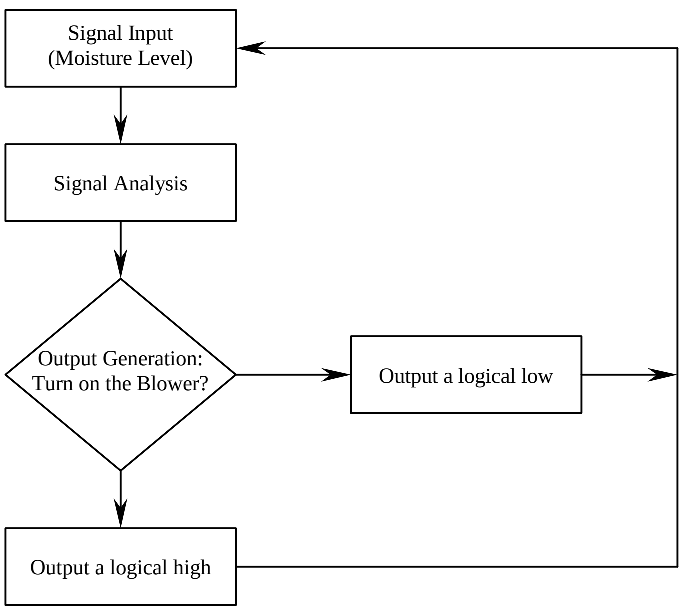

Figure 11. The Flowchart for the Signal Processing Unit

5.2. Threshold Level

The input signal to the signal processing unit is the reflected laser intensity level at the particular moment. When the laser intensity level is high, the moisture level on the windshield is low. In other words, low laser intensity level equals foggy windshield. Hence, the blower will be activated whenever the input signal is below a threshold point. With repeated testing and trials, a threshold level will be determined.

5.3. Sampling Rate

To avoid switching a blower on and off frequently, we will limit the sampling rate according to the output state. When the current output is logical low (blower's off), the signal processing unit samples the input every 2 seconds. The off-position sampling rate is determined by experiment, which is the minimum time required for moisture to accumulate on the windshield. When the current output is logical high, the system samples the input every 20 seconds. This interval is determined such that the passengers would not be annoyed by the flickering of the blower.

5.4. Output Generation

Figure 12 shows the state changes of output signal according to the input signal and the output state. The latency of state changes in output signal is due to the sampling rate as described in section 5.3.

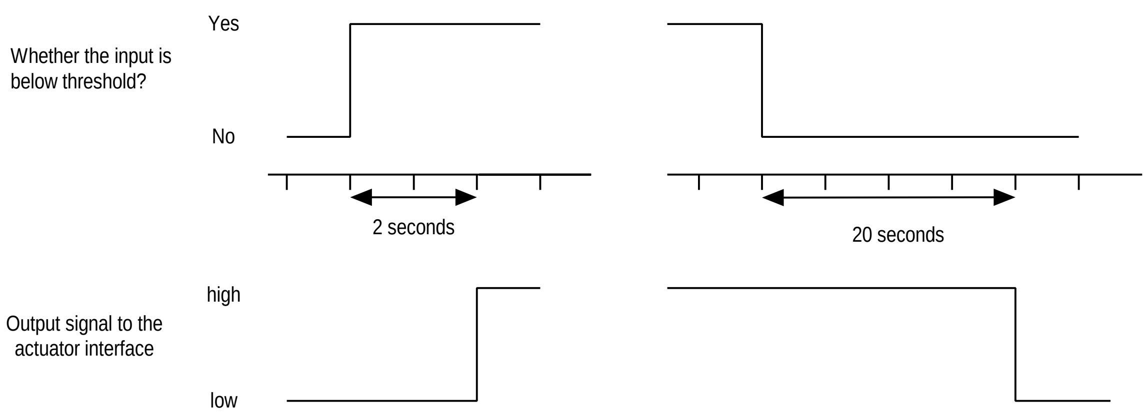

Figure 12. Changes of the Output Signal

5.5. Microprocessor Selection

The core of the signal processing unit is the microcontroller. Some of the microcontrollers we considered were Motorola 68HC11, National COP8, and Microchip PIC16F84. We chose the Microchip PIC16F84 primarily because it has 1K flash program memory, 68 bytes data memory, 8-bits manipulation, and 13 I/O pins with individual direction controls. With all these capabilities, PIC16F84 has sufficient power for the WAFS project. The following table summaries the features of PIC16F84.

