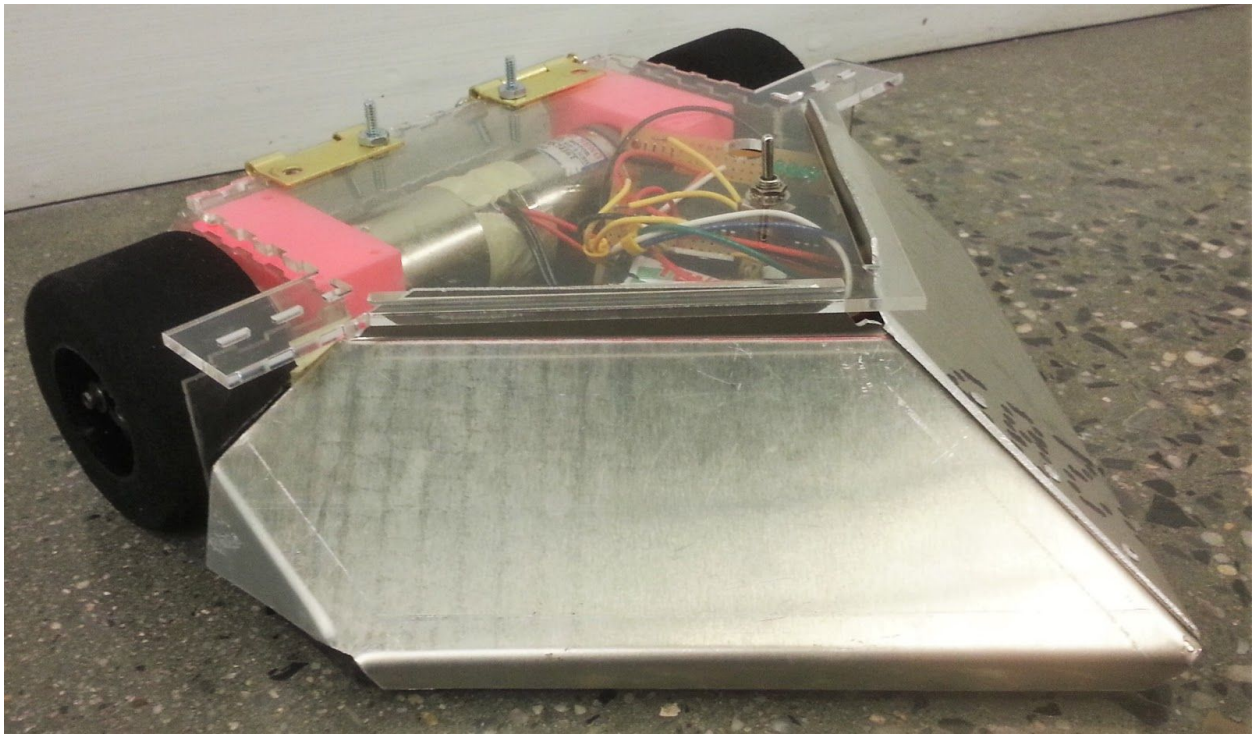

DARSOJIBOT

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Jihu Kim
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Advisor: Prof. Brian Cusack
ME153- Mechatronics
May 2016

Table of Contents

1. Introduction (Objectives/Overview)

a. Sumo robot history:

The Sumo Robot competition was originally invented in Japan in the late 1980s, and then imported to the United States a few years after. The first sumo robot competition was held in Japan in August 1989. Since the early 1990s, robot sumo tournaments, and their popularity, have grown exponentially. Sumo robots typically consist of two types: autonomous and remote-controlled. Autonomous robots run completely on their own without any human guidance, and remote-controlled robots use standard radio-control equipment to control the robot. The chart below describes the classifications of sumo robots based on height, breadth, length, and weight:

Class	Height(cm)	Breadth(cm)	Length(cm)	Weight(g)
Heavy Japon sumo	unlimited	30	30	10.000
Standart Sumo	unlimited	20	20	3.000
Mini Sumo	unlimited	10	10	500
Micro Sumo	5	5	5	100
Nano Sumo	2,5	2,5	2,5	25
Femto Sumo	1	1	1	

Chart 1: http://www.robotiksistem.com/sumorobot.htmln

2 a. Strategy/Design Overview

i. Strategy:

The main strategy of the robot is to push the opponent backwards as shown in Figure 1. During battles, the robot attempts to undercut opposing robots and lifts them to reduce traction of their wheels on the ground. Also the robot ensures that its wheels do not slip, and that its frame does not buckle.

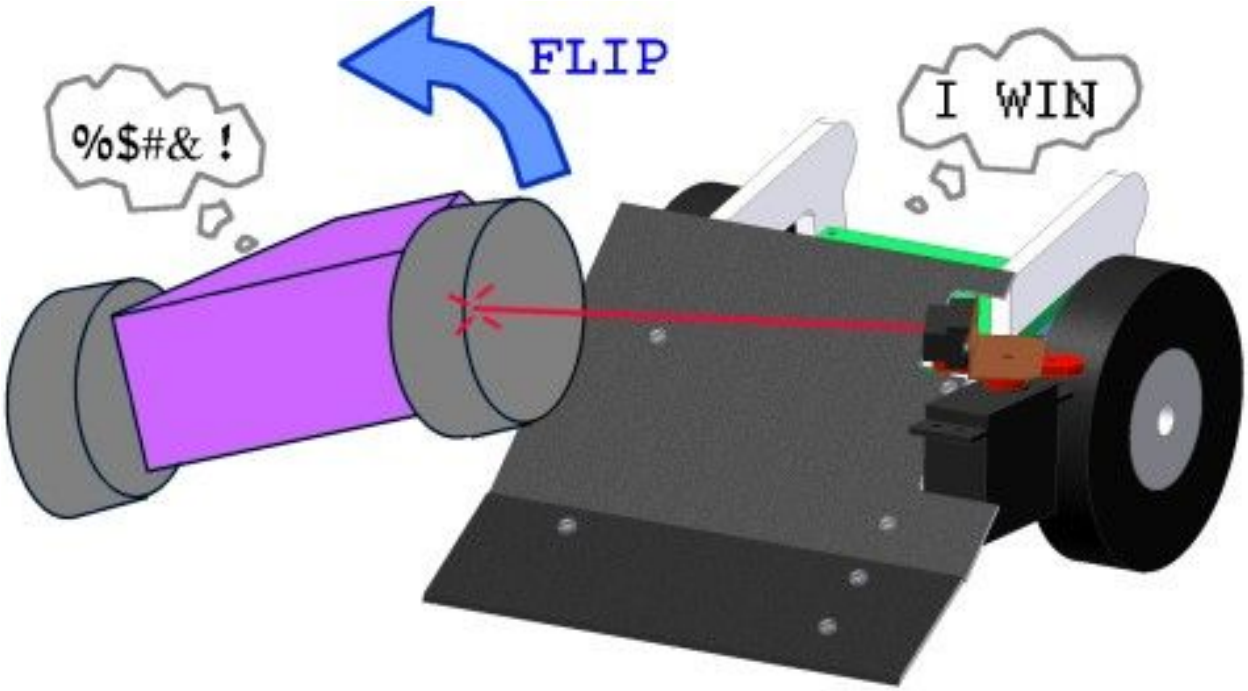


Figure 1: A robot undercutting another. The use of a wedge to undercut the enemy robot helps to ensure that the enemy robot's wheels lose traction
(source: http://www.societyofrobots.com/robot_sumo.shtml)

ii. Design:

In order to undercut opposing robots, strong wedges are essential. Low friction rubber low to the ground is attached on the end of the wedge to bring opponents onto the wedge.

It is also important to safeguard from opponents' undercutting tactics. A flap is added on the back of the robot for defense as shown in Figure 2.

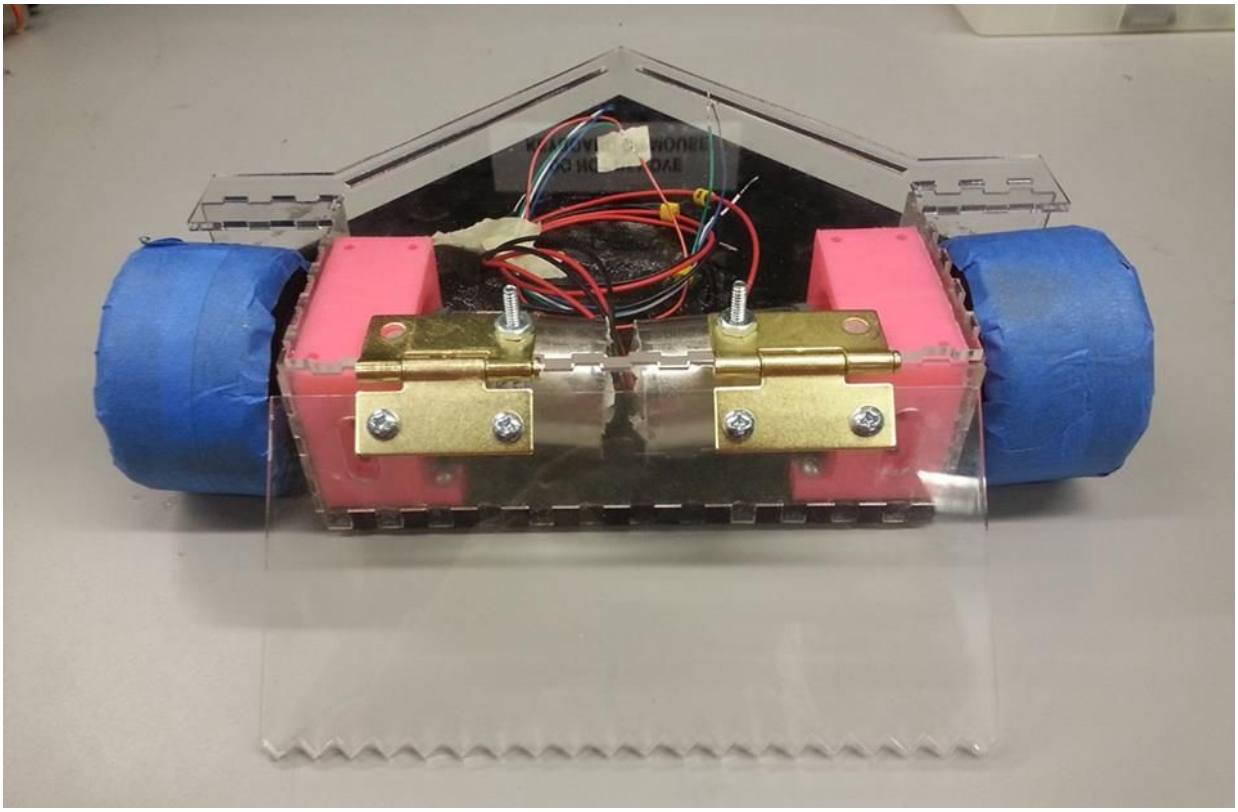


Figure 2: An image of a flap on a robot

To ensure that the robot will not slip on the ground, teeth (Figure 3) on the bottom of the base dig into the ground when pushed from the front.

