HelperTech.
School of Engineering Science, Burnaby, BC, V5A 1S6

February 14, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

Re: ENSC 305/440 Design Specification for Remote Control Snow Blower Robot

Dear Dr. Rawicz:

The enclosed document clearly describes the design specification of our developing snow blower robot, RoboBlow, which is a wireless remote control robot for snow removal. Our proposed robot will provide the utility of snow removal without the necessity of going outdoors in person. The main functionality of the robot will include salt spraying, snow throwing, and real time video transmission from the robot to the remote controller.

The attached document describes the design specification to achieve the functionality requirements of the robot as well as the solutions and the systems in mechanical, electrical, and programming aspects. The mechanical parts and models that will be used in this project are also listed in this attachment.

HelperTech is a research team found by four talented and innovative senior engineering students: Leo Cheng, Peter Hsiao, Joseph Shen, and YuYuan Liu. If there are any questions or concerns regarding our proposal, please feel free to contact me by phone or by email.

Sincerely,

Leo Cheng
President and CEO, HelperTech
Phone: (604) 760-1283
Email: hpc5@sfu.ca

Enclosure: *Design Specification for Remote Control Snow Blower Robot*

Design Specification
Remote Control Snow Blower Robot

Spring 2011

Submitted to: Andrew Rawicz (ENSC 440)
Michael Sjoerdsma (ENSC 305)

Project Team: Leo Cheng (301084573)
Peter Hsiao (301025638)
YuYuan Liu (301046236)
Joseph Shen (301032167)

Executive Summary

This design specification document provides detail description of the technical solutions to the functional requirements of RoboBlow, which is a remote-controlled robot for snow removal. RoboBlow can be controlled wirelessly and it is attached with two cameras, one snow thrower, and one mechanical part to spray salt for snow removal such that the user can stay indoors and remove snow outdoors.

Section 2 discusses the design of snow thrower in the physical, mechanical, and electrical aspects. Section 3 describes the solution to snow-out direction control with the physical design and method to monitor the snow-out process. Section 4 discusses the salt spraying unit and section 5 shows the overall physical design of the robot. Finally, section 6 provides a detail description on the remote controller in various aspects.

This document is believed to explain the design specifications to the RoboBlow functionality and following the design specifications in this document should lead to a completion of the prototype of RoboBlow.

Table of Contents

List of Figures

Glossary

LCD	Liquid Crystal Display, a flat electronic visual display
Snow Intake	The amount of snow that the snow thrower can handle at a given moment
H-bridge	A well know electronic circuit used to control motor rotation direction
ARM9	The version 9 ARM CPU. ARM is a global leading company for designing embedded system processor. ARM9 is one of their product models.
MCU	Micro-controller. It is a small computer on a single IC containing a processor, memory and programmable I/O [2]. It is usually used in automatically controlled products and devices.
IEEE 802.11	It is a set of standards carrying out wireless local area network computer communication in the 2.4, 3.6 and 5 GHz [1].
USB HID	The USB human interface device class ("USB HID class") is a USB device class that describes human interface devices such as keyboards, mice, game controllers and alphanumeric display devices.
Linux kernel	The Linux kernel is an operating system kernel used by the Linux family of Unix-like operating systems. It is one of the most prominent examples of free and open source software.

1. Introduction

RoboBlow is a remote-controlled snow thrower robot which enables its operator to remove the snow and prevent ice formation on walkways or driveways while staying inside his/her home. The remote controller of RoboBlow allows its operator to move RoboBlow in any direction with desirable speeds and offers the utility to switch on/off a snow thrower attached to the robot and to spray salt from the robot. This design specification discusses the technical approach to the RoboBlow development for these functions and the functional specifications outlined in the document of RoboBlow Functional Specification.

1.1 Scope

This design specification clearly describes the technical solutions for RoboBlow development to approach the requirements listed in the RoboBlow Functional Specification.

The possible hardware and software approaches are discussed in this document.

1.2 Audience

This document is proposed for development use in the HelperTech research team. This document has provided a design guideline with the detail solutions to the final product requirements. Engineers should use this document as reference when implementing and testing the final product.

2. Snow thrower Module

2.1 Snow Thrower Physical and Mechanical Design

Due to the level of difficulties and time limitations, we decide to purchase an off market electrical powered snow thrower from Canadian Tire [1]. The figure below shows the thrower unit we will facilitate.

Figure 1: Yardworks Electric Snow Thrower

The blade shown in the figure is rotated by an AC motor inside the snow thrower. The purpose of the blade is to "stir" the snow in the front and creates an upward force to the snow. The vane can be rotated manually so the snow with upward force can be blown into a desired direction. (The direction of the vane will be robotized and is discussed in another section.)The physical and mechanical specification and limits are lists on the operation manual and are presented in the table below.

Table1: Snow Thrower Physical and Mechanical Specification

Specification	
Blade Speed	Up to 2600 RPM (no load)
Clearing Width	40.6 cm
Clearing Depth	15.2 cm
Impeller Size	35.6 cm
Weight	10.2 kg

2.2 Snow Thrower Electrical Design and Power

2.2.1 Circuit diagram:

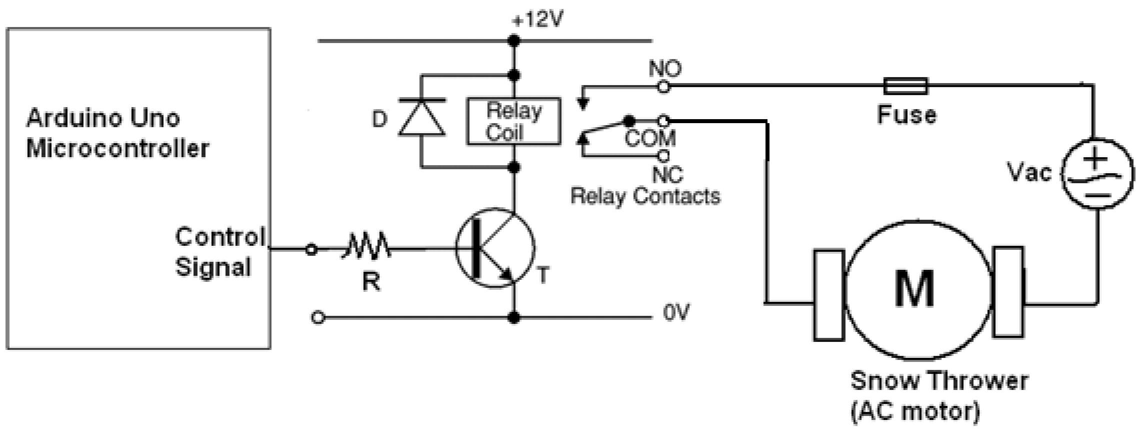


Figure 2: Power switch module for the snow thrower

We wish to be able to turn on/off our snow thrower on our robot through the microcontroller on board. The snow thrower is purchased from Canadian Tire which uses an AC motor that operates at 120V, 9A, 60Hz to rotate the turbine. Therefore, we need a relay so that we can switch AC power from the wall plug. The relay is a mechanical device that enables lower power signals to switch another high power circuit. From the diagram above, in order to switch on the relay, we can output an “on” control signal to the transistor which will put the transistor into saturation mode. Once the transistor is switched on, the switch in the relay contacts would turn to the NO node which completes the circuit to turn on the motor. We can then output an “off” control signal to the transistor so there would be no current flowing through the relay coil, and the switch in the relay contacts would turn back to the NC node which opens the circuit and turn off the motor.

2.2.2 Part information:

Table 2: Circuit components list

Component:	Name:	Value/rating:
Diode	1N4148	450 mA max.
Transistor	2N3904	200 mA max.
Resistor	N/A	1K ohm
Relay	1EC255	240VAC, 10A max.
AC motor (Snow thrower)	Electric snow thrower	120V, 60Hz, 9A

2.2.3 Operating Limits

By inspecting the data sheets and the description of each of the components in the switch circuit, we have implemented mechanisms to prevent the components from going over their limits.

1. AC motor

The AC motor inside the snow thrower is rated to operate at 120V, 60Hz, 9A. The power supply is coming directly from the wall plug. Inside the original switch component (it comes with the product), there is already a fuse installed. Therefore, we decided to replace the push bottom switch with our relay but keep the original fuse to prevent the AC motor drawing excess current.

2. Relay

The relay we purchased is rated to operate at 240Vac, 10A maximum on its contacts. Since we already have a fuse that comes with the snow thrower, we are certain that the operating power would not exceed the relay operating limits, or else the fuse would break down and prevent damages to the relay or the motor.

3. Transistor

According to datasheet, the maximum current that the 2N3904 BJT can handle is 200mA. When we apply the 8V to the relay, we can make sure the current is below 200mA by minimizing the power supply current when the transistor is in saturation mode. However, when the relay is switched off, there might be a brief high voltage produced due to the back emf of the coil. In order to prevent this voltage causing undesired high current flowing through the transistor while it is cut off, we direct this current away from the transistor by using the 1N4148 diode so the current can be dissipated gradually through the loop as the back emf disappeared.

4. Microcontroller

The current from the digital pin of the Arduino microcontroller is about 40mA. In order to prevent more current drawing from the I/O pin, we place a 1K ohm resistor in between the base of the BJT and the microcontroller to limit the current flow to about 4mA. The operating points will be discussed in the next section.

2.3 Power Distribution

The power distribution module on board is responsible to provide sufficient electrical power supplies to each of the component in the robot. The below block diagram illustrates the responsibilities of the module:

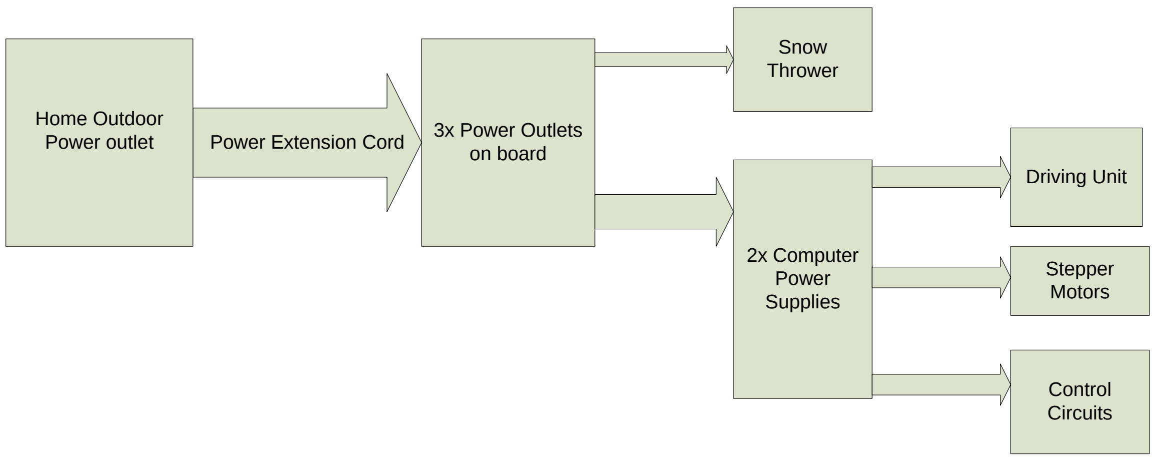


Figure 3: Inside the Power Distribution Module

Table 3: Power requirements for each component on board

Components:	Power Requirement:
Snow Thrower	120 Vac, 60Hz, 9A
Driving Unit (including 2x H bridges)	12 Vdc, 15A max each
Stepper Motors	12 Vdc, 0.33A max each
Control Circuits: -Power Switch Circuit -On Board Microcontroller -Interfacing BJTs for power MOSFETs	 -8 V -5V (Max 10Watt) -About 10V
Total:	< 1500 Watts

Note: The power extension cord should be able to handle the power rating of up to 1500 Watts. Therefore, the one rated as contractor grade with three outlets from Canadian Tire will be selected. (Please see [3])

2.3.1 Electronic Design

Powering the Snow Thrower Module

The snow thrower purchased off the market already comes with a switch circuit and the plug. Therefore, we modify the switch circuit as discussed in the snow thrower module section and simply plug the power cord to one of the three power outlets from the extension cord and the snow thrower can be powered when the power switch is on.

ATX Computer Power Supply

Since we need to design and implement circuits for driving unit, stepper motors, and control unit modules, we have to use sufficient power supplies in order to meet different power requirements of each module. The power supply for computers is our number one choice. The output voltages from computer power supplies are regulated, and the currents can be chosen with respect of the number of wires connected. We use two ATX power supplies (Provide maximum power 400Watt each) recycled from old computers. The table below displays the power ratings of these power supplies.

Table 4: A 400 Watt ATX Power Supply Distribution

Voltage	Total Current	Color of Wire	Number of Wires	Current/Wire
12V	22A	Yellow	9	2.4A
5V	20A	Red	10	2A
3.3V	10A	Orange	5	2A
GND		Black	25	

In order to turn on the power supply with no connection to computer motherboards, we just need to short the PS_ON pin on the power supply main connector to the ground pin as indicated by the green line shown in the below figure.