Table 4. PIC16F84 Device

Maximum Frequency of Operation (MHz)	10
Flash Program Memory	1K
Data Memory (bytes)	68
Data EEPROM (bytes)	64
I/O Pins	13
Voltage Ranges (V)	2.0-6.0
Packages	18-pin DIP

5.6. Microchip PIC16F84

The following figure illustrates the pin connection diagram for the PIC16F84. It has 8-bit input signal, two A/D converter control pins and one A/D converter acknowledge pin.

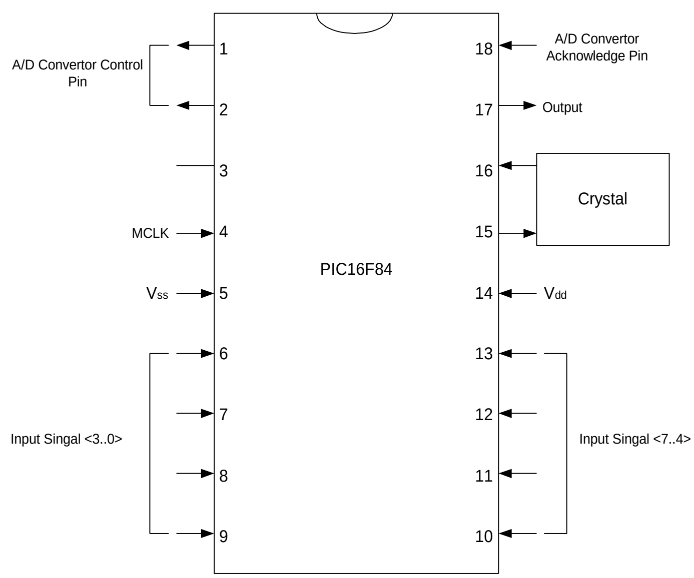

Figure 13. Pin Diagram for PIC16F84

Pin 5 is identified to be the V_{ss}, which acts as ground terminal for the microcontroller. Pin 14 are noted to be V_{dd}, which is the supply voltage. The operating voltage of the microcontroller is approximately 4.5 V to 5.5 V at 8 MHz. Pin 4, marked with MCLK, is an active low reset pin. Since the WAFS doesn't need any reset during the operation, pin 4 is connected to V_{dd} with a 50 Ω resistor. The 50 Ω resistor can prevent damage from current surge of the power supply.

The pins marked with Input Signal are the input pins from the signal conditioning unit. The output to the actuator interface is pin 17, Output. In order to obtain input data, the microcontroller has to control the A/D converter in signal conditioning unit. Pin 1 and pin 2 are the A/D converter control pins, which control the read and write process of A/D converter. Pin 18 is identified as A/D converter acknowledge pin, which is the acknowledgment of data-ready from the A/D converter.

Pin 15 and pin 16 interacts with the crystal circuit, which provides 8 MHz oscillation. The PIC16F84 requires the use of a parallel cut crystal. The use of a series cut crystal may give a frequency out of the crystal manufacturers specifications. Figure 14 shows the basic elements in the crystal circuit. The purpose of the capacitor, C_1 and C_2, in the crystal circuit is to increase the stability of the oscillator. However, the higher capacitance also increases the start-up time. At 8 MHz operation, the capacitors should be chosen between 15 pF and 33 pF.