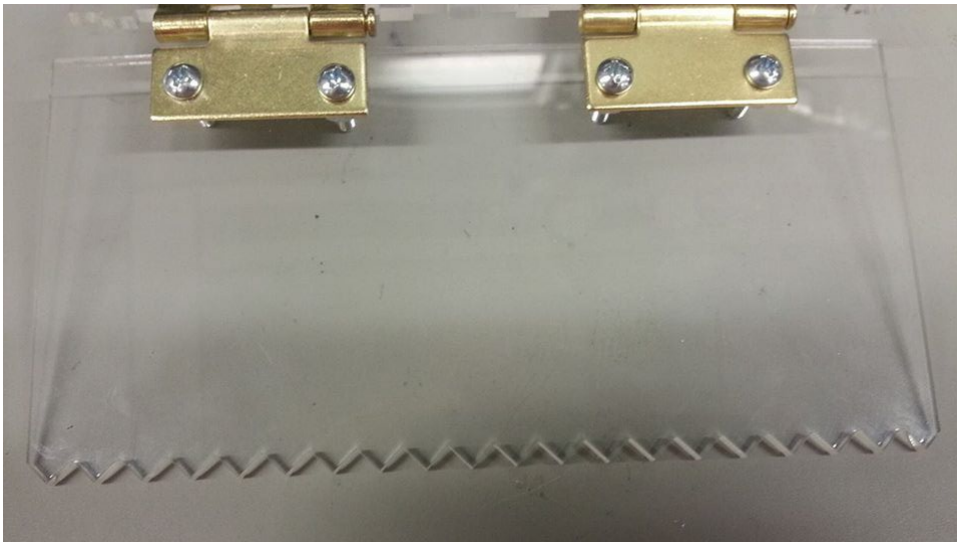


Figure 3: An image of teeth on a flap. The teeth are designed to dig into the ground when pushed, to provide extra resistance against being pushed back.

Large, high-traction wheels with maximal surface area are chosen in order to reduce the chance of slippage, and motor torque is maximized in the decision between speed and force in hopes of overcoming the opponent. Lastly, it is important to ensure that frame will not buckle. Walls are built using acrylic for ease of design, and wedges are made from aluminum for strength and robustness.

2b. Mechanical Design

i. Fabrication:

To fabricate the robot, acrylic walls are laser cut as shown in Figure 4 and Figure 5. Then, a flat cutout of the wedge is plasma cut as shown in Figure 6. After locations to bend aluminum are marked onto the flat cut-out, an aluminum bender bends the aluminum to appropriate angles as shown in Figure 7. An electronic protractor is also used to measure and confirm angles on the wedge. When an angle is overshot, a clamp is used to reduce the angle; alternatively, when an angle is undershot, a bender refines the angle until the aluminum reaches to the desired angle.