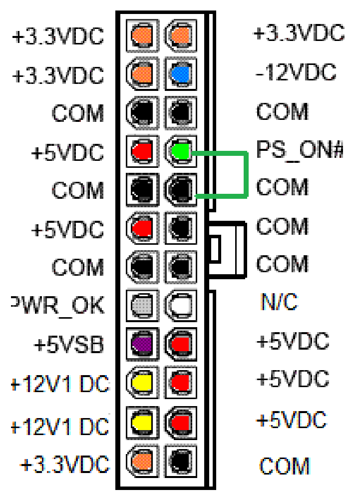


Figure 4: ATX Power Supply Main Connector

Powering the Driving Units

We will facilitate one H bridge for each of the two robot driving DC motors. As indicated by table 3, the power requirement to drive each motor is 12 V and 15 A maximum. Therefore, according to table 3, we will connect six 12V yellow wires together so we will have a maximum of 14.4 A current supply to each motor. Subsequently, six black wires should be connected so the power supply can handle the same amount of current to the ground. Tongue terminals are used to connect the ends of each bundle. We need to use two power supplies because each of them can only provide 9 12V wires and we need at least 12 wires.

Powering Stepper Motors

The power requirement for stepper motors is 12V and 0.33A maximum. Each 12V yellow wire from the ATX power supply provide up to 2.4A of current. The control H Bridge IC can only handle the maximum current of 0.33A as well. Therefore we need to use high power resistor in series with the control IC to limit the current flow in order to prevent damages to the IC. We can also facilitate current dividers which we can make sure only one eighth of 2.4 A is drawn to the IC. More details will be researched and the specific value of the current limiting resistors will be determined as we make further progress into our project.

Powering the Microcontroller and other control circuits

To power the microcontroller, we need a 5V supply with 10 Watt maximum power. This requirement indicates we can simply connect one of the 5V red wires directly to the microcontroller since it only supplies up to 2A of current. However, we will need to install a fuse in series with the power input of the microcontroller to prevent more current causing damages to the circuitry.

Each of the control circuits such as the power switch and H Bridge driving BJTs require voltages and current much lesser than one 12V yellow wire supply. When we use standard electronic lab power supplies, we can choose the right amount of power needed for each circuit. However, since the ATX power supply can only output fixed amount of power, we need combinations of voltage current dividers with power resistors to limit the power outputs. Again, more details such as resistor values are to be determined as we move further into our development. Also, test plans will be discussed and carried out.

2.4 Driving Unit

The driving unit is responsible of the movement of our RoboBlow robot. Two geared DC motors are used in this module. Control signals are inputted from the on board microcontroller to control the speed and the direction of these motors. The two Bridges act as the interface to between power, control signals and the motors. The figure in below illustrates this relationship.

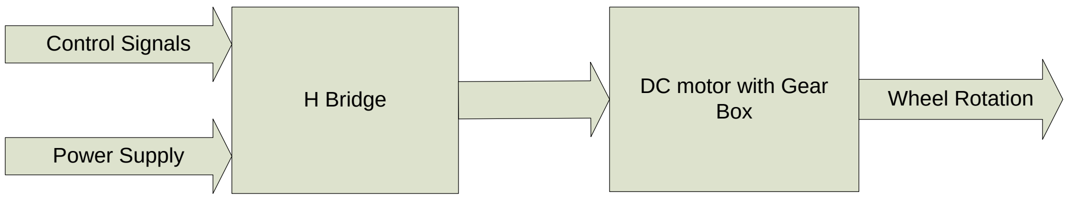


Figure 5: Driving Unit Module

2.4.1 Physical and Mechanical Design

<u>DC Motor Performance</u>

Our robot driving motor is purchased from NPC robotics, a war robot specialized vendor. The motor is bought as a set which includes a DC motor with gear box connected with the gear ratio of 34:1. The wheel is also included. The below figure shows the CAD diagram of the geared motor.

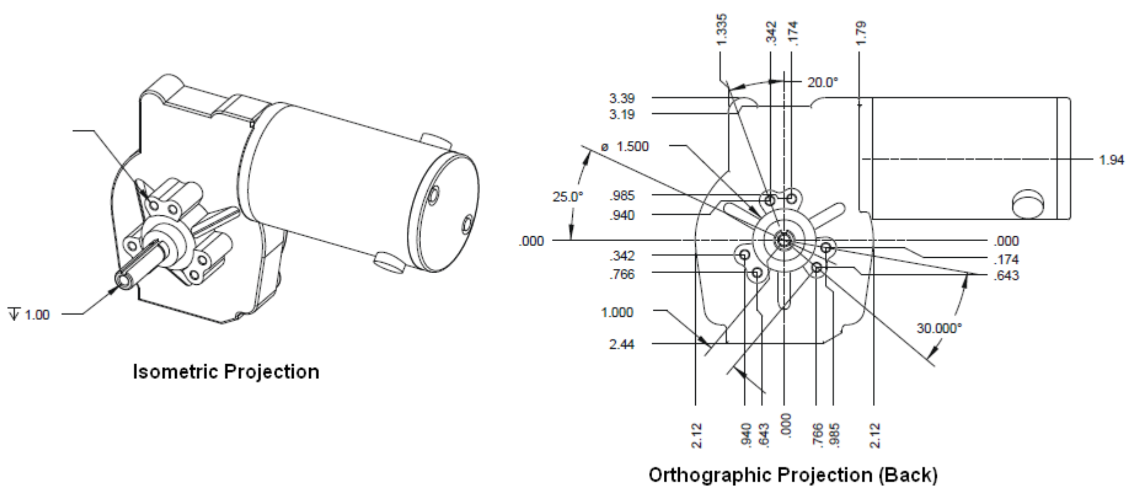


Figure 6: DC geared motor CAD diagram, units are in inches. (Cited from NPC Robotics [5])

Since the DC motor is already geared, the torque the shaft outputs is increased, but the speed of the rotation is decreased which suits our application where higher torques are needed. The table below shows the performance of the geared motor output with respect to various current supplied.

Table 5: Torque, RPM and amperage relationship @ 12V [5]

Test Results at 12V			
torque in in/lbs	Amps	RPM	HP
.42	4.0	93	.001
10	5.47	91	.014
20	6.78	89	.028
30	8.19	86	.040
40	9.55	84	.053
50	10.96	82	.065
60	12.42	80	.076
70	13.75	78	.087
80	15.14	76	.097
90	16.50	74	.107
100	17.97	72	.116 →
260	56		

<u>Material of the Wheel</u>

The wheel of our robot is included in the set with the geared motors. The diameter is 8" long and the width is about 0.8" wide. The surface of the wheel is smooth and made of rubber which would not be sufficient for our robot to drive in icy conditions. Therefore, we plan to cut two pieces of strips from a slip proof mat of width 0.8" and length of 25" and use superglue to attach them to our wheels. There might be alternative solutions to improve the traction of our wheels. More details will be addressed as we make further progress into this module.

2.4.2 Electronic Design

In order to rotate our motors in two directions, we need to implement an H-bridge circuit for each of them. The figure below presents the schematic of a standard H bridge [6].

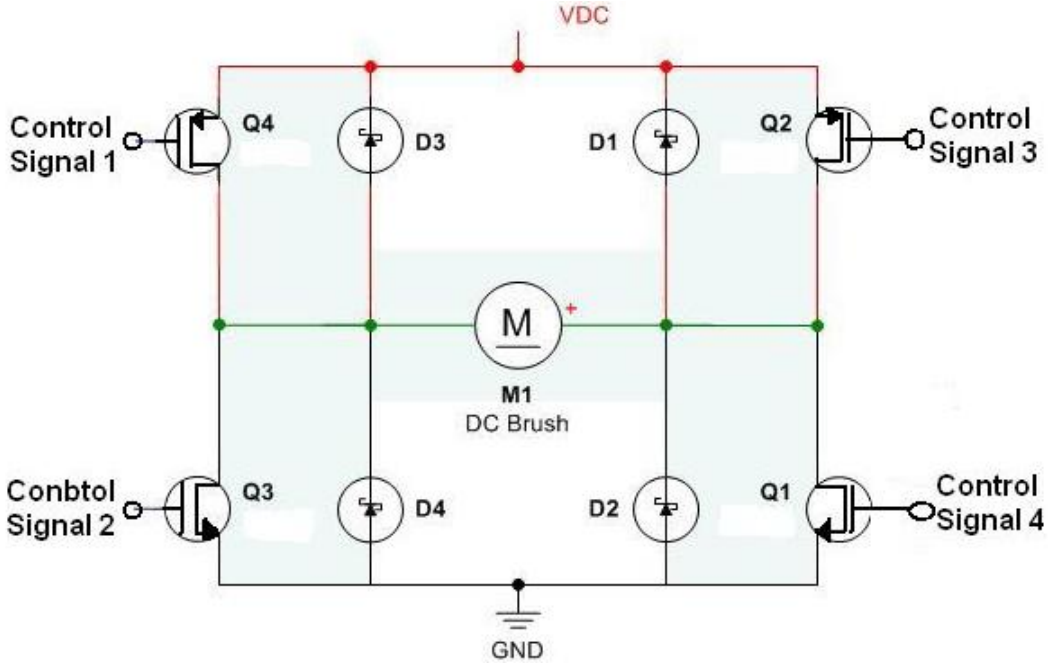


Figure 7: H-Bridge Schematic

The goal of an H-bridge circuit is to supply electrical power to motors in two directions so the motor can be rotated in either counter clockwise or clockwise direction. The theory of operation is fairly simple. From the above figure, when control signal 1 and 4 switch on the Q1 and Q4 transistors while the Q2 and Q3 transistors stay off, Q4 will source current to the motor while Q1 sinks the current to the ground. In order to reverse the rotation of the motor, control signals switch on Q2 and Q3 transistors while Q1 and Q4 transistors are turned off. D1 to D4 are flyback diodes. Their main purpose is to prevent sudden voltage change applied across inductive loads in order to protect the transistors from damages caused by excess current. The table below presents the basic components we will use to build our H-bridge circuit.

Table 6: Basic Components in H-Bridge

Component:	Device:	Description:
Q4, Q2	IRF 9540	N-channel Power MOSFET
Q1, Q3	IRF 540	P-channel Power MOSFET
D1 to D4 (might not be used)	1N4001	Flyback diodes
BJT on control signal (not shown)	2N3904	General Purpose NPN BJT
M1	NPC-41250	DC Geared Motor

The four power MOSFETs selected are mainly used for high power applications which can handle current up to 22A. Since we plan to supply 15 A to our motor, these transistors are suitable for our purpose. The control signals outputted by our microcontroller are 5V and 40mA maximum when they are digitally HIGH. Therefore, we might have to add a general purpose bipolar junction transistor on each control signal in order to amplify these signals in order to sufficiently turn on either set of the power transistor. Specific details of this issue will be researched and addressed as we make further progress into this module. The flyback diodes might not be needed in our H bridge circuit because these diodes are already fabricated with the power transistors.

One of the most important concerns of our H-bridge circuit is the power generated from the transistors during operation. This power can be estimated using equation:

$$P = {I_D}^2 * R_{DS_{(on)}}$$

Where Id is the drain current, and Rds(on) is the resistance between drain and source when the transistor is conducting. According to data sheet, the Rds(on) is about 0.055 to 0.077 ohm. We will use 0.066 ohm as estimation and take the drain current to be 16 A, and we could find the power generated would be about 17 Watt. Based on the calculation, we would need to add heat sinks in order to dissipate the heat generated. The figure below shows how the heat sink is added to the power transistor. The insulating Mica is placed on the metal plate of the transistor so the heat sink is insulated. The washer is used to provide electrical insulation to the screw.

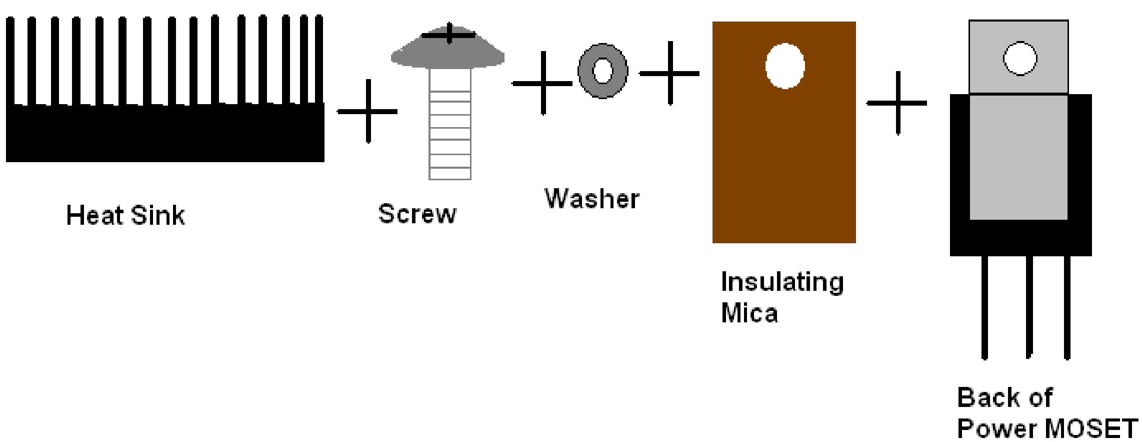


Figure 8: adding Heat Sink to the power transistor

2.5 Safety Design

Safety is the most important factor when it comes to designing a product. Roboblow is targeted to bring convenience to people's life. Despite its main task which is to clean the snow, It should not make damages to any properties or cause injuries to any life form by any means.