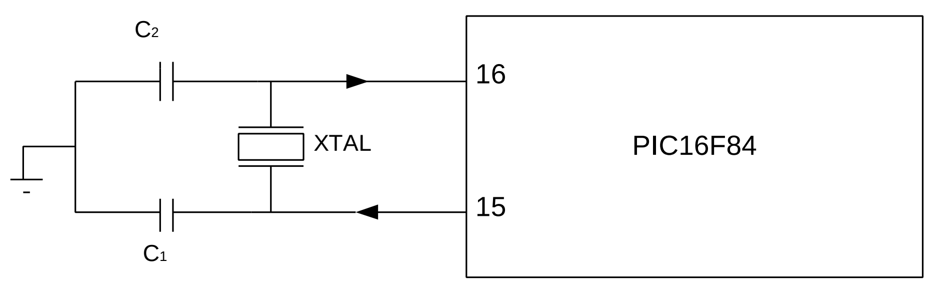

Figure 14. Crystal Configuration

6. Actuator Interface

The actuator interface is similar to a light switch, except is controlled by signal processing unit. Figure 15 below illustrates the stage of actuator interface in the system.

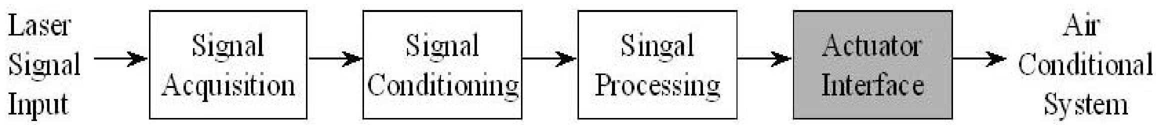

Figure 15. The Position of Actuator Interface

The actuator interface is an adapter that plugs onto the automobile battery. At the same time, a blower is connected to the actuator interface as shown in Figure 16.

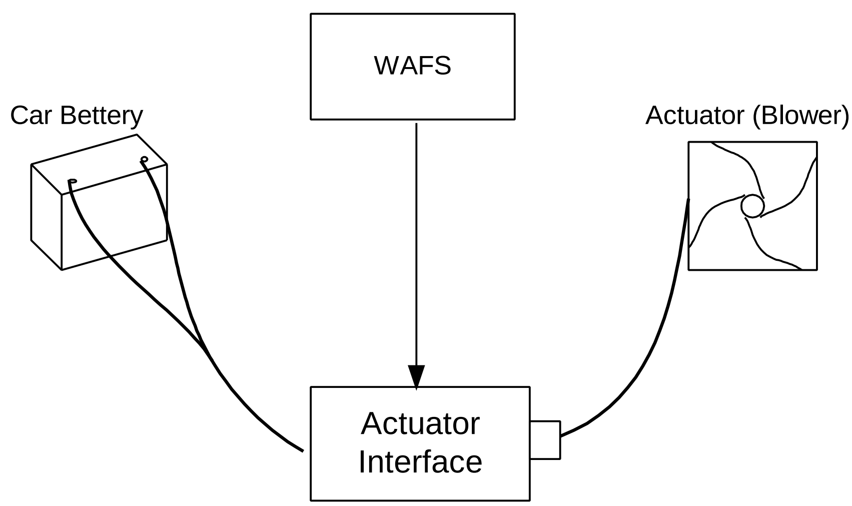

Figure 16. The Connection of the Actuator Interface

Whether actuator receives power from the car battery will be controlled by a signal from the WAFS. When the WAFS detects the laser intensity lower than the threshold value, it will provide a continuous logical high or 5 V signal to the actuator interface. Then the actuator interface will switch power to the actuator. When the input signal is above the threshold level, the logical high signal will go low, which will turn the blower off.

The element in the actuator interface is shown in Figure 17.

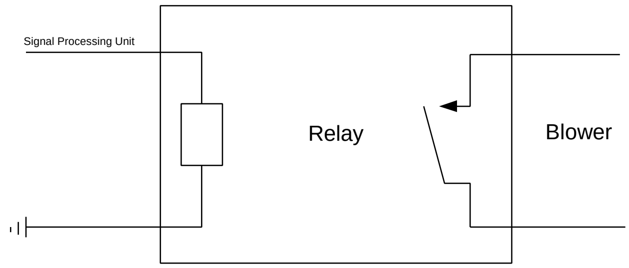

Figure 17. The Actuator Interface

We have chosen to use a relay to switch on and off power to the actuator. Specifically, the Omron G5CE-1-DC5 is used to isolate the DC or AC blower from the rest of the circuit. This device was chosen because it supports rated load of 15A at 110VAC and 10A at 30VDC. In addition, the input voltage is only 5V and the input current is only 30mA. The power consumption of the relay is as low as 150 mW, which is suitable for our design. The following table summarizes the characteristic of the G5CE-1-DC5.