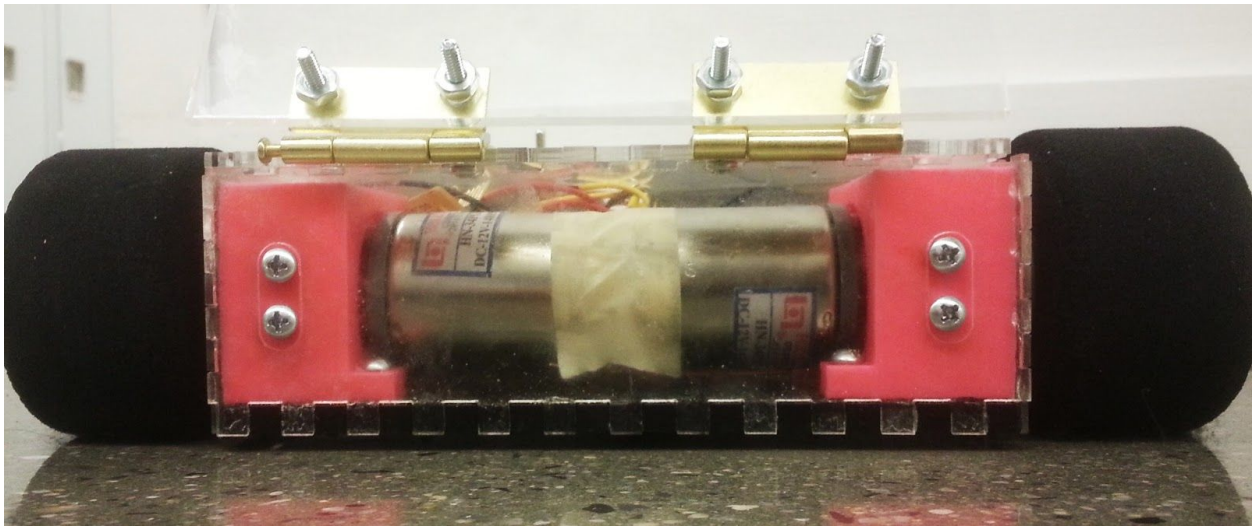


Figure 4: Laser Cut Acrylic Walls

Figure 5: Laser Cutting Acrylic Sheets

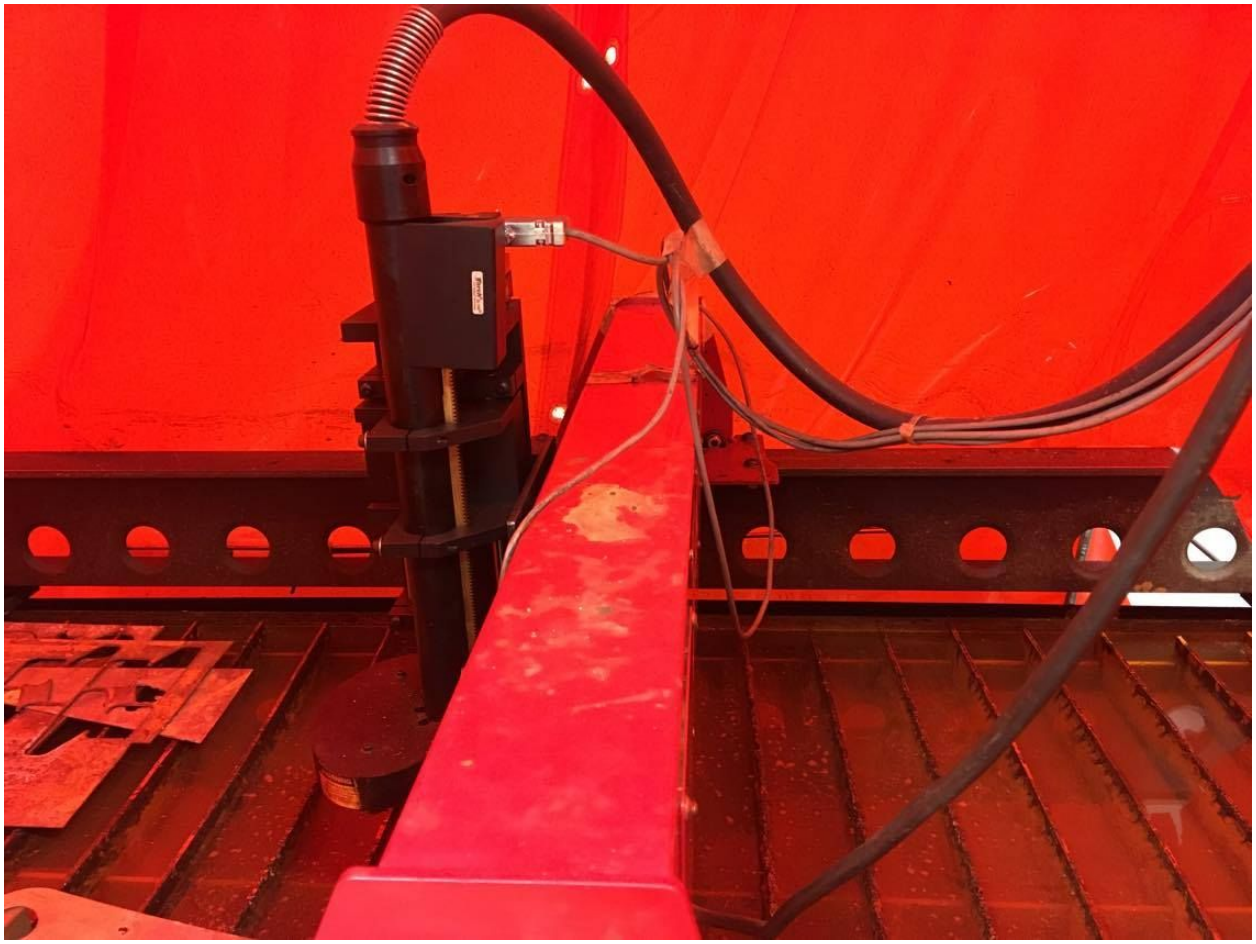


Figure 6: Plasma Cut Aluminum Cutouts

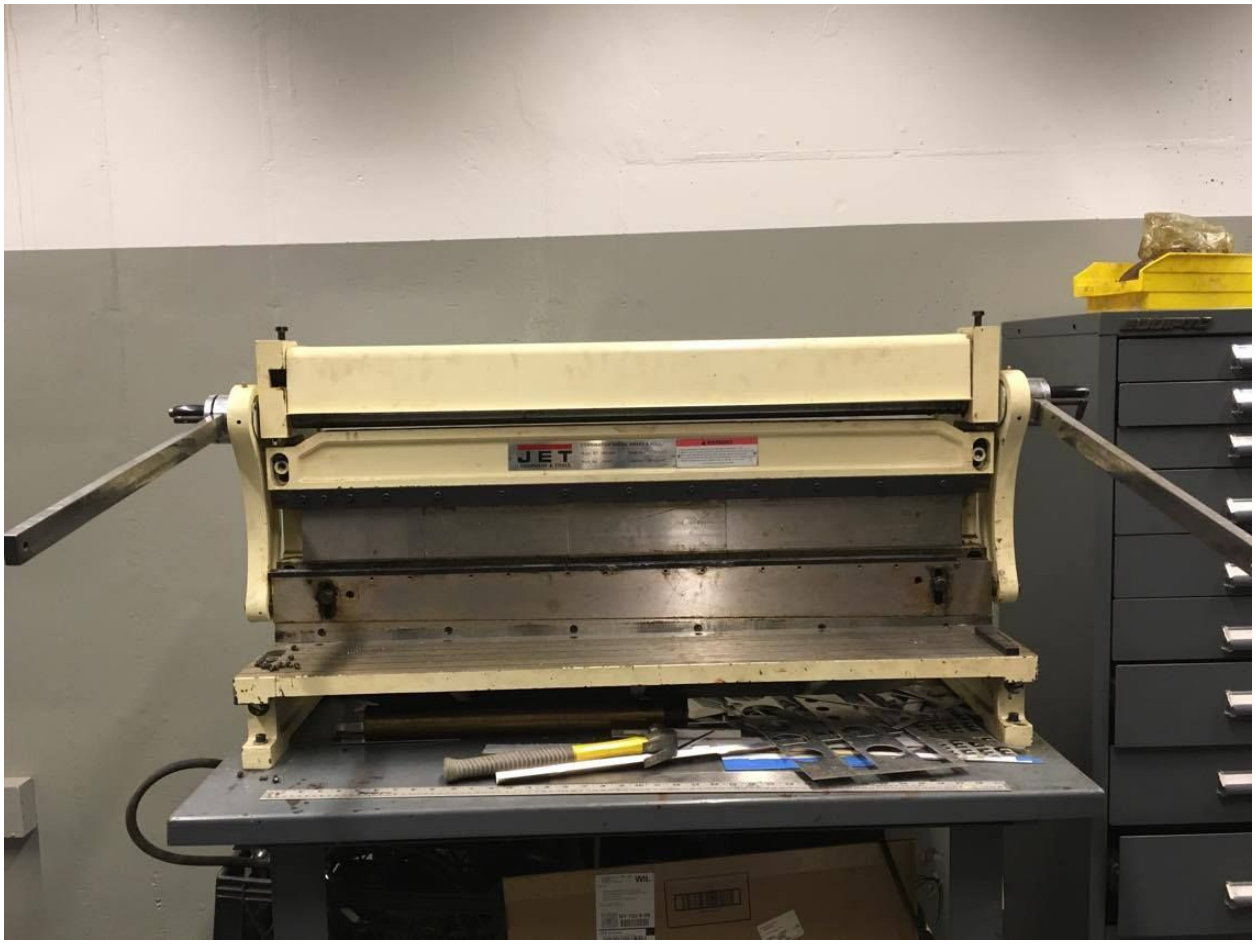


Figure 7: Bending Aluminum

ii. Assembly:

After fabricating each part of the robot, parts are assembled using appropriate chemical/mechanical methods as shown in Figure 8. Epoxy attaches acrylic pieces to one another, and also bonds acrylic to aluminum. The aluminum wedges are riveted together, and the motor mounts are attached to the motor and base via screws and tapped holes.

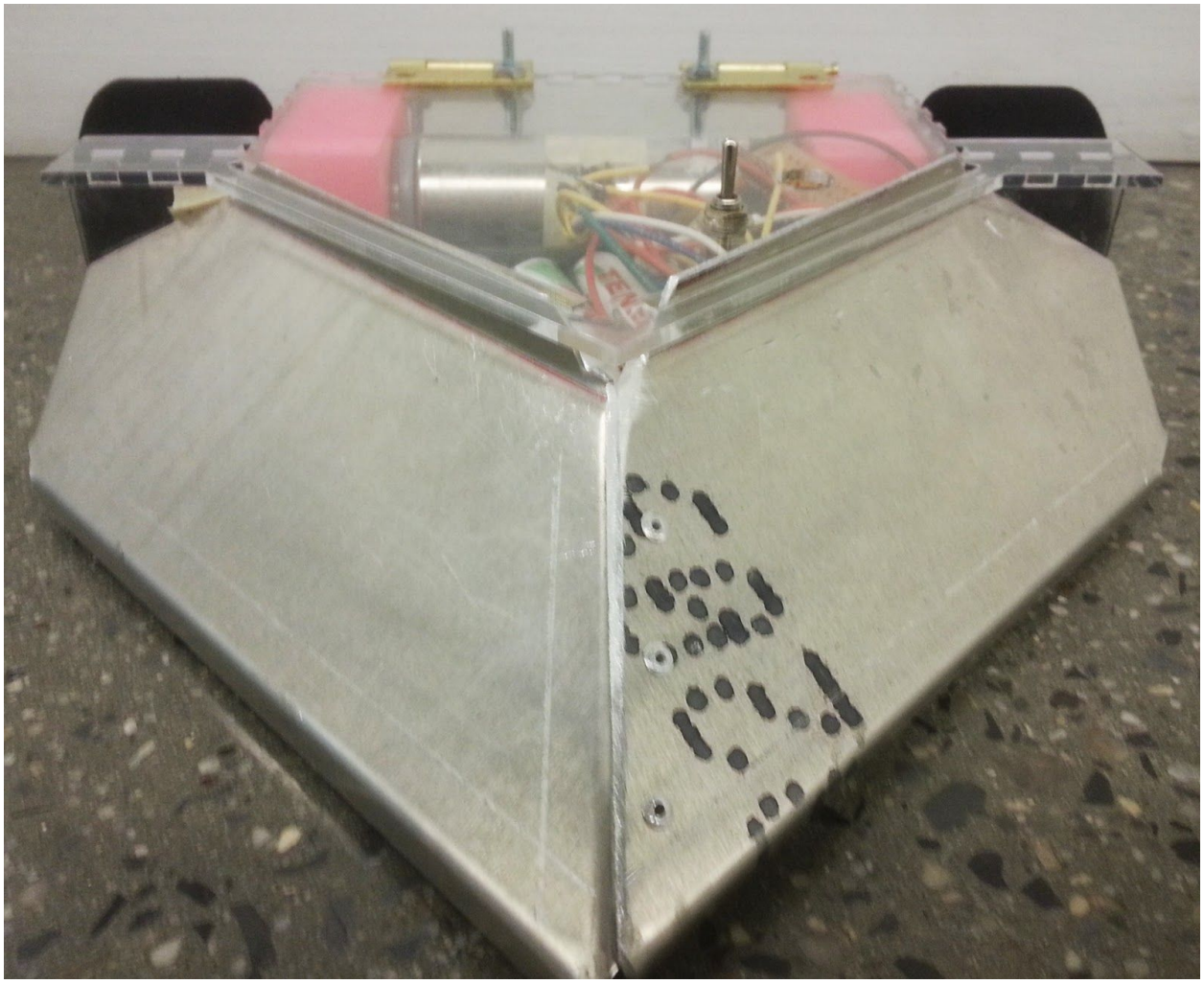


Figure 8: Assembled Robot

2c. Electronics

i. Strategy and design

It is essential for the robot to be capable of autonomy, learning about the environment and reacting accordingly without a necessity for human input for the duration of the competition. To accommodate this need, an OPB704WZ infrared sensor (IR sensor) is used to detect the edge of the ring during the competition so that the robot would know when to move backwards. A PIC18F4520 PIC microcontroller is chosen to allow for intake of signals from the IR sensor, as well as to send control signals towards the motor. An L298N H-bridge is used to allow for a higher power signal to be sent towards the motor, and large DC motors are used in order to

maximize torque. A simple flow diagram illustrating this strategy is shown below (figure 9).

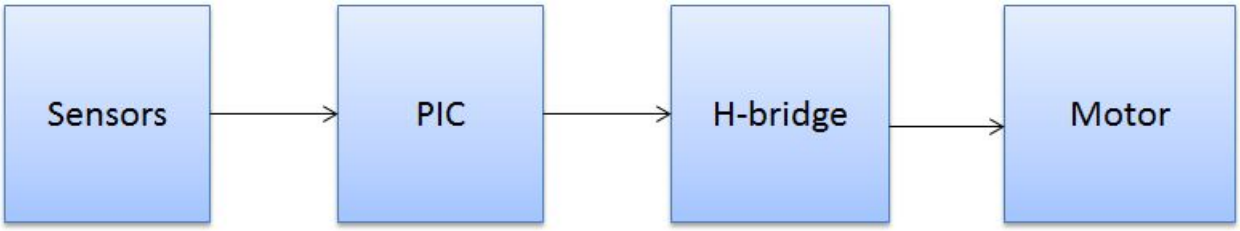


Figure 9: Flow Diagram for electronics (A full circuit diagram is available in Appendix B)

ii. Implementation

The IR sensor is used to detect the edge of the ring during the competition. The sensor shines infrared wavelength light on the ground using an LED, and detects the reflected light using a phototransistor. As the edge of the ring is of a lighter shade (bright white tape) when compared to the center of the ring (dark rubber), the sensor will be able to indicate that the robot has reached the edge of the ring when the sensed "ground" is over a certain reflectiveness. The sensor is located in the front bottom of the base of the robot, at .15 inches from the floor, as recommended from the datasheet, so that the light is as in focus as possible.

From there, the robot is controlled by the PIC18F4520 microcontroller, which can understand when it has reached the edge of the ring and needs to move backwards to avoid losing by leaving the ring. The microcontroller is clocked using a crystal oscillator, which provides to it a concept of time. The microcontroller also controls the the DC motors, using an H-bridge to bridge the gap in voltage and current in order to move the robot forwards or backwards, or to turn the robot. The microcontroller is programmed into C, which is then assembled into PIC assembly. All electronics are also placed on a perfboard, or PC board, due to the reduced size and weight of such a board, as well as increased robustness and permanence. This strategy is illustrated in the figure below (Figure 11).