There are two cameras installed on the robot, one monitoring the front, and the other one can be rotated wirelessly by the operator. When the operator sees any incoming danger of operation, he/she can shut down the onsite robot remotely through the wireless controller. However, there should be other safety mechanism on the robot itself, so other people can be warned or directly shut down the robot when troubles are about to happen. We have planned three mechanisms that would help dealing with these safety issues.

Flashing LEDs during Operation

We plan to use four LEDs so that two of them will be flashed for a second whenever the microcontroller on board is powered on. The colors of LEDs have to be in bright tones such as yellow and red so people nearby the area can notice the machine is in operation. The figure below illustrates how the LED flashing circuit will be connected. When digital output1 is HIGH, the two LEDs at the top are lighted, and vice versa for the bottom two LEDs. The two resistors are implemented in order to limit the current. Specific resistor values and LED colors will be decided as we make further progress into our safety module.

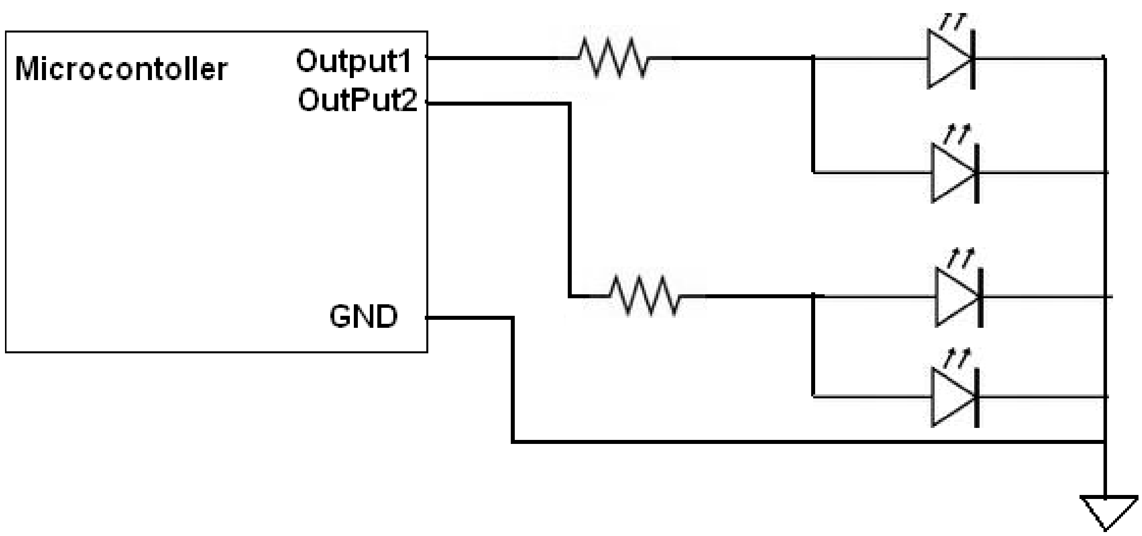


Figure 9: Flashing LED using microcontroller

Motion Detection for Warning Alarm

Although there are two cameras installed on the robot with one able to rotate, there are still plenty of blind spots when the robot is in operation. Therefore, we need to add other sensors on the robot in order to monitor the surrounding so warnings can be given to live forms nearby. We plan to install three motion sensors on our robot, so all sides of the machine can be monitored except for the front side where there is always a camera looking forward.

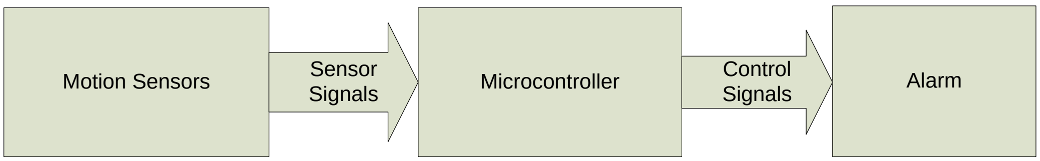


Figure 10: Motion Detection for Warning Alarm

According to the above diagram, the motion sensors installed on our robot will send signals to the on board microcontroller whenever any motion is detected from the surroundings. Once the microcontroller receives any of the sensor signals, it will send control signal to sound the alarm so live forms nearby can be warned. We will use PIR motion sensors and adequate electronic alarm to construct our circuit.

Button-Triggered Emergency Power Off

This mechanism is relatively simple to be achieved and is also one of the most crucial functions on our robot. A red button with very noticeable sign will be installed on the cover of our robot, so whenever it is pressed, the robot under operation will be shut down and power off immediately. At the hardware level, we simply have to connect the button to the microcontroller and label the button clearly on the cover of our robot. At the software level, there will be an if-statement checking the status of the button before each loop with other functions is executed.

2.6 Test Plan

Power Switch Test Plan

Turning the switch between NO and NC nodes in relay contacts

Since we have no previous experience with a relay, we first start by checking if the relay purchased works according to its description. We connect the two ends of the relay coil to the power supply in our electronics lab with minimum current and gradually increase the voltage on. There are no connections to the relay contacts. As soon the voltage reaches 8V, the switch inside the relay clicks to another side of the two contacts. Therefore, we conclude that we only need 8V to switch on the relay.

Connect the circuit according to the diagram with LED as load instead of motor

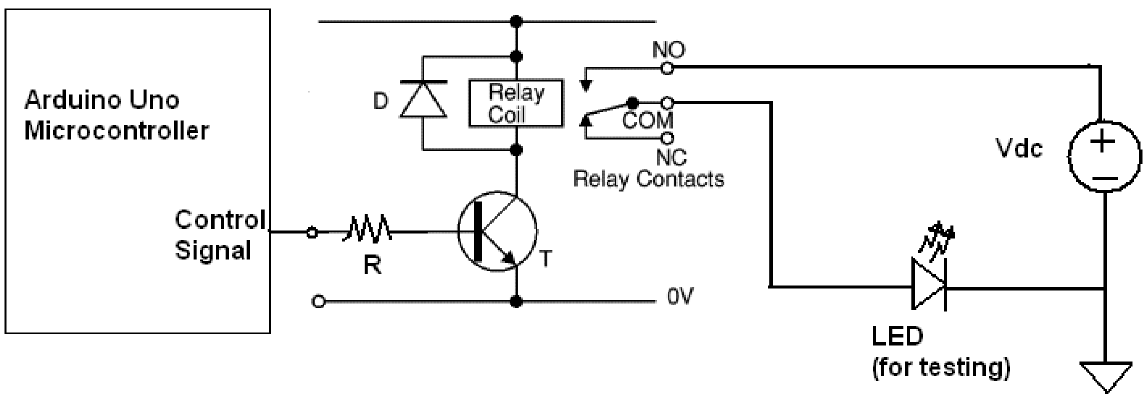


Figure 11: Testing the power switch circuit with low power application

After making sure our relay works according to its description, we then connect the switch circuit like above. We use a LED instead of the AC motor, and Vdc with ~1V from the power supply in our lab with minimum current to make sure our switch circuit works according to the theory before we actually put the high power application on site. Upon connecting the necessary circuit components and apply adequate voltages for the switch circuit and Vdc, we observe the LED turning on/off according to the digital control signal given by the microcontroller.

3. Snow-out Direction Unit

3.1 Physical and Mechanical Design

To control the snow blowing direction, we use a DC stepper motor attaching to the handle on the body of the snow thrower to turn the snow direction vanes on the thrower. To ensure that the vane can rotate full range without breaking the limit (the vane has its physical limit that it can only rotate to a certain instance.) we need to carefully select the initial position of the motor and the range of degree that the handle rotates within ±90° to prevent breaking.

The following diagram shows the snow thrower vane that is controlled by the motor (The handle is hidden behind the vane, inside the robot body.) The following diagram shows the vane that controls the snow blowing direction.

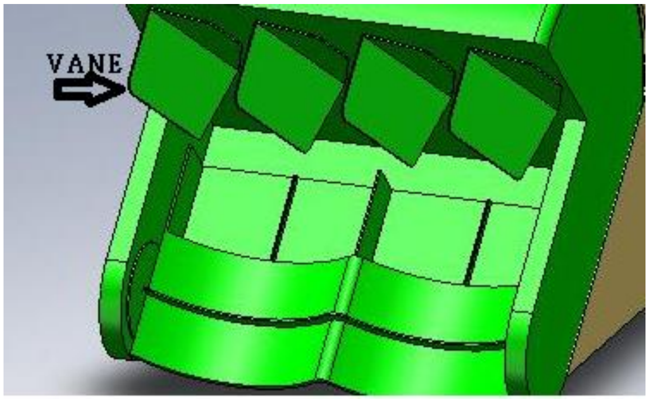


Figure 12: Snow Thrower and the Vane

Stepper Motor

We need to choose a stepper motor that has sufficient torque to apply force to rotate the handle. Since the motor is attached to the end of the handle, it needs much more force to drive. We choose a Sm-42b-yg011-25 mercury stepper motor to serve this purpose. The bipolar motor is driven by a L293dne IC chip. The following diagram shows the connection between IC, motor, and the Arduino microcontroller. Note that Arduino MCU is only used for testing.

Figure 13: Stepper Motor

The motor has four colored wires that are blue, green, red, and yellow, respectively.

3.1.1 Control Circuit

The following diagram shows the PCB connection of the L293N IC and the motor, where RA0 is Blue, RA1 is yellow, RA2 is green, and RA3 is red.

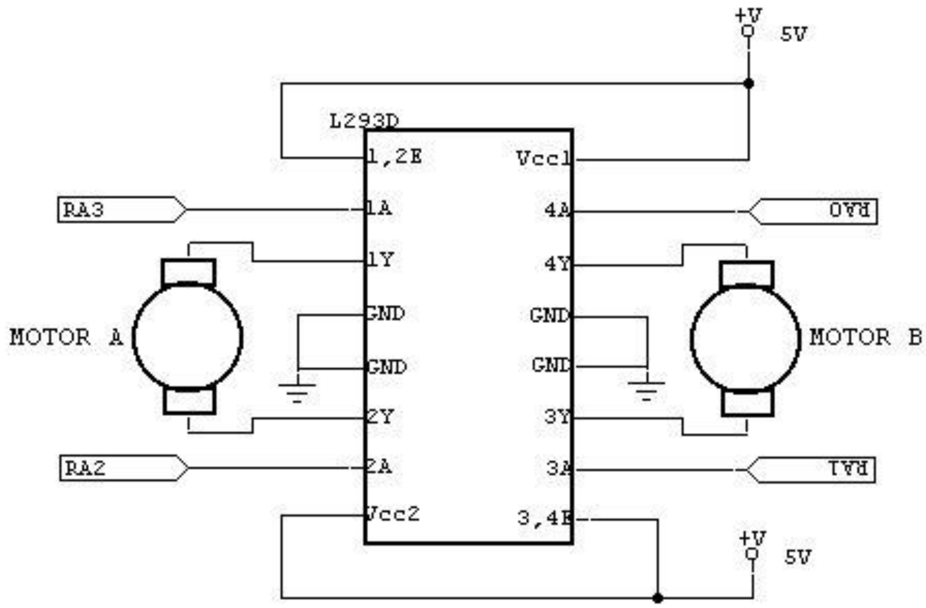


Figure 14: PCB connection of the L293N IC and the motors

The mechanism we use is standard full-step iteration. Since precision is not highly required for this application, half-step iteration is not used. The bipolar step motor is consisting of two electromagnets. The red and green wire controls one magnet and need to be always inverted to each other, while the blue and yellow wire controls another one and need to be always inverted to each other.

To control the above circuit by microcontroller, we apply positive or negative digital signals to the pins 1Y, 2Y, 3Y, and 4Y by a specific order. The order can be summarized by the following table:

Table 7: Pin signal sequence for snow-out direction

1Y	2Y	3Y	4Y
+	-	-	+
-	+	-	+
-	+	+	-
+	-	+	-
"+" stands for positive digital signals "-" stands for negative digital signals			

We keep looping the signal order and insert a delay of 75ms between the iterations. Each iteration would cause the motor to rotate 1.8°. When applying the order reversely, the motor would rotate in reverse direction.

3.1.2 Method of attaching

To make the motor apply force to the handle, we screw a hole on the handle, stick a metal rod inside the hold, then attach the metal rod and the end of the handle to the top of the motor.

To ensure that the motor is properly attached to the handle, we choose to use the electrical glue gun.

3.2 Camera Unit

3.2.1 Physical design

In order to be able to constantly check the surrounding environment 360 degrees wise, we need two USB cameras on the robot. Camera A is mounted on top of a robot and is able to rotate 360˚(controlled by another stepper motor used for controlling the snow blowing direction). Camera B is mounted solid in the front of the robot as the picture shows below, and has no freedom to rotate. Camera B is used to constantly monitor images in front of the robot to the ground to ensure safety. The cameras are securely placed outside the robot, and covered by acrylic boards which are two centimeters thick. We also install a transparent glass shield in front of the camera to make it possible to be used under snow and wet condition.