Table 5. The Characteristic of G5CE-1-DC5

Contact	
Form	SPST-NO
Material	AgCdO
Coil	
Input voltage (V)	5
Input current (mA)	30
Coil resistance (Ω)	166.7
Contact	
Max. operating voltage (V)	110 VAC or 30 VDC
Max. operating current (A)	15
Max. switching capacity	2500 VA or 300 W
Operate time (ms)	10 max. (mean value: 6.70)
Release time (ms)	10 max. (mean value: 0.90)

Since the input to the G5CE-1-DC5 will be a constant 5V signal with little variation provided by the microcontroller, we will not need any extra circuit to boost the voltage. However, we may need a current amplifier to boost the current from the microcontroller because the maximum output current transferred by the Output pin of the microcontroller is only 20 mA.

7. Enclosure

Plastic enclosures will be employed for the WAFS and an aluminum enclosure will be employed for the actuator interface. The plastic enclosures provide a lightweight, and are resistive to salt that the device may be exposed to in winter. The aluminum enclosure for the actuator interface provides short-circuit current protection when the enclosure is grounded properly. In addition, fault energy and noise from other parts of the automobile can be drained to the outside earth ground system efficiently without affecting the operation of the relay.

8. Testing

8.1. Signal Acquisition Stage

The signal acquisition stage will be tested using the following procedure.

1. Measure the output voltage of sensor 2. This is the signal given by the external lights, for example, sunlight.
2. Place sensor 1 at least 2 cm away from sensor 2. Project the laser beam onto sensor 1. Measure the output voltage of sensor 1.
3. Make sure that the output of sensor 1 is larger than the output of sensor 2..

8.2. Signal Condition Stage

The signal condition stage will be tested using the following procedure.

1. Input two different voltage into ADC (the difference should be less than 2.55V).
2. Measure the binary output, and verify with the inputs.

8.3. Signal Processing Stage

For the prototype, it shall be tested before installation. The testing procedure is as follows:

1. Connect the mircocontroller as described in Section 5.6 with V_{dd} and V_{ss} equals to 5V and ground, respectively.
2. Connect the input pins with 10K resistance.
3. Connect the output pin with a LED and a resistor serially.
4. Turn on the power.
5. Supply voltage to the input pins. If the value is below the threshold level, the LED will light up. If the value is equal or greater than the threshold level, the LED will be off.

8.4. Actuator Interface

1. Plug the actuator interface into the automobile battery.
2. Plug the actuator (the blower) into the actuator interface and turn on the actuator power switch.
3. The actuator should be off.
4. Apply a 5V constant DC signal to the signal processing input port of the actuator interface.
5. The actuator should be on.

8.5. Overall System

The WAFS will be tested using the following procedure:

1. Set up the whole system as discussed in this document.
2. Turn on the switch of the system.
3. The blower should be off since no fog is on the windshield.
4. Create fog by applying steam on the windshield.
5. The blower should be on.
6. The blower should turn off after 20 seconds, since the fog is eliminated.

9. Reference

[1] NVG, Inc., http://www.nvginc.com

[2] Omron, http://www.omron.ca

[3] NAiS Relays, http://www.aromat.com

[4] Microchip, http://www.microchip.com

[5] Analog Device, http://www.analog.com/

[6] Burr-Brown, http://www.burr-brown.com

[7] Sharp, http://www.sharp.com

[8] Electro-sonic Catalog

[9] Active Device Catalog

Appendix

Part List

Item	Manufacturer	Part Number	Quantity
Analog-to-Digital Converter	Analog Device	AD670	1
Capacitor		22nF	2
Crystal		8.000MHz-HC49S	1
LED			1
Microcontroller	Microchip	PIC16F84	1
Monolithic photodiode	Burr-Brown	OPT101	2
Relay	Omron	G5CE-1-DC5	1
Resistor, 0.25W, 1%		50Ω	2
Transistor		2N3904	1
Visible red laser emitting diode	NVG	NVG D6605I	1
Voltage regulator	National	LM317	1