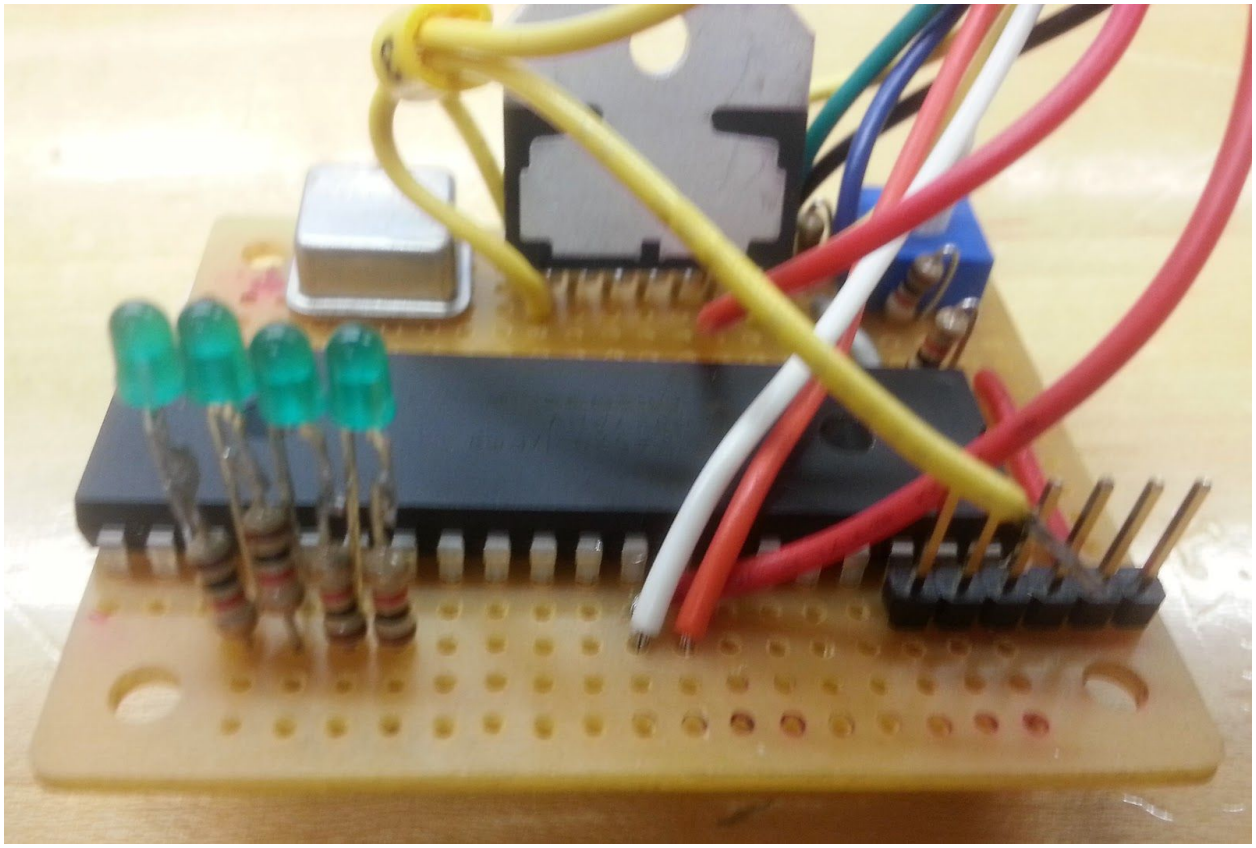


Figure 10: All electronics on a perforated board

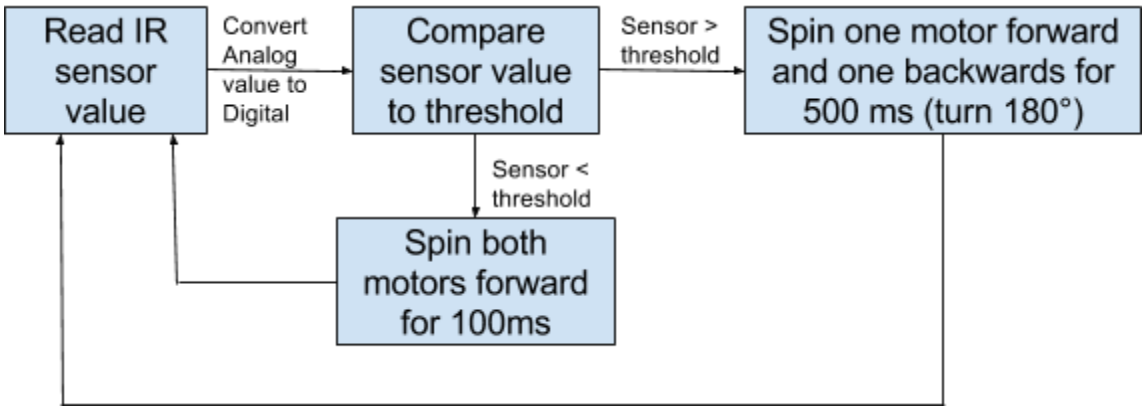


Figure 11: Flow Diagram for code

3. Discussion

One of the challenges encountered during the design process was that of large motors whose length approached the width limit imposed on the robot by the competition rules. In conjunction with the wheels' suggested mounting method, the width of the robot would surpass competition width limit. Therefore, to reduce the width of the robot, wheels were attached to the motor in an inverted matter, which hid the set screws and made assembly slightly more difficult, but significantly decreased the width of the robot. Custom motor mounts were also designed and manufactured to avoid use of stock motor mounts, which often added to the length of the motor. Additionally, the positive and negative electrical leads of the motor were bent to reduce the length of the motor and protected with electrical tape to reduce the spacing between the motors necessary to prevent short circuits.

Additionally, whereas the aluminum wedges were easily plasma cut, they had to be bent in angles not available to the aluminum bending machine available in the machine shop. Therefore, the aluminum wedges' angles were often iteratively manufactured, bending the aluminum a bit at a time, in order to minimize chances of overshooting the preferred angles. This is because if an angle were to be overshot, it would then have to be reduced by bending it back, which would severely reduce its strength and easily lead to shear cracking.

Various materials were chosen due to the varying material properties needed. For instance, the wedges were to be used to push opposing robots, aluminum was chosen for its strength. The body of the robot was manufactured mostly with acrylic due to convenience in manufacturing and assembly. Thicker acrylic was used for parts that required to handle more load than other parts of the body.

Due to stock motor mounts often adding to the length of the motors, custom motor mounts were designed using SolidWorks and manufactured via 3D Printing. The motor mount was also designed to be flush with the back and side walls of the robot, to provide additionally structural support.

A final concern was that of the H-bridge used for the robot's electronics. It would easily detach from the breadboard, which would disable the robot's motors. Therefore, it was decided to move all electronics from a breadboard to a perforated board.

4. Conclusion

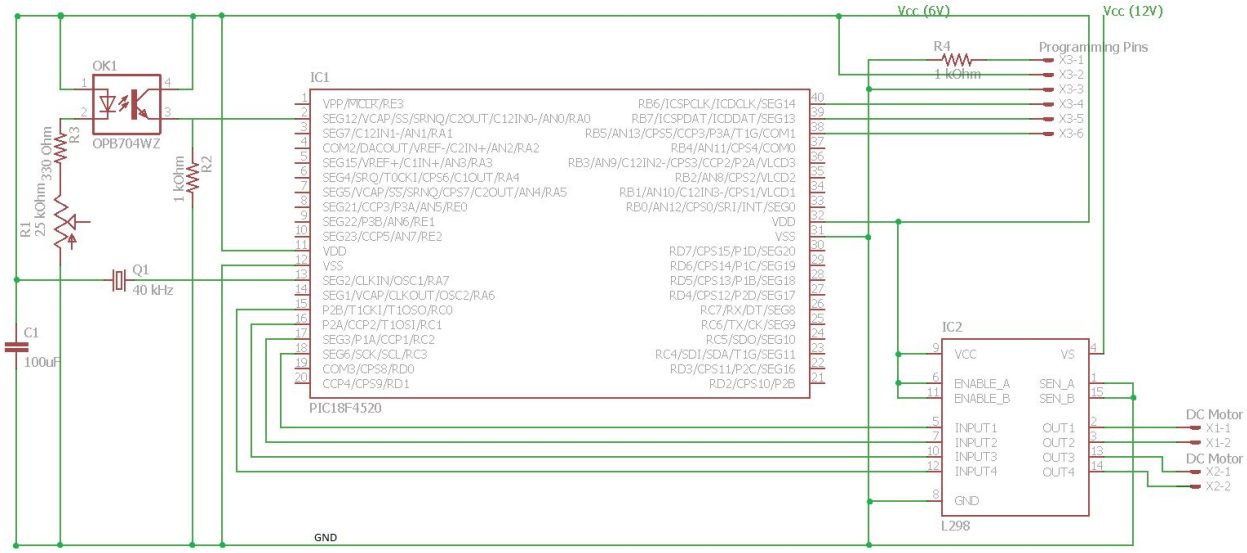
The Darsojibot was a success, and operated as preferred. However, there were some difficulties concerning robustness, as the robot's electronics often would stop working for various reasons. The combination of aluminum and acrylic in design was not only strong and effective, but aesthetically pleasing and impressive, and the robot fared fairly well in test runs against opposing robots.