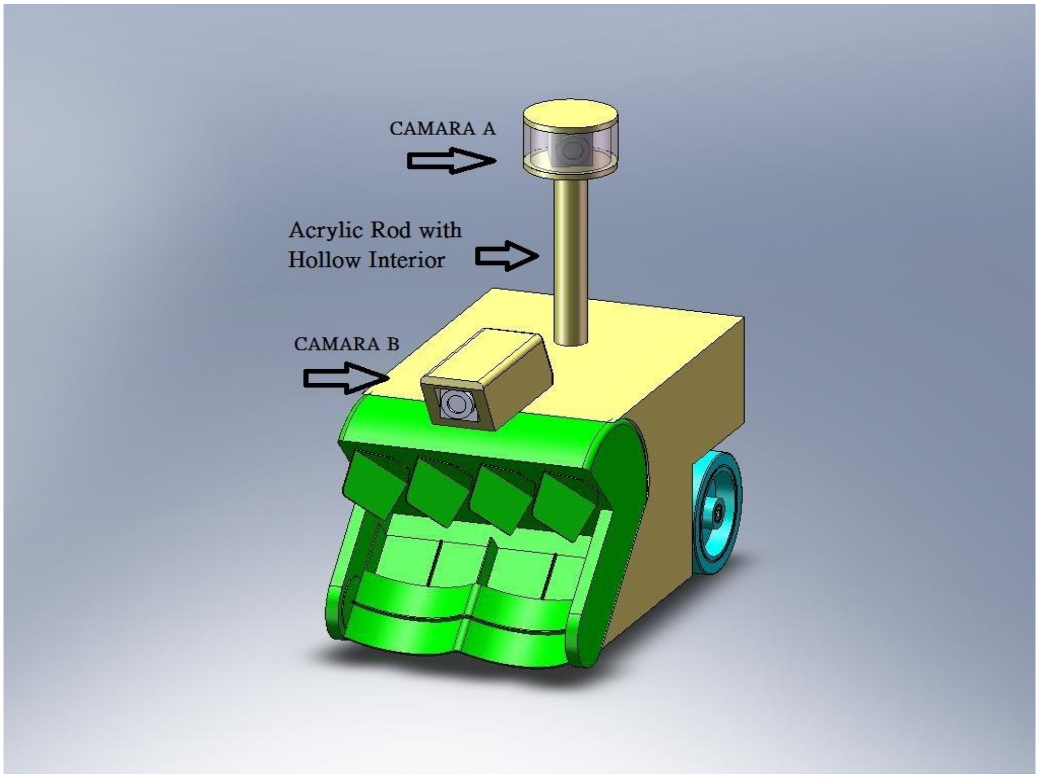


Figure 15: Camera location in the robot

3.2.2 Camera

We choose Webcam camera SPCA5xx by Vimicro Corp for both of our camera. This camera supports Linux kernel and can be configured to send real time image to the central MCU on the robot, where the MCU on the robot sends the image back to the LCD screen for the user to monitor. Below is an image of SPCA5xx, a stable, high quality webcam camera.

3.2.3 Step Motor Connection

We use the same mechanism and step motor as described in the snow blowing direction section. To connect the camera to the motor, we make use of the cylinder acrylic rod, which is hollow in the interior. We insert a solid rod from the interior, connect the camera on one end via superglue, and connect the other end on the top of stepper motor by electrical glue gun. This application requires precise rotating degree, hence, we employ the half-stepping technique of stepper motor. To look at the reference diagram of stepper motor connection again:

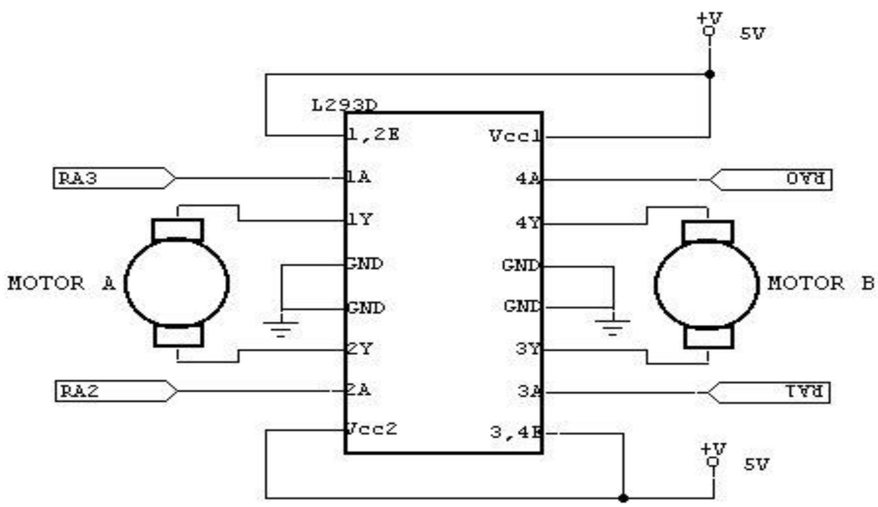


Figure 16: PCB connection of the L293N IC and the motors

We give 1/0 digital signals to 1Y, 2Y, 3Y and 4Y according to the following table of order:

Table 8: Pin signal sequence for camera direction

Step	1Y	2Y	3Y	4Y
1	+	-	-	-
2	+	+	-	-
3	-	+	-	-
4	-	+	+	-
5	-	-	+	-
6	-	-	+	+
7	-	-	-	+
8	+	-	-	+

This technique has twice as many as steps comparing to the standard technique used in controlling the thrower vane. This way, the resolution is double and each step rotate the motor 0.9 degree, hence increase the precision.

4. Salt Spraying Unit

4.1 Physical and Mechanical Design

The salt spraying unit serves the purpose of spraying salt on the areas that the robot goes through. The unit is placed under the bottom of the robot. The important issues we need to consider is how to control the amount of salt carefully so we don't waste salt or runs out of salt too fast. Second of all, we want to limit out budget and design complicity on this part as much as possible. Therefore, using another stepper motor is not in our consideration for this case. The design can be broken into 3 parts: The salt box, the salt stopper, and the salt filter. The box containing the salt needs to be made of material that doesn't easily conduct heat to prevent the salt from melting. The box should at the same time be waterproof. We choose to make the box with plastic. The box should be 30cmx40cm to contain 1.2 liters of salt.

4.2 The Salt Stopper

As above graph illustrates, we drill a hole at the bottom of the plastic box and put a stopper at the hole to fill the hole. We want to be able to control the stopper with microcontroller. The design we think of is that we use an electromagnet to be the salt stopper, and place one permanent magnet at the top of the box and superglue another one below the hole on top of the salt filter. If we configure it that way, When the Salt Spraying unit is off, counter-clock wise current is applied by the microcontroller, to force the filter end to become N polar, hence is forced to touch the magnet at the top of filter and filled the hole. When the unit is on, the current is applied reversely and the top end is forced to be N polar, hence the stopper touches the top and leave the hole by a tiny amount, allowing salt to go through holes and spray through the filter. The following graph shows the electromagnet we are going to use

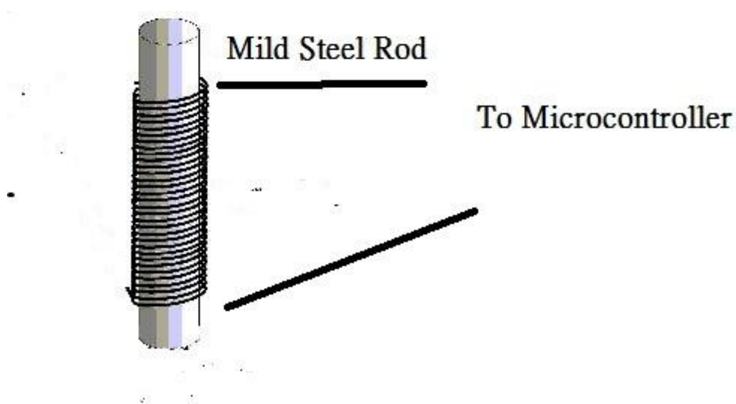


Figure 17: Electromagnet

4.3 The Salt Filter

We want the filters to have as small holes as possible which would be just a little bit bigger than a single salt. We choose to use the stainless-steel filter for tea set for our salt filter. To prevent from wasting salt, the enable of the microcontroller signal is attached to the wheel motor signals so that whenever the robot is not moving, the salt spraying unit always stops spraying. The magnet we are using is one standard medium round craft magnet. If applied enough current to the electromagnet, this magnet would have enough magnetic force to attract/repel the electromagnet even with the resistance from the salt. The same magnet is attached to the top of the box to form a switch for the stopper. The following graph shows the tea set filter and the medium round magnet.

Figure 18: Tea set filter

5. The Entire Body Building

5.1 Physical Design

The robot needs to overcome snow condition hence there is no doubt it needs to be waterproof. While we are driving the robot with only two NPC motors, the weight of the robot is going to be another issue. The robot functions in best efficiency when the totally weight is at around 60 pounds. Considering the weight and the waterproof issue, we choose acrylic board for our body material. We can get the acrylic boards from industrial plastic and paints. Another choice would be that to build the body of aluminum, which is light and waterproof, too. We can bring our design to a local welding company, where they can fabricate the body in aluminum. As the following graph illustrates, the body is more like a square box, with the back cut to fit in the wheels. All of our design circuitry and motors are well hidden inside the body.

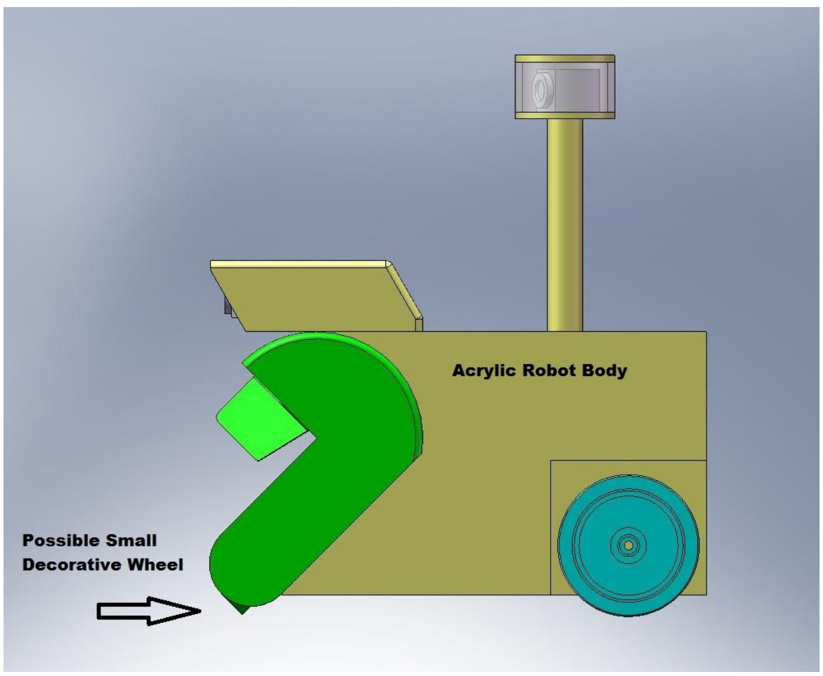


Figure 19: Physical design of the robot

The above graph is the right side view of the robot. The yellow part is the body of the robot. We might install a pair of small decorative wheels at the front of the thrower to reduce the friction.

5.2 Method of Connection

To make sure the body is attached solidly, we take the body to the machine shop in Simon Fraser University, drill holes in them and use screws to connect the body. The reason we want to use screw instead of electrical glue gun is because it's easier to repair if we can open the body easily. The body needs to connect to the thrower perfectly to ensure proper functionality.

5.3 Partition in the Bottom Board

To place the component, circuitries and power supply solidly inside the body, we need a mechanism to ensure that they don't move around. We partition the bottom body by installing acrylic board boundaries. The parts consist of 2 motor blocks, one power supply block, one cylindrical block (for the upper camera), two stepper motor blocks, MCU block and circuit blocks. The concept is illustrated in the following graph.