5. Appendices

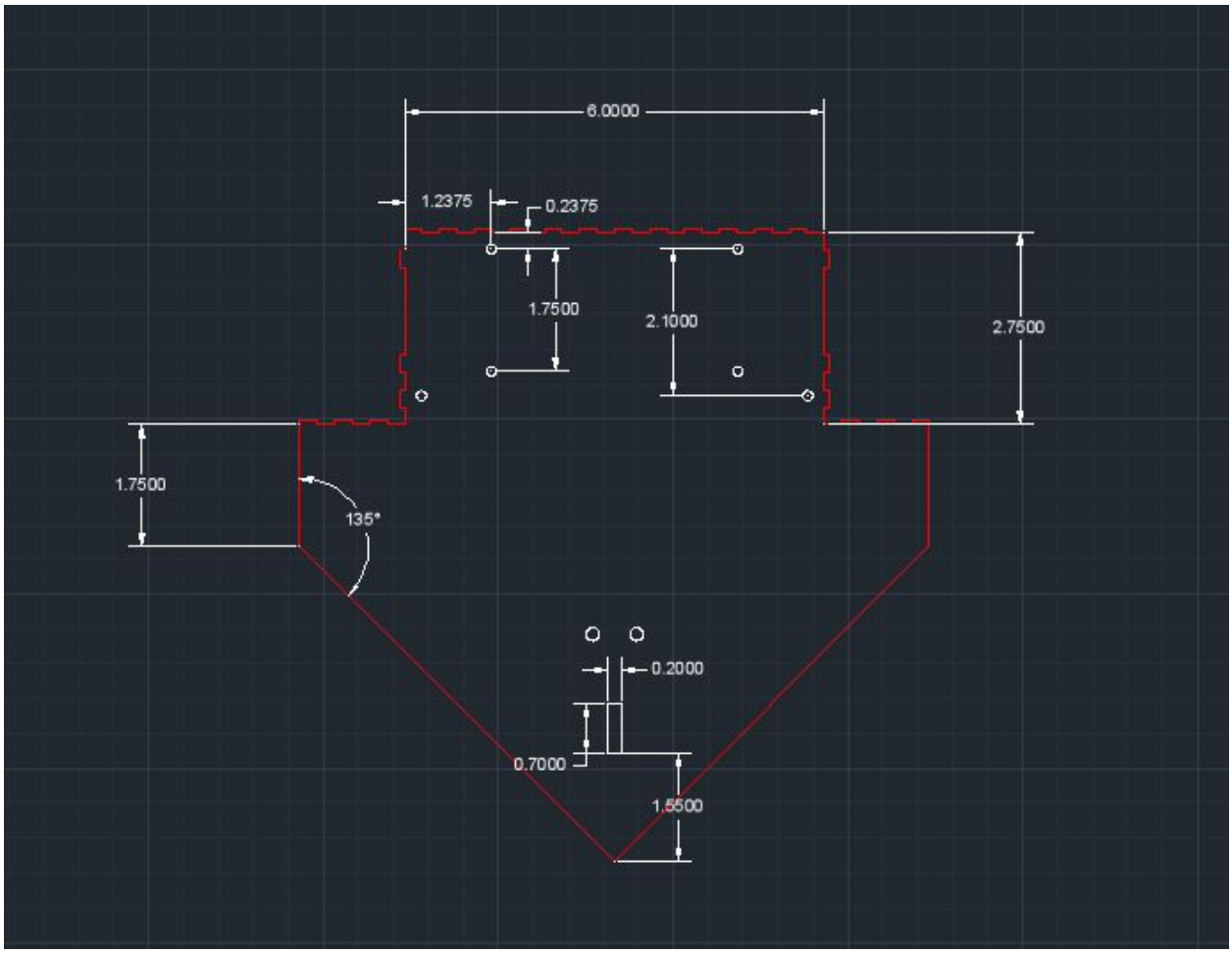
ME 153 - Mechatronics
Cost Report
Team Darsojibot: Jihu, Darwin, Soyoung

Quantity	Part Number	Part Description	Vender	Link	Unit Price	Bulk Price/Robot
2	PGHM-02	Motor	Lynxmotion	http://www.lynxmotion.com/p	39.95	79.90
1	TSR-03	Wheel Pair	Lynxmotion	http://www.lynxmotion.com/p	15.75	15.75
1	HUB-02	Wheel Hub Pair (6mm)	Lynxmotion	http://www.lynxmotion.com/p	7.65	7.65
1	G2756607	Epoxy	Zoro	https://www.zoro.com/gorilla-	4.5	4.50
0.8	8560K91	Acrylic(1/4" thick) - Opaque (12"*12")	Canal Plastics	http://www.mcmaster.com/#a	9.42	7.54
0.4	8560K171	Acrylic(1/16" thick) - Clear (12"*12")	Canal Plastics	http://www.mcmaster.com/#s	4.99	2.00
0.8	8560K239	Acrylic(1/8" thick) - Clear (12"*12")	Canal Plastics	http://www.mcmaster.com/#a	8.13	6.50
1	89015K183	6061 - T6 Aluminum Sheet (8"*8")	McMaster-Carr	http://www.mcmaster.com/#s	8.49	8.49
1	RB-pol-95	Ball Caster	Robotshop	www.robotshop.com	1.9	1.90
1	8633K52	Flexible, low-friction rubber (12*12)	McMaster-Carr	http://www.mcmaster.com/#s	6.201	6.20
14	91773A622	Round Head Phillips Machine Screw	McMaster-Carr	http://www.mcmaster.com/#r	0.0803	1.12
6	91857A192	Round Head Slotted Machine Screw	McMaster-Carr	http://www.mcmaster.com/#r	0.074	0.44
1		Electronics Kit	Prof Cusack		25	25.00
0.1	ABS-1	3-D Printing Material	Orb Polymer	http://www.orbpolymer.com/p	29.95	3.00
3	97525A305	Rivets	McMaster-Carr	http://www.mcmaster.com/#r	0.1132	0.34
1	7343K184	switch	McMaster-Carr	http://www.mcmaster.com/#s	6.53	6.53
0.5	20102	NiMH Batteries (AA) 16-pack	Amazon	http://www.amazon.com/Ten	26	13.00
2	12BH348/CS-GR	AA Battery Holder	Mouser	http://www.mouser.com/sear	0.96	1.92
1		Hinge (2-pack)	Basics Plus	https://basicsplus.com/	5	5.00
					Total	196.7798

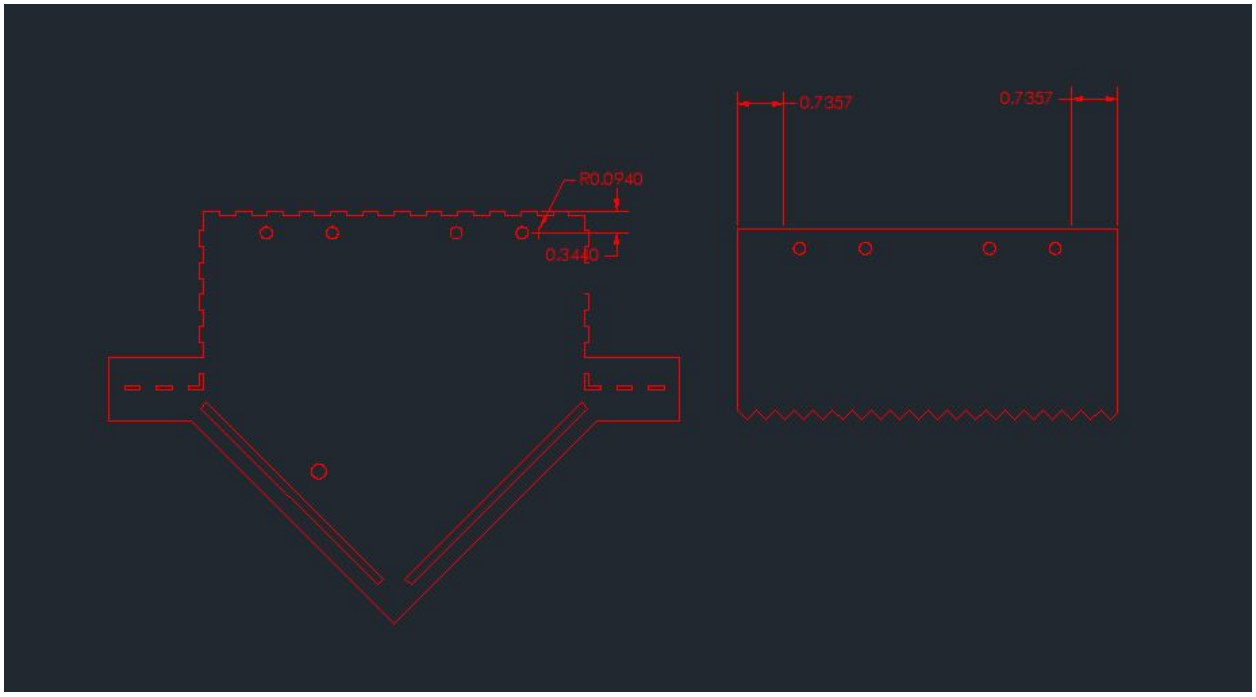
Appendix A: Cost Report of the robot. The final cost of 196.78 is for each robot, when making 100 robots.



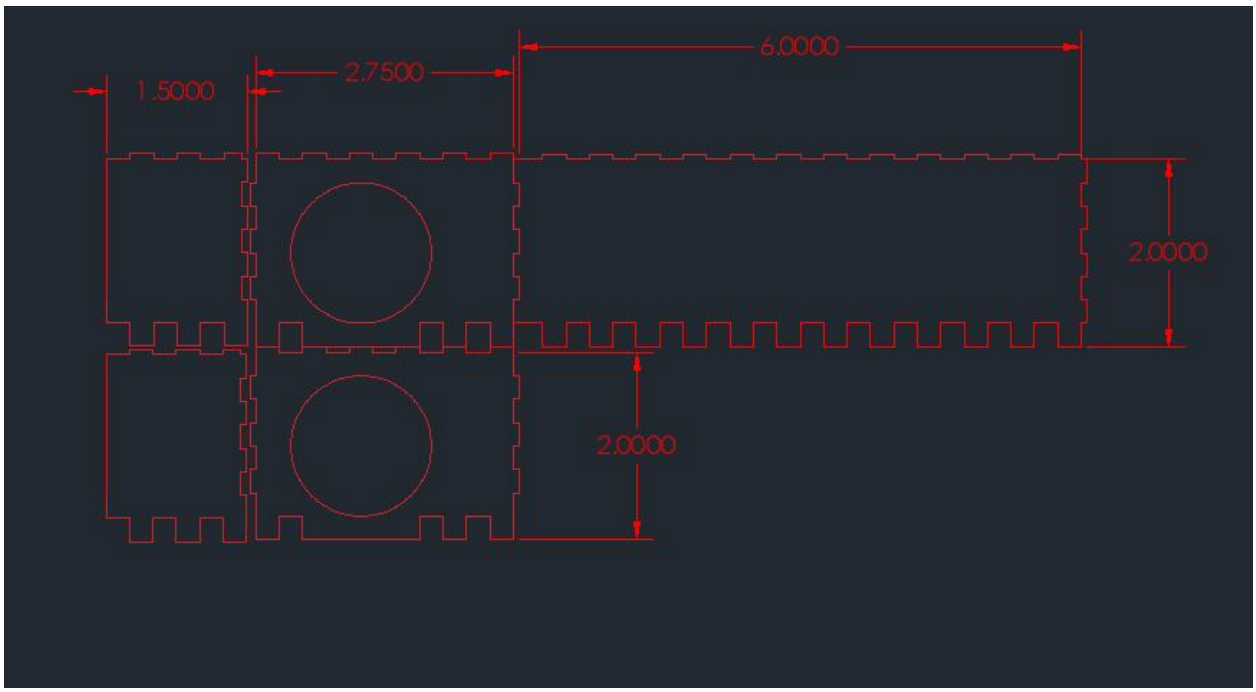
Appendix B: The electronics circuit diagram illustrates how components were attached and connected in the robot.



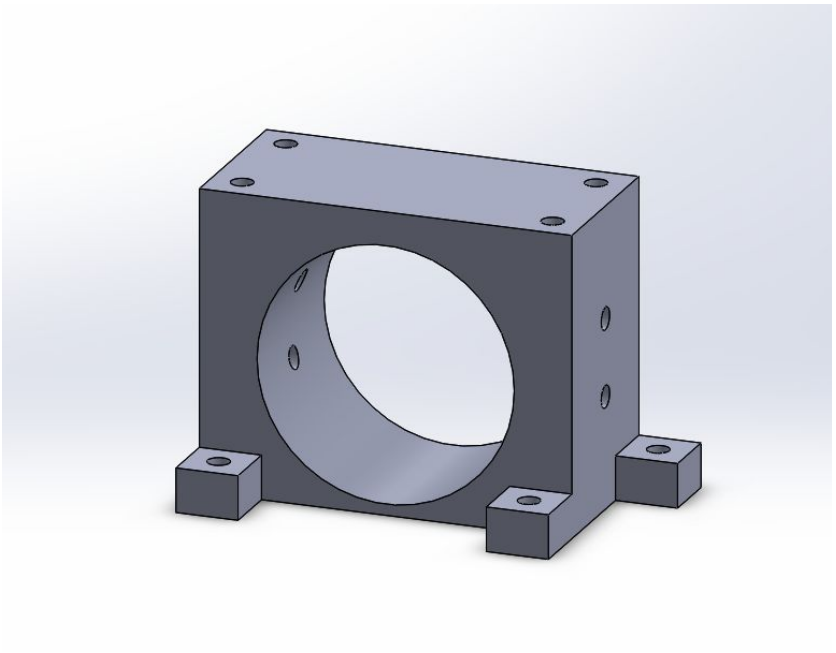
Appendix C1: CAD file of the base, with holes to support motor mounts, sensors, and ball caster, as well as notches for fitting walls.



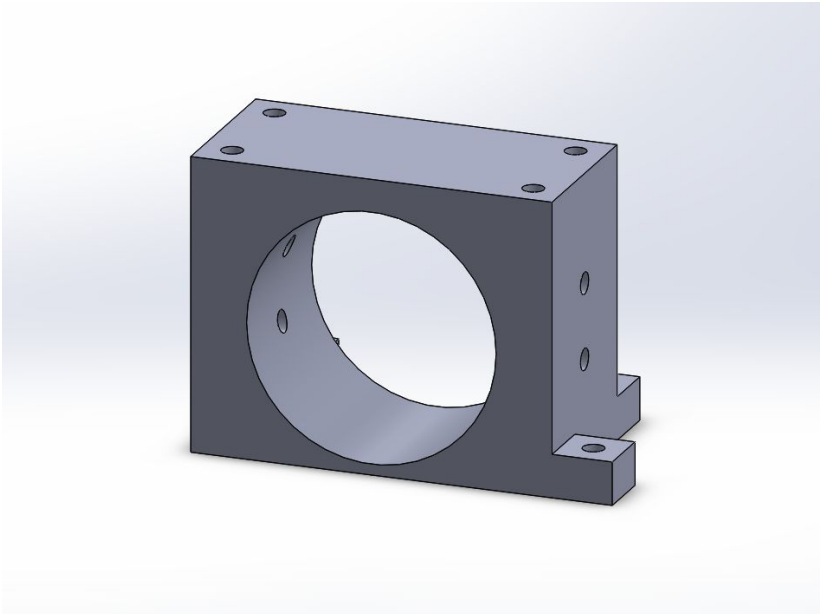
Appendix C2: CAD files for the ceiling and back flap, with notches for wall attachments, as well as holes to attach the hinges, kill switch, and aluminum wedge.



Appendix C3: CAD files of all acrylic walls, with notches to attach to one another. The circular hole allows for a motor to go through.



Appendix D: SolidWorks Model for Motor Mount (Right Side)



Appendix E: SolidWorks Model for Motor Mount (Left Side)

```
//Darsojibot code.

#include "user.h"
#include <xc.h>
```

```
#include <delays.h>

void main(void) {
    unsigned int setFront;
    unsigned int testFront;
    InitApp(); //initialize everything

    setFront = DetectFront();
    setFront = setFront >> 2;
    while(1){
        testFront = DetectFront();
        testFront = testFront >> 2;
        if (testFront > setFront){
            TurnRight();
            for(int i = 0; i < 15; i++){
                Delay10KTCYx(255);
                Delay10KTCYx(255);
            }
        } else {
            MoveForward();
            Delay10KTCYx(255);
            Delay10KTCYx(255);
        }
    }
}
```

Appendix F1: Main.C

```
#include <xc.h>       /* XC8 General Include File */
#include <adc.h>
#include "user.h"

/* <Initialize variables in user.h and insert code for user
algorithms.> */

void InitApp(void) {
    TRISCbits.RC0 = 0; //Motor A1
    TRISCbits.RC1 = 0; //Motor A2
    TRISCbits.RC2 = 0; //Motor B1
    TRISCbits.RC3 = 0; //Motor B2
```

```
    TRISA = 1;
    OpenADC( ADC_FOSC_32 & ADC_RIGHT_JUST & ADC_12_TAD, ADC_CH0 &
ADC_INT_OFF & ADC_VREFPLUS_VDD & ADC_VREFMINUS_VSS, 14 );
}

void MoveForward(void){
    PORTCbits.RC0 = 1;
    PORTCbits.RC1 = 0;
    PORTCbits.RC2 = 1;
    PORTCbits.RC3 = 0;
}

void TurnRight(void){
    PORTCbits.RC0 = 0;
    PORTCbits.RC1 = 1;
    PORTCbits.RC2 = 1;
    PORTCbits.RC3 = 0;
}

unsigned int DetectFront(){
  SetChanADC( ADC_CH0 );
  ConvertADC();
  while( BusyADC() );
  return ReadADC();
}

void wait(unsigned int time){
    while(time > 0){
        time--;
    }
}
```

Appendix F2: User.C

```
/******************************************************************
**************/
/* Files to Include
*/
/******************************************************************
**************/


#include <xc.h>       /* XC8 General Include File */

/******************************************************************
**************/
/* Configuration Bits
*/

/* General C18/XC8 syntax for configuration macros:
*/
/* #pragma config <Macro Name>=<Setting>, <Macro Name>=<Setting>,
...         */
/* A feature of MPLAB X is the 'Generate Source Code to Output'
utility in    */
/* the Configuration Bits window.  Under Window > PIC Memory
Views >          */
/* Configuration Bits, a user controllable configuration bits
window is       */
/* available to Generate Configuration Bits source code which the
user can    */
/* paste into this project.
*/
/*
*/
/******************************************************************
**************/

// CONFIG1H
#pragma config OSC = HS         // Oscillator Selection bits (HS
oscillator)
```

```
#pragma config FCMEN = OFF      // Fail-Safe Clock Monitor Enable
bit (Fail-Safe Clock Monitor disabled)
#pragma config IESO = OFF       // Internal/External Oscillator
Switchover bit (Oscillator Switchover mode disabled)

// CONFIG2L
#pragma config PWRT = OFF       // Power-up Timer Enable bit
(PWRT disabled)
#pragma config BOREN = SBORDIS  // Brown-out Reset Enable bits
(Brown-out Reset enabled in hardware only (SBOREN is disabled))
#pragma config BORV = 3         // Brown Out Reset Voltage bits
(Minimum setting)

// CONFIG2H
#pragma config WDT = OFF        // Watchdog Timer Enable bit (WDT
disabled (control is placed on the SWDTEN bit))
#pragma config WDTPS = 32768    // Watchdog Timer Postscale
Select bits (1:32768)

// CONFIG3H
#pragma config CCP2MX = PORTC   // CCP2 MUX bit (CCP2
input/output is multiplexed with RC1)
#pragma config PBADEN = ON      // PORTB A/D Enable bit
(PORTB<4:0> pins are configured as analog input channels on
Reset)
#pragma config LPT1OSC = OFF    // Low-Power Timer1 Oscillator
Enable bit (Timer1 configured for higher power operation)
#pragma config MCLRE = ON       // MCLR Pin Enable bit (MCLR pin
enabled; RE3 input pin disabled)

// CONFIG4L
#pragma config STVREN = ON      // Stack Full/Underflow Reset
Enable bit (Stack full/underflow will cause Reset)
#pragma config LVP = ON         // Single-Supply ICSP Enable bit
(Single-Supply ICSP enabled)
#pragma config XINST = OFF      // Extended Instruction Set
Enable bit (Instruction set extension and Indexed Addressing mode
disabled (Legacy mode))
```

```
// CONFIG5L
#pragma config CP0 = OFF        // Code Protection bit (Block 0
(000800-001FFFh) not code-protected)
#pragma config CP1 = OFF        // Code Protection bit (Block 1
(002000-003FFFh) not code-protected)
#pragma config CP2 = OFF        // Code Protection bit (Block 2
(004000-005FFFh) not code-protected)
#pragma config CP3 = OFF        // Code Protection bit (Block 3
(006000-007FFFh) not code-protected)

// CONFIG5H
#pragma config CPB = OFF        // Boot Block Code Protection bit
(Boot block (000000-0007FFh) not code-protected)
#pragma config CPD = OFF        // Data EEPROM Code Protection
bit (Data EEPROM not code-protected)

// CONFIG6L
#pragma config WRT0 = OFF       // Write Protection bit (Block 0
(000800-001FFFh) not write-protected)
#pragma config WRT1 = OFF       // Write Protection bit (Block 1
(002000-003FFFh) not write-protected)
#pragma config WRT2 = OFF       // Write Protection bit (Block 2
(004000-005FFFh) not write-protected)
#pragma config WRT3 = OFF       // Write Protection bit (Block 3
(006000-007FFFh) not write-protected)

// CONFIG6H
#pragma config WRTC = OFF       // Configuration Register Write
Protection bit (Configuration registers (300000-3000FFh) not
write-protected)
#pragma config WRTB = OFF       // Boot Block Write Protection
bit (Boot block (000000-0007FFh) not write-protected)
#pragma config WRTD = OFF       // Data EEPROM Write Protection
bit (Data EEPROM not write-protected)

// CONFIG7L
#pragma config EBTR0 = OFF      // Table Read Protection bit
(Block 0 (000800-001FFFh) not protected from table reads executed
in other blocks)
```

```
#pragma config EBTR1 = OFF      // Table Read Protection bit
(Block 1 (002000-003FFFh) not protected from table reads executed
in other blocks)
#pragma config EBTR2 = OFF      // Table Read Protection bit
(Block 2 (004000-005FFFh) not protected from table reads executed
in other blocks)
#pragma config EBTR3 = OFF      // Table Read Protection bit
(Block 3 (006000-007FFFh) not protected from table reads executed
in other blocks)

// CONFIG7H
#pragma config EBTRB = OFF      // Boot Block Table Read
Protection bit (Boot block (000000-0007FFh) not protected from
table reads executed in other blocks)
```