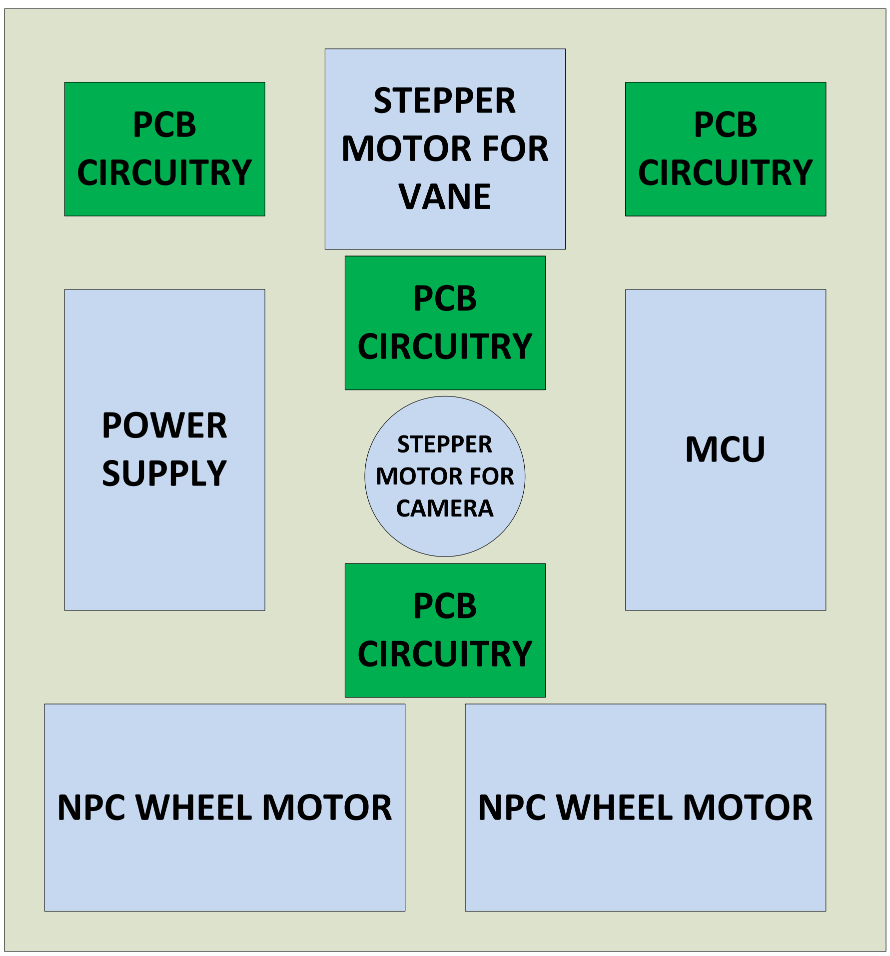


Figure 20: Partition in the Bottom Board

6. Remote controller

The design specification of the remote controller will be provided from physical design, hardware design and software design aspects. In physical design, the controller dimension, weight and material will be stated. It will also provide internal structure of the controller which includes the detailed information of the different hardware as well as their inside positions. In order to make this demonstration easier, the SolidWork graph of the controller will be shown in the physical design subsection. In hardware design, each hardware information and its functions will be presented. It also provides how each hardware interacts with others. In software design aspect, the embedded software architecture will be given. This includes the software working mechanism and the algorithm of each process.

6.1 physical design specification

For the ease of understanding this section, please refer to the figure 21 and figure 22.

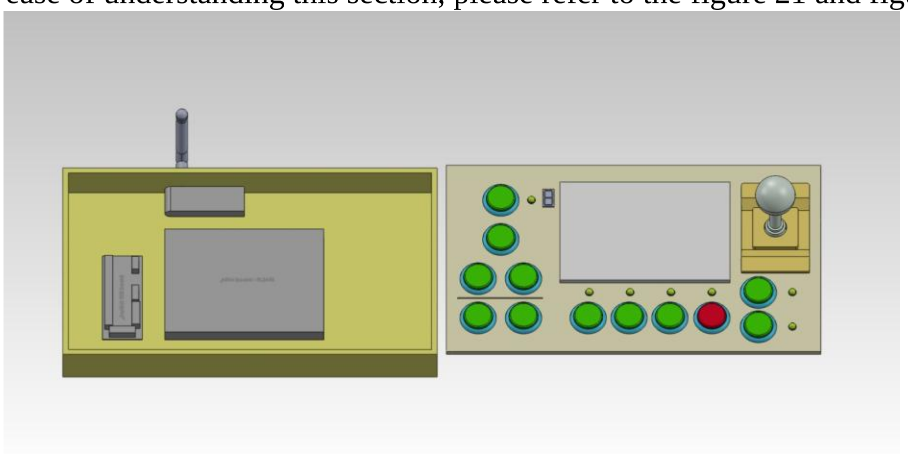


Figure 21: the remote controller with cover opened.

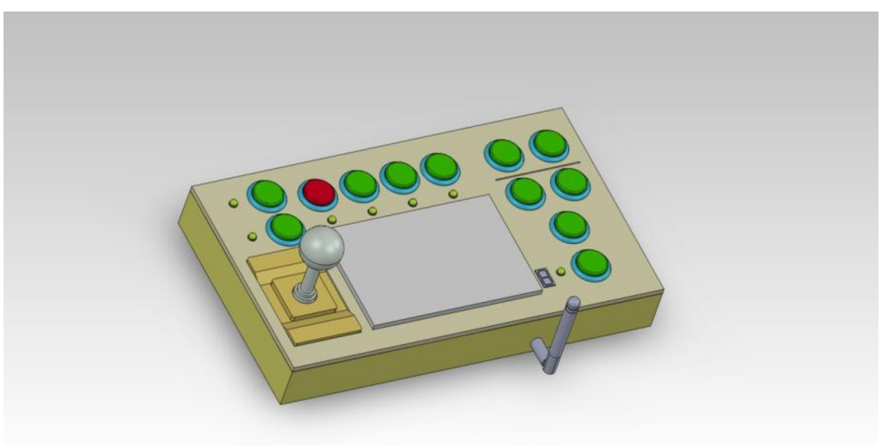


Figure 22 the remote controller with the cover closed

6.1.1 Dimension, weight and material

The shape of the controller is a rectangular block. The length is 330mm, the width is 190mm and the height is 45mm. The weight is less than 1 kg. We make this size and weight mostly for the portable consideration. When user is controlling the joystick, the base of the controller should be able to provide enough fictions so that it will not slip with the human operation. Thus at the bottom of the controller, there will be four rubbers at four corners to increase the fiction. The cover of the controller will be made by Acrylic, because Acrylic material can provide enough strength. Its density is suitable. It is also very cheap.

6.1.2 Controller panel design

The control panel layout is shown in figure 23. The button distribution is design based on the controller panel convention, function importance and ease of controlling. In addition, buttons controlling the same module are arranged together. The joystick is positioned at right side of the controller which is designed for right-handed user. We also have the similar design for left-handed user. The only difference from right-handed design is that the positions of the joystick and buttons are switched. A 5.6 inches LCD screen used to display the real-time image from camera is located in the middle area of the controller. The speed display is right beside the screen.

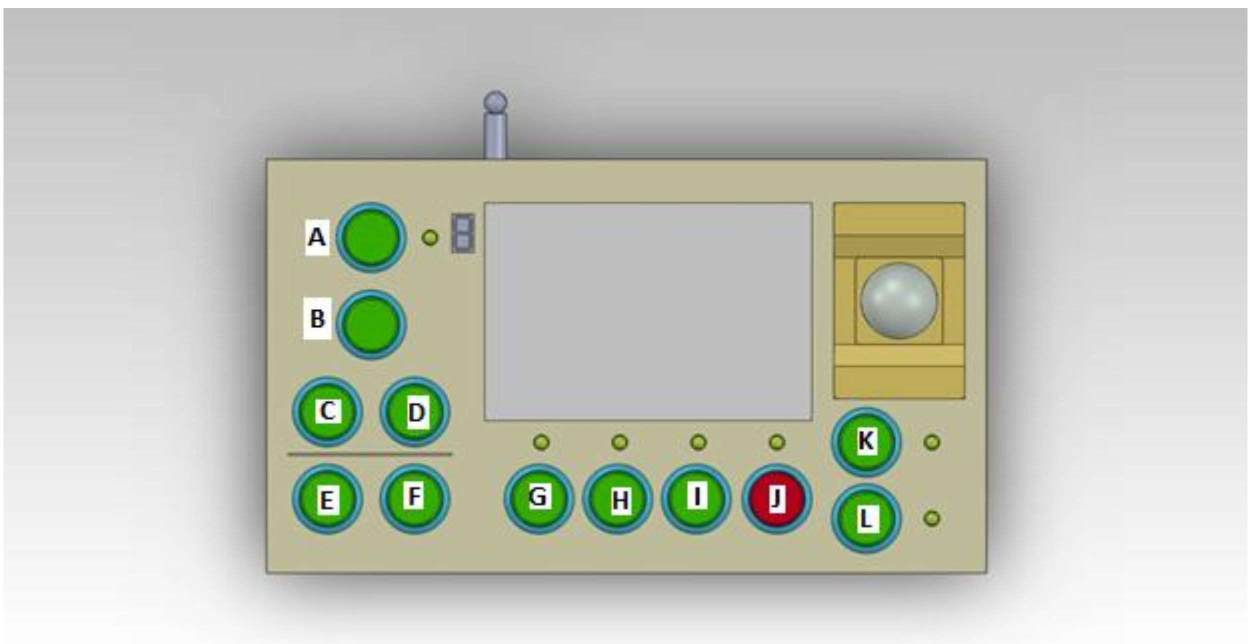


Figure 23: the top-view of the remote controller

Table 9: All the buttons on the control panel as well as their functions.

Button	functions
A	Camera switch
B	Switch the camera view
C	Rotate camera counter-clockwise
D	Rotate camera clockwise
E	Snow out direction rotate counter-clockwise
F	Snow out direction rotate clockwise
G	Snow blower switch
H	Salt spraying switch
I	Power switch for controller
J	Emergency switch
K	High speed
L	Low speed

6.1.3 Internal structure

The ARM development board, USB breadboard and WIFI module are placed and fixed inside the controller. USB breadboard and WIFI module are both connected to the ARM development board. Buttons and joystick are connected to the USB breadboard. LCD screen, LEDs and seven segment display are connected to ARM development board.

6.2 Hardware design specification

ARM development board is the central processing unit of the controller. It is responsible for collecting all the user inputs, data received from WIFI module. It is also designed to process all the data it received and send out the proper commands. Linux OS has already been built in. The kernel version is 2.6.12. It enables us to use multi-process/threads programming skills when writing the embedded software. The RAM is 64MB which is enough for our products.

USB breadboard connected to the buttons belongs to USB HID class. It will recognize the inputs from user and send the corresponding USB format data to ARM MCU. The driver for this device can be found in Linux kernel, the dynamically module installation method is chosen for mounting this device.

WIFI module (802.11g) is also connected to ARM board by USB. It receives the data from robot and send out the command issued by ARM MCU in the controller. The effective wireless communication distance is 100-150 meters depending on environment situation. Considering that the usage of the robot is mainly for family, this communication distance is enough for our products. The device driver can be downloaded from manufacturer’s website. The dynamically module installation method is chosen for mounting this device.

Buttons and Joystick are directly connected to the USB breadboard. Joystick has eight directions (forward, left forward, right forward, backward, left backward, right backward, left and right).

LCD screen is connected to ARM development board. The driver is built inside the Linux kernel.

LEDs and seven segment display are connected to I/O extension port in ARM development board. The driver is created by our team. The dynamically module installation method is chosen for mounting this character device.

6.3 Software design specification

6.3.1 Driver development

I/O extension driver is developed by our team. It is used to assign a single pin to be high or low voltage at a time. The driver specification is stated as following:

1. The device is registered as character device. The device name is ioext.
2. Once the device is opened, all the pins will be set as low voltage. All pull up resistors associate with the pins will be set.
3. The pins can be set as input or output pins by ioctl function.
4. Before writing to/read from a pin, that pin must be first configured as output/input pin by using ioctl function.
5. The pin can be read by using read() function.
6. The pin can be write by using write() function.

Note that the complete API will not be provided as it is under development.

6.3.2 Software architecture in Nutshell

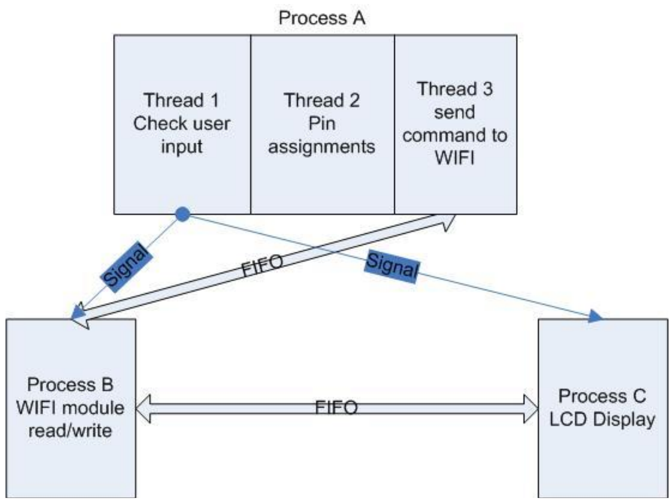


Figure 24 the software architecture in the controller

As indicated in the nutshell graph, there are 3 main processes in our embedded software. Process A has 3 threads. Thread 1 is continuously detecting the input from USB buttons and joystick. Thread B does the I/O extension pin assignments according to the output from thread 1, so that LEDs and 7 segment display can works properly. Thread 3 is used to send the command obtained from user input to the WIFI module which will be transferred to the robot wirelessly later on. Since WIFI communication usually has more time delay, FIFO inter-process communication method will be used to communication with WIFI process (process B). Process B is WIFI process. It is used to read/write to the WIFI module. Reading WIFI module means getting the data received from WIFI while writing WIFI module means sending data to the robot. This module will accept the data from FIFO that connects to process A. It will also transfer the camera image data to LCD process (process C) via another FIFO. LCD process is responsible to decode the camera image data and display it on the LCD screen. Note that process B and process C are also controlled by process A via signal mechanism.

6.3.2 Algorithm flow chart

Processes and threads algorithm can be found in appendix. The following table indicates the appendix indexes for each process and thread.