Appendix F23: Configuration_bits.C

Aluminum 6061-T6; 6061-T651

Composition Notes:
Aluminum content reported is calculated as remainder.
Composition information provided by the Aluminum Association and is not for design.

Key Words: al6061, UNS A96061; ISO AlMg1SiCu; Aluminium 6061-T6, AD-33 (Russia); AA6061-T6; 6061T6, UNS A96061; ISO AlMg1SiCu; Aluminium 6061-T651, AD-33 (Russia); AA6061-T651

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	95.8 - 98.6	Mg	0.8 - 1.2	Si	0.4 - 0.8
Cr	0.04 - 0.35	Mn	Max 0.15	Ti	Max 0.15
Cu	0.15 - 0.4	Other, each	Max 0.05	Zn	Max 0.25
Fe	Max 0.7	Other, total	Max 0.15		

Material Notes:
Information provided by Alcoa, Starmet and the references. General 6061 characteristics and uses: Excellent joining characteristics, good acceptance of applied coatings. Combines relatively high strength, good workability, and high resistance to corrosion; widely available. The T8 and T9 tempers offer better chipping characteristics over the T6 temper.

Applications: Aircraft fittings, camera lens mounts, couplings, marines fittings and hardware, electrical fittings and connectors, decorative or misc. hardware, hinge pins, magneto parts, brake pistons, hydraulic pistons, appliance fittings, valves and valve parts; bike frames.

Data points with the AA note have been provided by the Aluminum Association, Inc. and are NOT FOR DESIGN.

Physical Properties	Metric	English	Comments
Density	2.7 g/cc	0.0975 lb/in³	AA; Typical
Mechanical Properties			
Hardness, Brinell	95	95	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	120	120	Converted from Brinell Hardness Value
Hardness, Rockwell A	40	40	Converted from Brinell Hardness Value
Hardness, Rockwell B	60	60	Converted from Brinell Hardness Value
Hardness, Vickers	107	107	Converted from Brinell Hardness Value
Ultimate Tensile Strength	310 MPa	45000 psi	AA; Typical
Tensile Yield Strength	276 MPa	40000 psi	AA; Typical
Elongation at Break	12 %	12 %	AA; Typical; 1/16 in. (1.6 mm) Thickness
Elongation at Break	17 %	17 %	AA; Typical; 1/2 in. (12.7 mm) Diameter
Modulus of Elasticity	68.9 GPa	10000 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Notched Tensile Strength	324 MPa	47000 psi	2.5 cm width x 0.16 cm thick side-notched specimen, K_t = 17.
Ultimate Bearing Strength	607 MPa	88000 psi	Edge distance/pin diameter = 2.0
Bearing Yield Strength	386 MPa	56000 psi	Edge distance/pin diameter = 2.0
Poisson's Ratio	0.33	0.33	Estimated from trends in similar Al alloys.
Fatigue Strength	96.5 MPa	14000 psi	AA; 500,000,000 cycles completely reversed stress; RR Moore machine/specimen
Fracture Toughness	29 MPa-m½	26.4 ksi-in½	K_{IC}; TL orientation.
Machinability	50 %	50 %	0-100 Scale of Aluminum Alloys
Shear Modulus	26 GPa	3770 ksi	Estimated from similar Al alloys.
Shear Strength	207 MPa	30000 psi	AA; Typical
Electrical Properties			
Electrical Resistivity	3.99e-006 ohm-cm		
Thermal Properties			
CTE, linear 68°F	23.6 µm/m-°C	13.1 µin/in-°F	AA; Typical; Average over 68-212°F range.
CTE, linear 250°C	25.2 µm/m-°C	14 µin/in-°F	Estimated from trends in similar Al alloys. 20-300°C.
Specific Heat Capacity	0.896 J/g-°C	0.214 BTU/lb-°F	
Thermal Conductivity	167 W/m-K	1160 BTU-in/hr-ft²-°F	AA; Typical at 77°F
Melting Point	582 - 652 °C	1080 - 1205 °F	AA; Typical range based on typical composition for wrought products 1/4 inch thickness or greater; Eutectic melting can be completely eliminated by homogenization.
Solidus	582 °C	1080 °F	AA; Typical
Liquidus	652 °C	1205 °F	AA; Typical
Processing Properties			
Solution Temperature	529 °C	985 °F	
Aging Temperature	160 °C	320 °F	Rolled or drawn products; hold at temperature for 18 hr
Aging Temperature	177 °C	350 °F	Extrusions or forgings; hold at temperature for 8 hr

Appendix G1: Aluminum Sheet MSDS

ALTUGLAS INTERNATIONAL
ARKEMA GROUP

Material Safety Data Sheet

PLEXIGLAS® G ACRYLIC SHEET

1. PRODUCT AND COMPANY IDENTIFICATION

Company

Arkema Inc.
2000 Market Street
Philadelphia, Pennsylvania 19103

Altuglas International

Customer Service Telephone Number: (800) 523-1532
(Monday through Friday, 8:30 AM to 5:30 PM EST)

Emergency Information

Transportation: CHEMTREC: (800) 424-9300
(24 hrs., 7 days a week)
Medical: Rocky Mountain Poison Center: (303) 623-5716
(24 hrs., 7 days a week)

Product Information

Product name: PLEXIGLAS® G ACRYLIC SHEET
Synonyms: Not available
Molecular formula: Not available
Chemical family: acrylic copolymer
Product use: Special applications, in general

2. HAZARDS IDENTIFICATION

Emergency Overview

Color: clear
Physical state: solid
Form: sheets
Odor: odourless

CAUTION!
PROCESSING MAY RELEASE VAPORS AND/OR FUMES WHICH CAUSE EYE, SKIN AND RESPIRATORY TRACT IRRITATION.

Potential Health Effects

Primary routes of exposure:
Inhalation and skin contact.

Signs and symptoms of acute exposure:
High molecular weight polymer. The product, in the form supplied, is not anticipated to produce significant adverse human health effects. Product dust may be irritating to eyes, skin and respiratory system. Effects due to processing releases: Irritating to eyes, respiratory system and skin. Inhalation of fume may cause flu-like symptoms. (severity of effects depends on extent of exposure) Prolonged or repeated exposure may cause: headache, drowsiness, nausea, weakness.

Remarks:

Appendix G2: Plexiglas Sheet MSDS

Handle in accordance with good industrial hygiene and safety practice. (sheets) Secondary operations, such as grinding, sanding or sawing, can produce dust which may present a respiratory hazard. This product may release fume and/or vapor of variable composition depending on processing time and temperature.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	CAS-No.	Wt/Wt	OSHA Hazardous
Polymethyl methacrylate copolymers	Proprietary*	99 - 100 %	N

The substance(s) marked with a "Y" in the Hazard column above, are those identified as hazardous chemicals under the criteria of the OSHA Hazard Communication Standard (29 CFR 1910.1200).

*The specific chemical identity is withheld because it is trade secret information of Arkema Inc.

While this material is not classified as hazardous under Federal OSHA regulations, this MSDS contains valuable information critical to the safe handling and proper use of this product. This MSDS should be retained and available for employees and other users of this product.

4. FIRST AID MEASURES

Inhalation:
If inhaled, remove to fresh air.

Skin:
In case of contact, immediately flush skin with plenty of water. If molten polymer gets on the skin, cool rapidly with cold water. Do not peel solidified product off the skin. Obtain medical treatment for thermal burns. Remove material from clothing. Wash clothing before reuse.

Eyes:
Immediately flush eye(s) with plenty of water. Obtain medical treatment for thermal burns.

Ingestion:
If swallowed, DO NOT induce vomiting. Get medical attention. Never give anything by mouth to an unconscious person.