Table 10: Appendix index for each process and thread

Process or thread name	Appendix index
Thread 1 (Process A)	Appendix 3
Thread 2 (Process A)	Appendix 4
Thread 3 (Process A)	Appendix 5
Process B	Appendix 6
Process C	Appendix 7

6.4 Control module inside the robot

The controlling module can be divided into two parts, hardware design and software design. In hardware design, MCU, WIFI module and camera as well as other devices will be introduced. In software design, the embedded software algorithm will be presented.

6.4.1 Hardware design

The MCU used inside the robot is the same as the one in the controller. It is responsible for receiving commands from controller and sending the corresponding commands to the robot. The pins in I/O extension port will be connected to the control circuit of the actual module. By controlling the transistor base voltage, the motor or other component can be switched on and off. The pin assignment can be found in the appendix 1 and 2. The I/O extension driver is created by our team members. The dynamically module installation method is chosen for mounting this device.

The WIFI module used inside the robot is the same as the one in the controller. It is connected to MCU by USB port. It is responsible for transmitting camera image to the controller and receiving the data from controller.

There are 2 cameras installed on the robot. The cameras are connected to the MCU by USB port. The driver is already inside the Linux OS.

6.4.2 Software design specification

6.4.2.1 Software architecture in nutshell

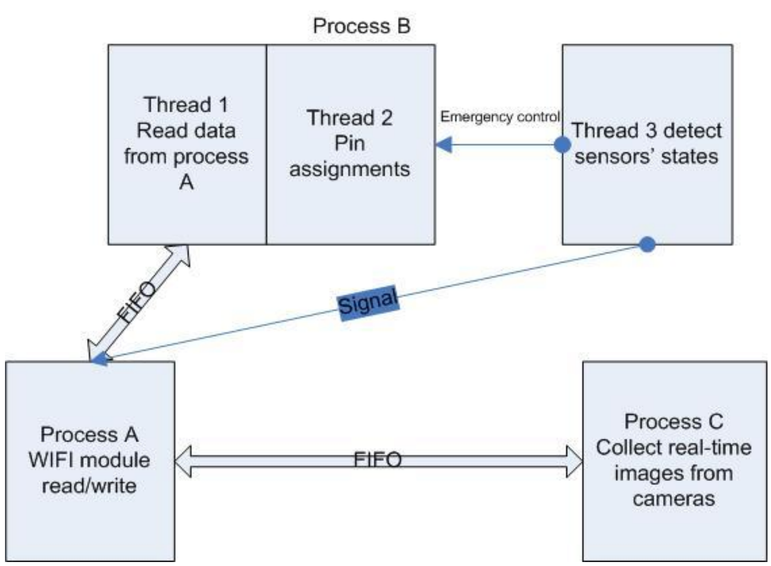


Figure 25: Software architecture in the robot

As indicated in the nutshell, there are 3 processes. Process A is WIFI process; it receives the data transmitted from the controller and send camera data to the controller. The received data will be further sent to the process B which consists of 3 threads. Thread 1 is used to receive the data from process A. Thread 2 does the pin assignment according to the received data. Thread 3 detects all the sensors states installed on the robot. If emergency situation occurs, it will stop all the working components in the robot and send emergency signal to controller. Process C collets the real-time image captured from two cameras and sends the data to process B.

6.4.2.2 Algorithm flow chart

Processes and threads algorithm can be found in appendix. The following table indicates the appendix indexes for each process and thread.

Table 11: Appendix index for each process and thread

Process or thread name	Appendix index
Thread 1 (Process B)	Appendix 8
Thread 2 (Process B)	Appendix 9
Thread 3 (Process B)	Appendix 10
Process A	Appendix 11
Process C	Appendix 12

7 Conclusion

This document has discussed the technical design solutions to meet the RoboBlow functional specifications as well as listing the hardware parts which are possible to be used in the product. The prototype of Roboblow is expected to be realized by following the designed specifications and test plans in this document.

8 Appendix

Appendix 1:

I/O extension pin assignment for MCU in the robot

I/O extension pin number	Associated CPU I/O pin	Function
PIN#1	GPE11	Power MOSFET #1 gate voltage control for robot left wheel H-bridge
PIN#2	GPE12	Power MOSFET #2 gate voltage control for robot left wheel H-bridge
PIN#3	GPE13	Power MOSFET #3 gate voltage control for robot left wheel H-bridge
PIN#4	GPG2	Power MOSFET #4 gate voltage control for robot left wheel H-bridge
PIN#5	GPG3	Power MOSFET #1 gate voltage control for robot right wheel H-bridge
PIN#6	GPG5	Power MOSFET #2 gate voltage control for robot right wheel H-bridge
PIN#7	GPG6	Power MOSFET #3 gate voltage control for robot right wheel H-bridge
PIN#8	GPG7	Power MOSFET #4 gate voltage control for robot right wheel H-bridge
PIN#9	GPG11	H-bridge Power MOSFET #1 gate voltage control for salt spraying motor
PIN#10	GPB0	H-bridge Power MOSFET #2 gate voltage control for salt spraying motor
PIN#11	GPB9	H-bridge Power MOSFET #3 gate voltage control for salt spraying motor
PIN#12	GPB1	H-bridge Power MOSFET #4 gate voltage control for salt spraying motor
PIN#13	GPB5	Snow blower power switch control
PIN#14	GPB6	H-bridge Power MOSFET #1 gate voltage control for snow out direction motor
PIN#15	GPB8	H-bridge Power MOSFET #2 gate voltage control for snow

		out direction motor
PIN#16	GPB10	H-bridge Power MOSFET #3 gate voltage control for snow out direction motor
PIN#17	GPA21	H-bridge Power MOSFET #4 gate voltage control for snow out direction motor
PIN#18	GPB7	H-bridge Power MOSFET #1 gate voltage control for camera rotation motor
PIN#19	AIN0	NULL
PIN#20	AIN1	NULL
PIN#21	AIN2	NULL
PIN#22	AIN3	NULL
PIN#23	GPF0	H-bridge Power MOSFET #2 gate voltage control for camera rotation motor
PIN#24	GPF2	H-bridge Power MOSFET #3 gate voltage control for camera rotation motor
PIN#25	GPF3	H-bridge Power MOSFET #4 gate voltage control for camera rotation motor
PIN#26	GPF4	NULL
PIN#27	IIC SDA	NULL
PIN#28	IIC SCL	NULL
PIN#29	VCC	NULL
PIN#30	GND	Ground

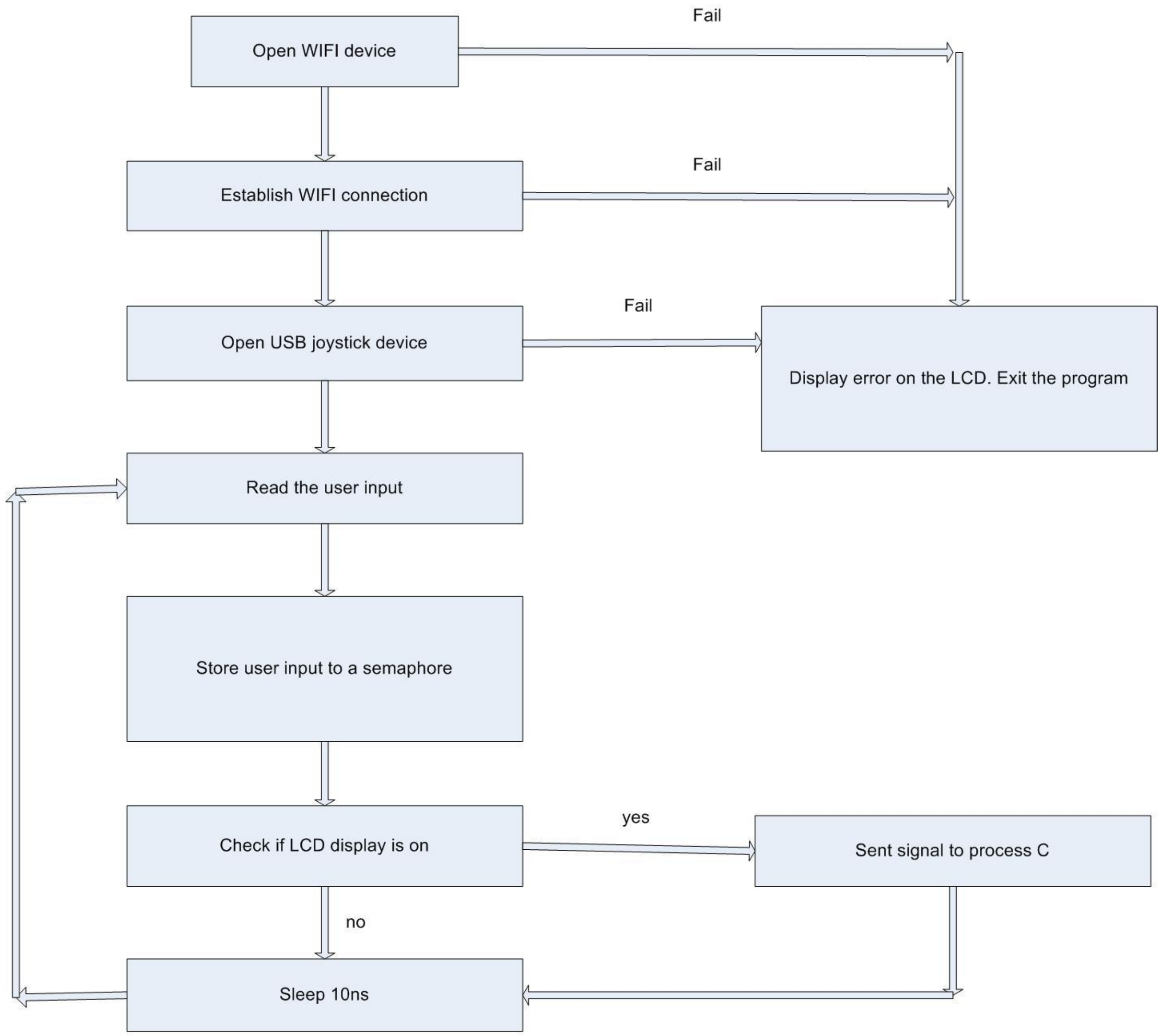
Appendix 2:

I/O extension pin assignment for MCU in the controller

I/O extension pin number	Associated CPU I/O pin	Function
PIN#1	GPE11	Power button LED
PIN#2	GPE12	Emergency button LED
PIN#3	GPE13	Camera on/off LED
PIN#4	GPG2	Snow blower switch LED
PIN#5	GPG3	Salt spraying switch LED
PIN#6	GPG5	Robot Speed level 1 LED
PIN#7	GPG6	Robot Speed level 2 LED
PIN#8	GPG7	7 segment display
PIN#9	GPG11	7 segment display
PIN#10	GPB0	7 segment display
PIN#11	GPB9	7 segment display
PIN#12	GPB1	7 segment display
PIN#13	GPB5	7 segment display
PIN#14	GPB6	7 segment display
PIN#15	GPB8	7 segment display
PIN#16	GPB10	NULL
PIN#17	GPA21	NULL
PIN#18	GPB7	NULL
PIN#19	AIN0	NULL
PIN#20	AIN1	NULL
PIN#21	AIN2	NULL
PIN#22	AIN3	NULL
PIN#23	GPF0	NULL
PIN#24	GPF2	NULL
PIN#25	GPF3	NULL
PIN#26	GPF4	NULL
PIN#27	IIC SDA	NULL
PIN#28	IIC SCL	NULL
PIN#29	VCC	NULL
PIN#30	GND	Ground

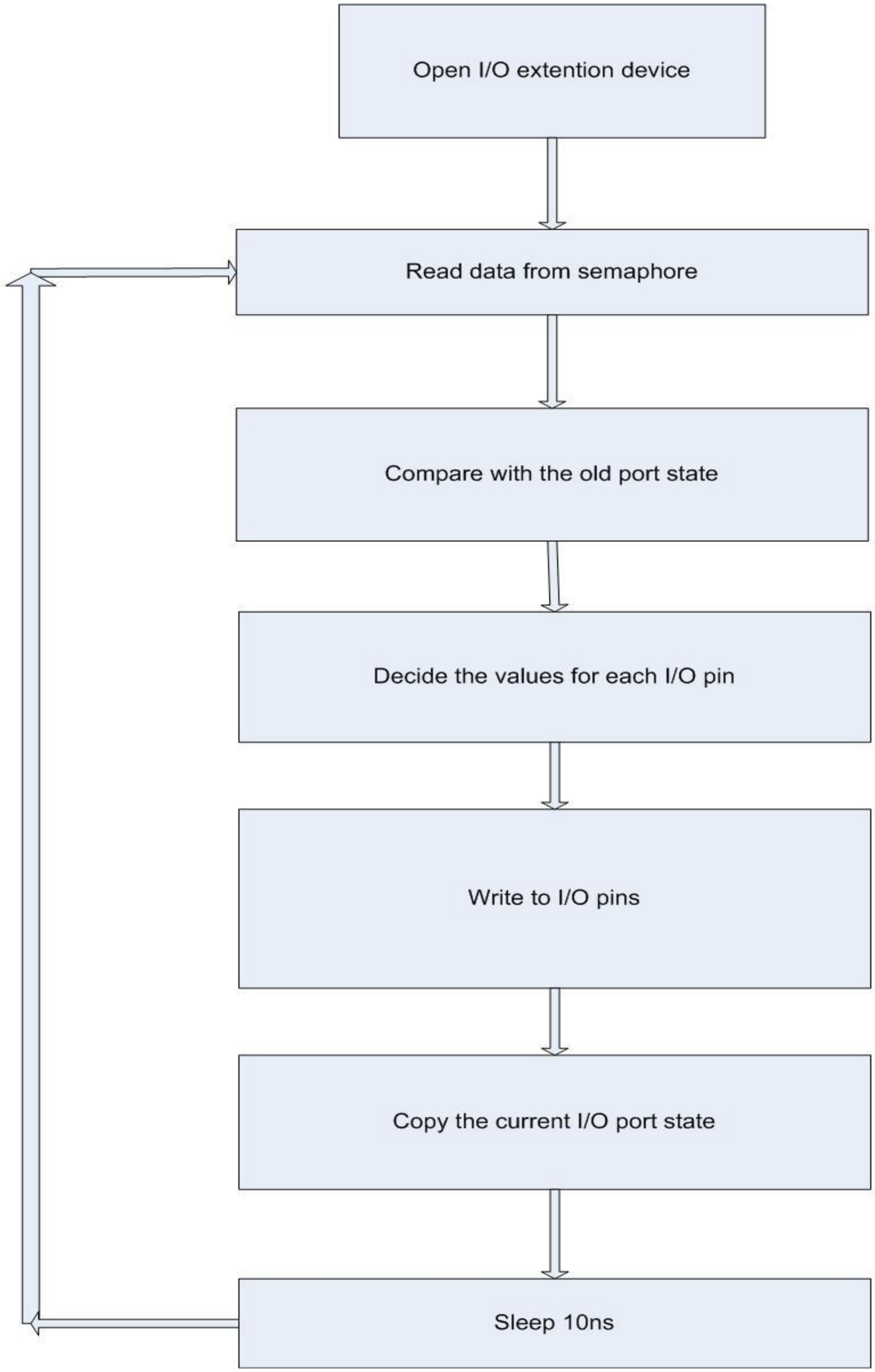
Appendix 3:

Algorithm flow chart of thread 1 in process A for software in controller MCU



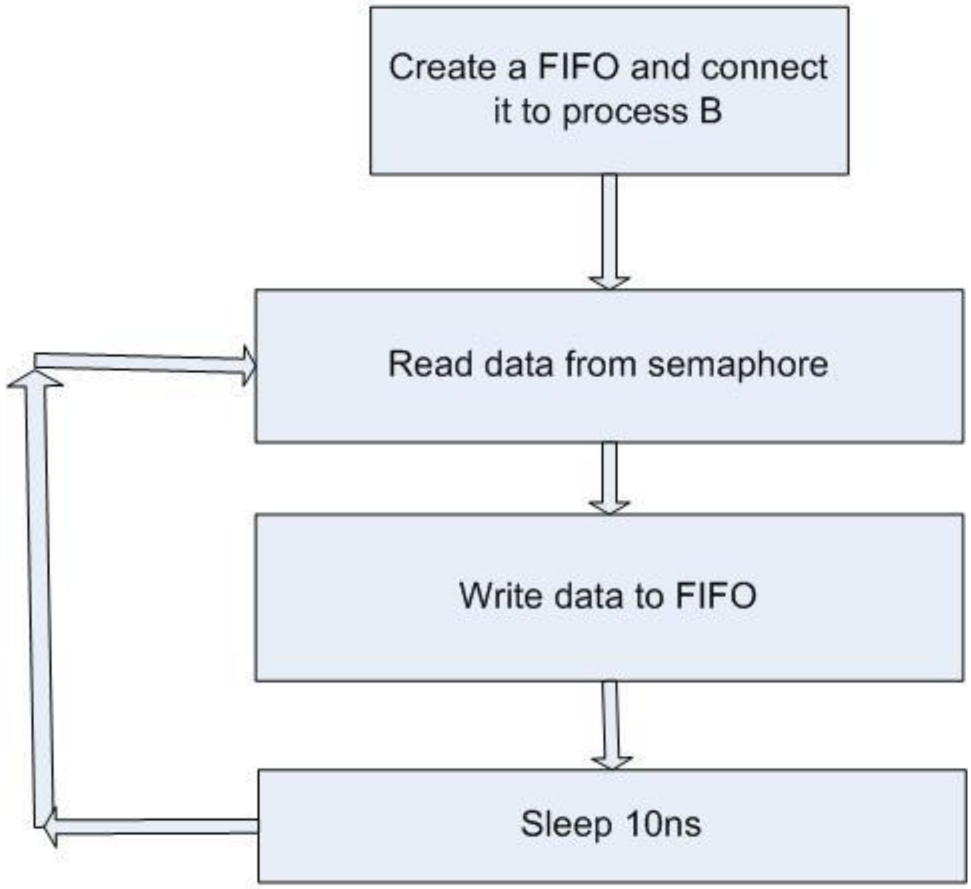
Appendix 4:

Algorithm flow chart of thread 2 in process A for software in controller MCU



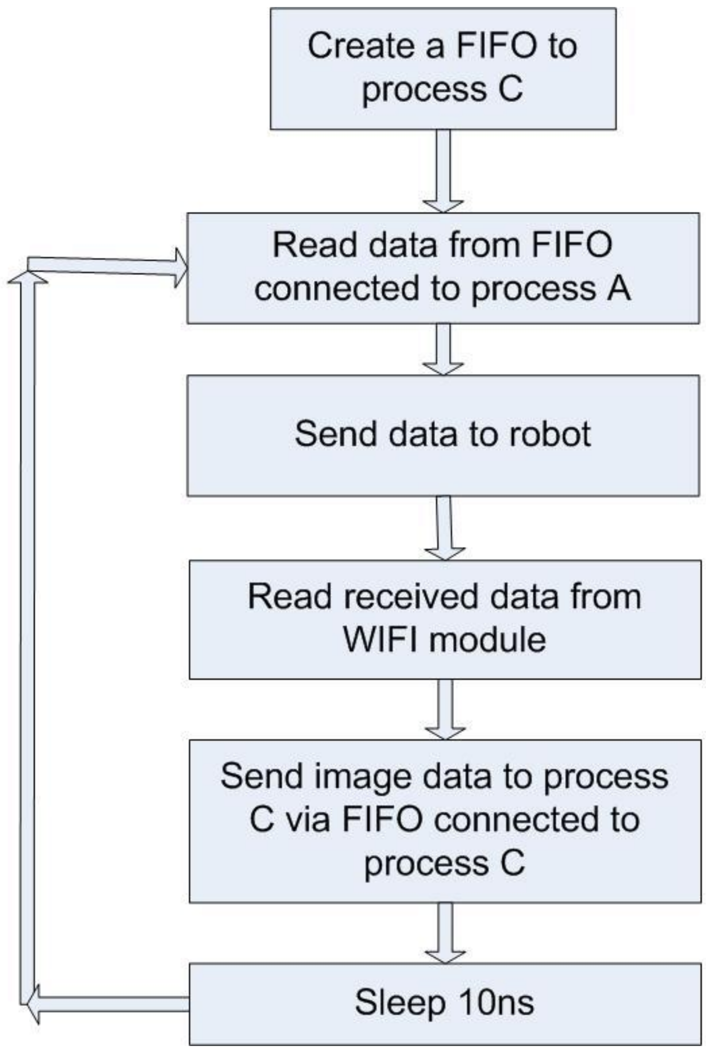
Appendix 5:

Algorithm flow chart of thread 3 in process A for software in controller MCU



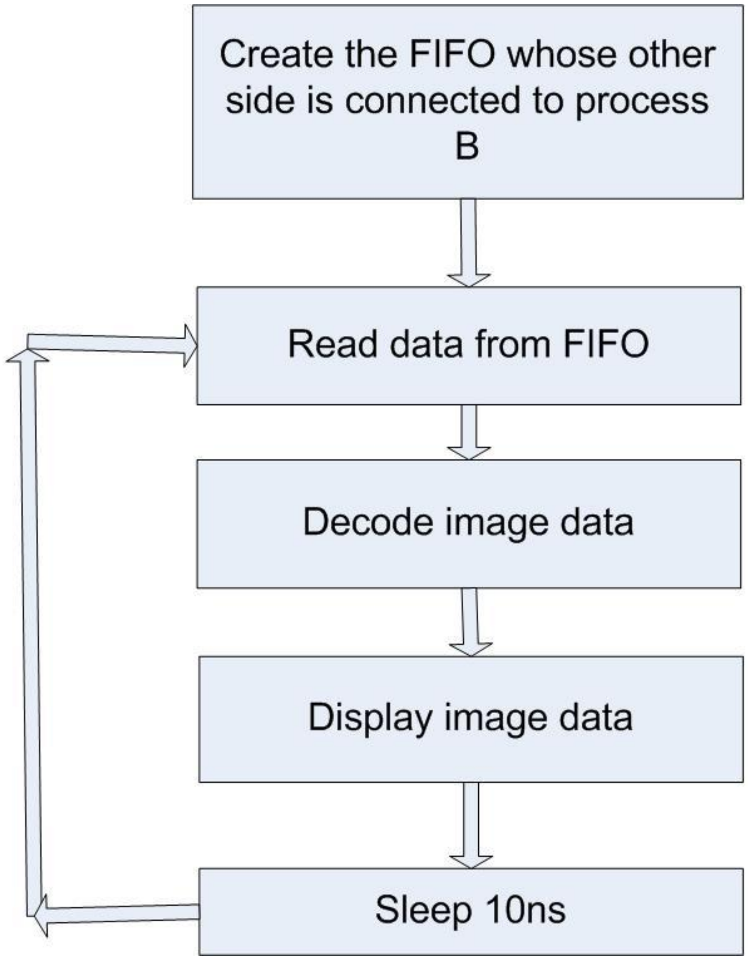
Appendix 6:

Algorithm flow chart of process B for software in controller MCU



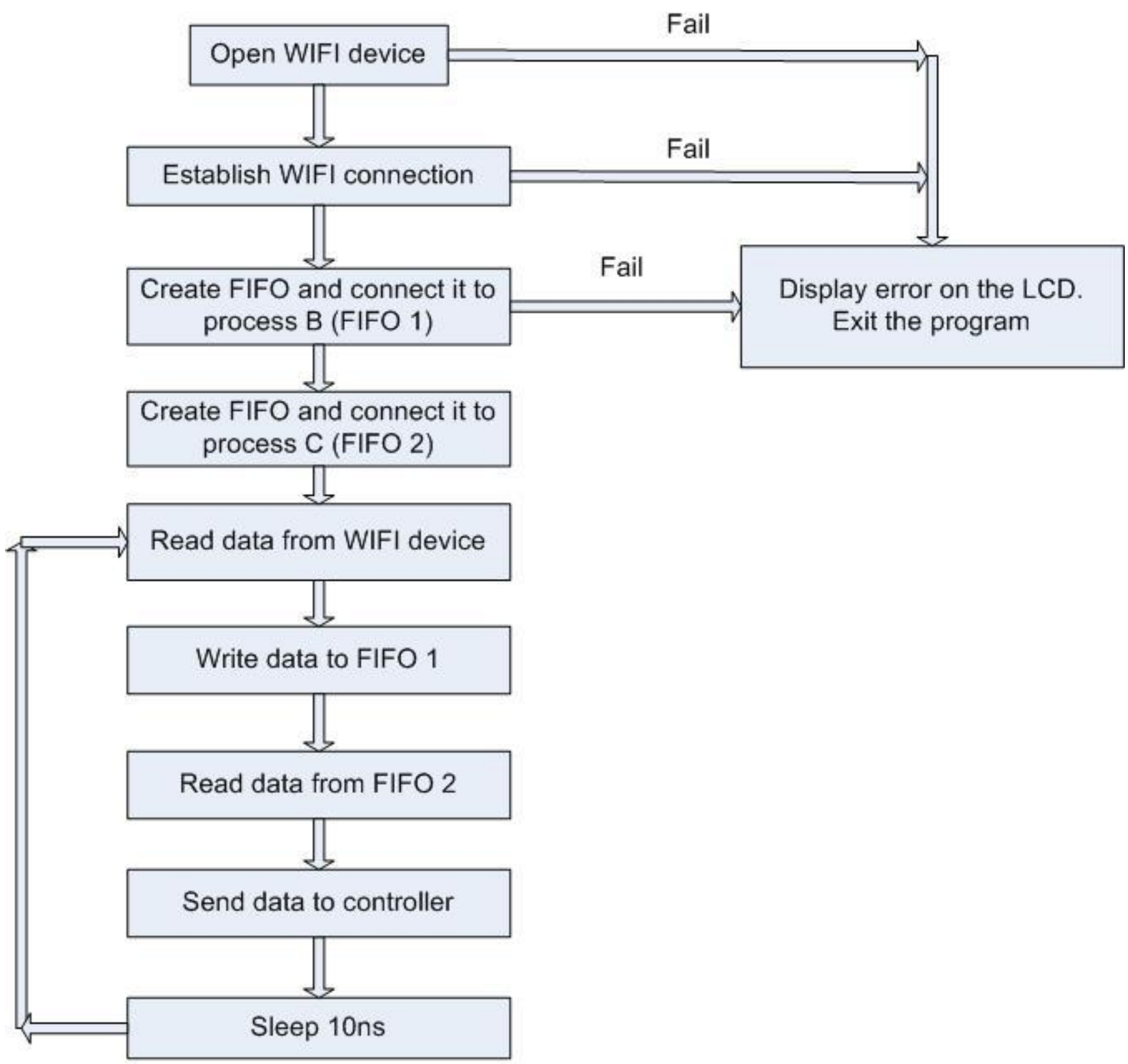
Appendix 7:

Algorithm flow chart of process C for software in controller MCU



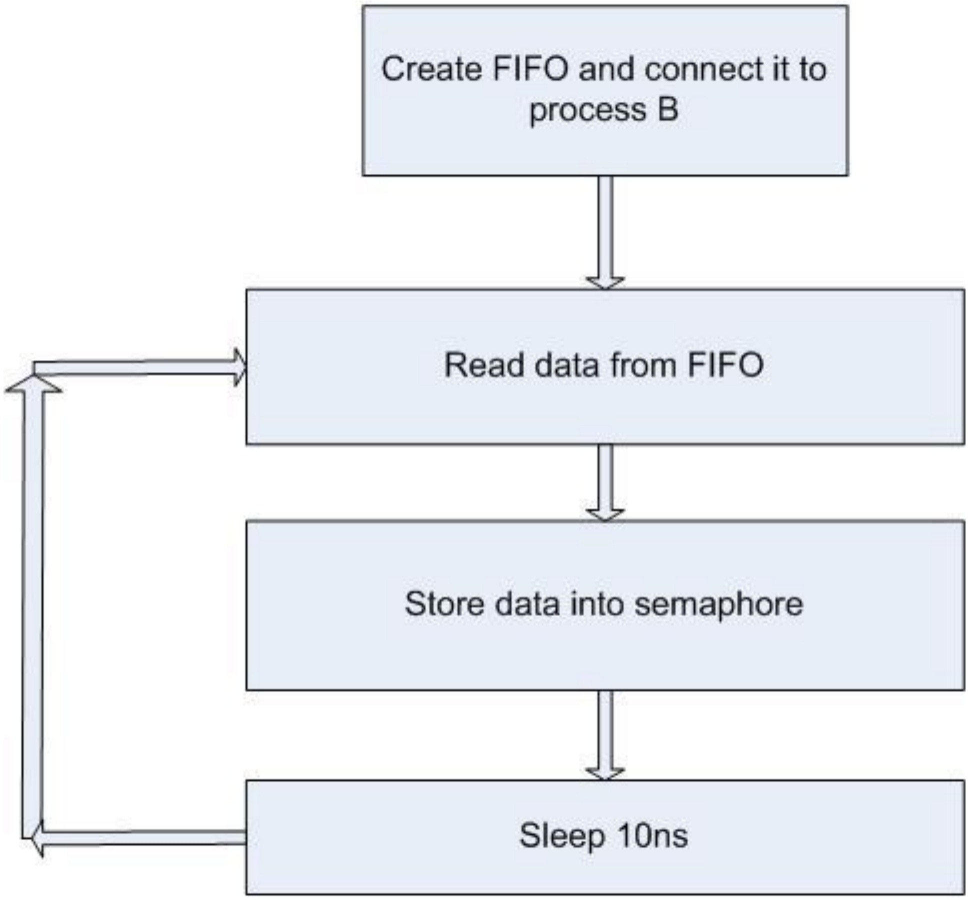
Appendix 8:

Algorithm flow chart of process A for software in robot MCU



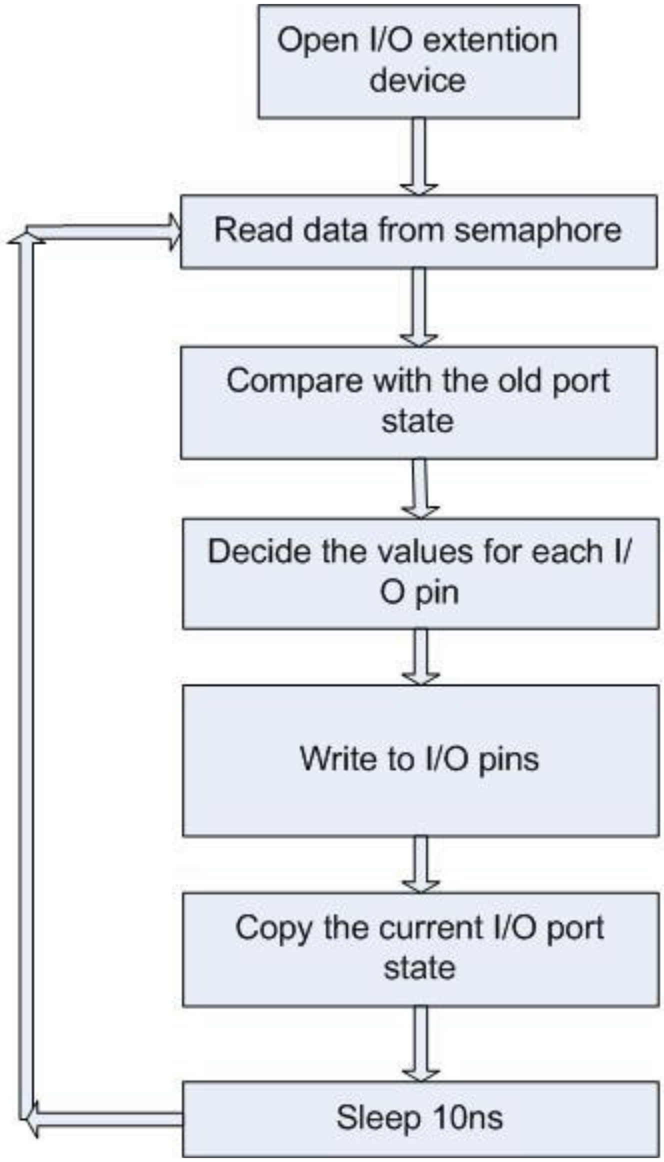
Appendix 9:

Algorithm flow chart of thread 1 in process B for software in robot MCU



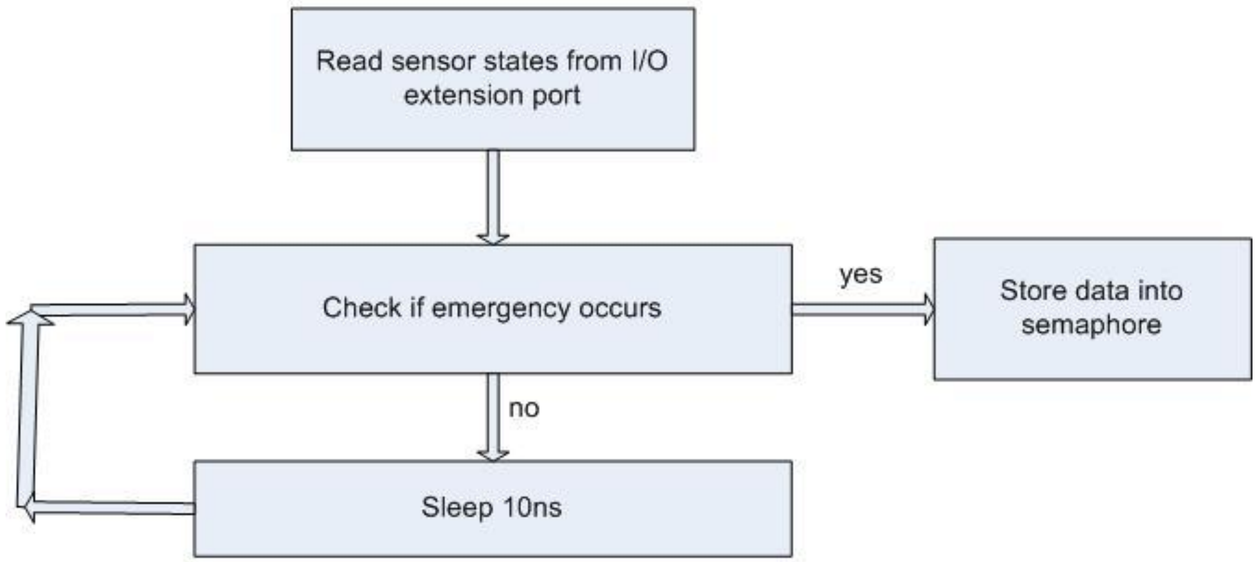
Appendix 10:

Algorithm flow chart of thread 2 in process B for software in robot MCU



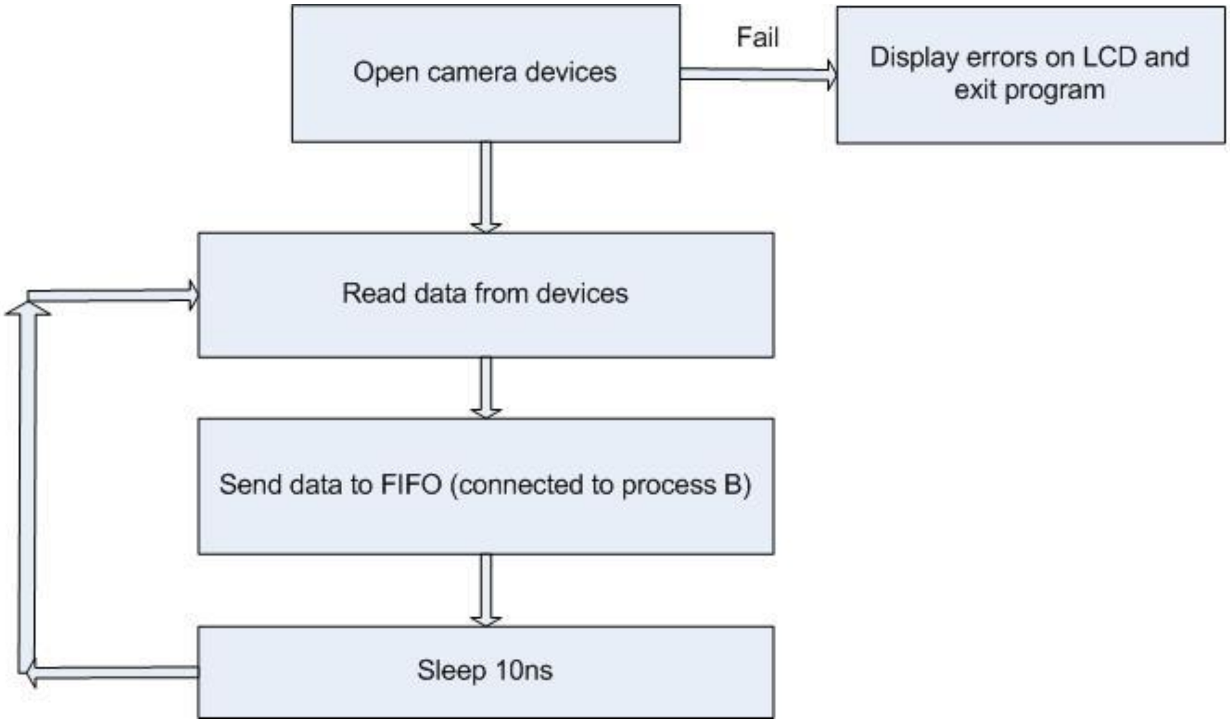
Appendix 11:

Algorithm flow chart of thread 3 in process B for software in robot MCU



Appendix 12:

Algorithm flow chart of process C for software in robot MCU



9 References

[1] Snow Thrower, [Online] Available: http://www.canadiantire.ca/AST/browse/2/OutdoorLiving/PowerEquipment/Snowthrowers/PRDOVR~0603982P/Yardworks%252B9A%252B%25252B%252B16-in%252BElectric%252BSnow%252BThrower.jsp?locale=en [Accessed: Mar 13th, 2011]

[2] Power Switch Circuit, [Online] Available: http://www.kpsec.freeuk.com/trancirc.htm [Accessed: Mar 13th, 2011]

[3] Power Extension Cord, [Online] Available: http://www.canadiantire.ca/AST/browse/3/HouseHome/2/Electrical/OutdoorPowerCords/PRDOVR~0522321P/Contractor%252BGrade%252BPower%252BBlock%252BCord%252B12%25252B3.jsp?locale=en [Accessed: Mar 13th, 2011]

[4] Converting ATX Power Supply, [Online] Available: http://www.instructables.com/id/Convert-an-ATX-Power-Supply-Into-a-Regular-DC-Powe/#step1 [Accessed: Mar 13th, 2011]

[5] Driving unit DC motor, [Online] Available: http://www.npcrobotics.com/products/viewprod.asp?prod=40&cat=20&mode=gfx [Accessed: Mar 13th, 2011]

[6] H-Bridge Circuitry. [Online] Available: http://www.robotroom.com/BipolarHBridge.html [Accessed: Mar 13th, 2011]

[7] Bipolar Step motor operation theory. [Online] Available: http://www.imagesco.com/articles/picstepper/02.html [Accessed: Mar 13th, 2011]

[8] Resource of SPCA5xx webcam by Vimicro Corp. [Online] Available: http://www.unixresources.net/linux/lf/11/archive/00/00/16/40/164005.html [Accessed: Mar 13th, 2011]