5. FIRE-FIGHTING MEASURES

Flash point not applicable

Auto-ignition temperature: 860 °F (460 °C)

Lower flammable limit (LFL): not applicable

Upper flammable limit (UFL): not applicable

Extinguishing media (suitable):
Dry chemical, water spray, carbon dioxide, foam

Protective equipment:

Fire fighters and others who may be exposed to products of combustion should wear full fire fighting turn out gear (full Bunker Gear) and self-contained breathing apparatus (pressure demand / NIOSH approved or equivalent).

Further firefighting advice:
Fire fighting equipment should be thoroughly decontaminated after use.

Fire and explosion hazards:
Heated material can form flammable vapors with air.

6. ACCIDENTAL RELEASE MEASURES

In case of spill or leak:
Pick up and transfer to properly labelled containers. Consult a regulatory specialist to determine appropriate state or local reporting requirements, for assistance in waste characterization and/or hazardous waste disposal and other requirements listed in pertinent environmental permits.

7. HANDLING AND STORAGE

Handling

General information on handling:
Avoid breathing processing fumes or vapors.
Avoid breathing dust.
Handle in accordance with good industrial hygiene and safety practices.
These practices include avoiding unnecessary exposure and removal of material from eyes, skin and clothing.

Storage

General information on storage conditions:
Avoid extreme temperatures.

Storage incompatibility – General:
Store away from sources of heat and light.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Airborne Exposure Guidelines:

2-Propenoic acid, 2-methyl-, methyl ester (80-62-6)

US. ACGIH Threshold Limit Values

Time Weighted Average (TWA):	50 ppm
Short Term Exposure Limit (STEL):	100 ppm

US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000)

PEL:	100 ppm (410 mg/m3)

Only those components with exposure limits are printed in this section. Limits with skin contact designation above have skin contact effect. Air sampling alone is insufficient to accurately quantitate exposure. Measures to prevent significant cutaneous absorption may be required. Limits with a sensitizer designation above mean that exposure to this material may cause allergic reactions.

Engineering controls:
Investigate engineering techniques to reduce exposures below airborne exposure limits. Provide ventilation if necessary to control exposure levels below airborne exposure limits (see above). If practical, use local mechanical exhaust ventilation at sources of air contamination such as open process equipment.

Respiratory protection:
Avoid breathing processing fumes or vapors. Avoid breathing dust. Where airborne exposure is likely or airborne exposure limits are exceeded (if applicable, see above), use NIOSH approved respiratory protection equipment appropriate to the material and/or its components and substances released during processing. Consult respirator manufacturer to determine appropriate type equipment for a given application. Observe respirator use limitations specified by NIOSH or the manufacturer. For emergency and other conditions where there may be a potential for significant exposure or where exposure limit may be significantly exceeded, use an approved full face positive-pressure, self-contained breathing apparatus or positive-pressure airline with auxiliary self-contained air supply. Respiratory protection programs must comply with 29 CFR § 1910.134.

Skin protection:
Processing of this product releases vapors or fumes which may cause skin irritation. Minimize skin contamination by following good industrial hygiene practice. Wearing protective gloves is recommended. Wash hands and contaminated skin thoroughly after contact with processing fumes or vapors. Wash thoroughly after handling.

Eye protection:
Processing of this product releases vapors or fumes which may cause eye irritation. Use good industrial practice to avoid eye contact. Where eye contact may be likely, wear chemical goggles and have eye flushing equipment available.

9. PHYSICAL AND CHEMICAL PROPERTIES

Color:	clear
Physical state:	solid
Form:	sheets
Odor:	odourless
pH:	not applicable
Density:	not applicable
Vapor pressure:	not applicable
Vapor density:	not applicable
Boiling point/boiling range:	not applicable
Freezing point:	not applicable

Only those components with exposure limits are printed in this section. Limits with skin contact designation above have skin contact effect. Air sampling alone is insufficient to accurately quantitate exposure. Measures to prevent significant cutaneous absorption may be required. Limits with a sensitizer designation above mean that exposure to this material may cause allergic reactions.

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Respiratory protection:
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Skin protection:
Processing of this product releases vapors or fumes which may cause skin irritation. Minimize skin contamination by following good industrial hygiene practice. Wearing protective gloves is recommended. Wash hands and contaminated skin thoroughly after contact with processing fumes or vapors. Wash thoroughly after handling.

Eye protection:
Processing of this product releases vapors or fumes which may cause eye irritation. Use good industrial practice to avoid eye contact. Where eye contact may be likely, wear chemical goggles and have eye flushing equipment available.

9. PHYSICAL AND CHEMICAL PROPERTIES

Color:	clear
Physical state:	solid
Form:	sheets
Odor:	odourless
pH:	not applicable
Density:	not applicable
Vapor pressure:	not applicable
Vapor density:	not applicable
Boiling point/boiling range:	not applicable
Freezing point:	not applicable

Skin contact:
Skin: Irritant but not a sensitizer. Mechanical irritation. (studied using human volunteers)

12. ECOLOGICAL INFORMATION

Chemical Fate and Pathway
No data are available.

Ecotoxicology
No data are available.

13. DISPOSAL CONSIDERATIONS

Waste disposal:
Where possible recycling is preferred to disposal or incineration. If recycling is not an option, incinerate or dispose of in accordance with federal, state, and local regulations. Pigmented, filled and/or solvent laden product may require special disposal practices in accordance with federal, state and local regulations. Consult a regulatory specialist to determine appropriate state or local reporting requirements, for assistance in waste characterization and/or hazardous waste disposal and other requirements listed in pertinent environmental permits. Note: Chemical additions to, processing of, or otherwise altering this material may make this waste management information incomplete, inaccurate, or otherwise inappropriate. Furthermore, state and local waste disposal requirements may be more restrictive or otherwise different from federal laws and regulations.

14. TRANSPORT INFORMATION

US Department of Transportation (DOT): not regulated

International Maritime Dangerous Goods Code (IMDG): not regulated

15. REGULATORY INFORMATION

Chemical Inventory Status

EU. EINECS	EINECS	Does not conform
US. Toxic Substances Control Act	TSCA	The components of this product are all on the TSCA Inventory.
Australia. Industrial Chemical (Notification and Assessment) Act	AICS	Conforms to
Canada. Canadian Environmental Protection Act (CEPA). Domestic Substances List (DSL). (Can. Gaz. Part II, Vol. 133)	DSL	All components of this product are on the Canadian DSL list.
Japan. Kashin-Hou Law List	ENCS (JP)	Conforms to
Korea. Toxic Chemical Control Law (TCCL) List	KECI (KR)	Conforms to

Philippines. The Toxic Substances and Hazardous and Nuclear Waste Control Act	PICCS (PH)	Conforms to
China. Inventory of Existing Chemical Substances	IECSC (CN)	Conforms to
New Zealand. Inventory of Chemicals (NZIoC), as published by ERMA New Zealand	NZIOC	Does not conform

United States – Federal Regulations

SARA Title III – Section 302 Extremely Hazardous Chemicals:
SARA 302: No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA Title III - Section 311/312 Hazard Categories:
No SARA Hazards

SARA Title III – Section 313 Toxic Chemicals:
SARA 313: This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Reportable Quantity (RQ):

The components in this product are either not CERCLA regulated, regulated but present in negligible concentrations, or regulated with no assigned reportable quantity.

OSHA Regulated Carcinogens (NTP, IARC, OSHA Listed):

NTP:
No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.

IARC:
No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

OSHA:
No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

United States – State Regulations

Massachusetts Right to Know

No components are subject to the Massachusetts Right to Know Act.

New Jersey Right to Know

No components are subject to the New Jersey Right to Know Act.

Pennsylvania Right to Know

Chemical Name	CAS-No.
Polymethyl methacrylate copolymers	Proprietary

California Prop. 65
This product does not contain any chemicals known to the State of California to cause cancer, birth defects, or any other reproductive defects.

16. OTHER INFORMATION

Latest Revision(s):

Revised Section(s):	Updated Section 2 and 9
Reference number:	000000036586
Date of Revision:	10/29/2008
Date Printed:	10/29/2008

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GP Batteries

Material Safety Data Sheet For NiMH Batteries

Document Number: RRS0541 Revision: 04 Page 1of 4

IDENTITY (As Used on Label and List) Nickel Metal Hydride Battery	Note: Blank spaces are not permitted if any item is not applicable or no information is available, the space must be marked to indicate that.

Section I – Information of Manufacturer

Manufacturer's Name GPI International Ltd.	Emergency Telephone Number
Address (Number, Street, City State, and ZIP Code) 8/F GP Building, 30 Kwai Wing Road,	Telephone Number for information 852-2484-3333
Kwai Chung, N.T. H.K.	Date of prepared and revision 13th July.2009
	Signature of Preparer (optional)

Section II - Hazardous Ingredients / Identity Information

Hazardous Components:

Hazardous Components:

A) The content of elements are based on homogeneous materials level of NiMH battery:

Element	Lead	Cadmium	Hexavalent Chromium (Cr^{6+})	Mercury	Polybrominated Biphenyls (PBBs)	Polybrominated Diphenyls Ethers (PBDEs)
Limit (mg/kg)	<1000	<100	<1000	<1000	<1000	<1000
CAS no.	7439-92-1	7440-43-9	18540-29-9	7439-97-6	59536-65-1	---

B) The content of elements are based on total weight of NiMH battery:

Element	Lead	Cadmium	Hexavalent Chromium (Cr^{6+})	Mercury	Polybrominated Biphenyls (PBBs)	Polybrominated Diphenyl Ethers (PBDEs)
Limit (mg/kg)	<40	<20	<5	<5	Nil	Nil

Element	Ni(OH)2 (Nickel Hydroxide)	30% KOH Solution (Potassium Hydroxide)	30% NaOH Solution (Sodium Hyroxide)	Non-Hazardous Materials
Limit (wt%)	<30%	<20%	<20%	<30%
CAS no.	12054-48-7	1310-58-3	1310-73-2	---

Section III - Physical / Chemical Characteristics

Boiling Point N.A.	Specific Gravity (H_2O=1) N.A.
Vapor Pressure (mm Hg) N.A.	Melting Point N.A.
Vapor Density (AIR=1) N.A.	Evaporation Rate (Butyl Acetate) N.A.
Solubility in Water N.A.	
Appearance and Odor Cylindrical Shape, odorless	

Section IV – Hazard Classification

Classification

N.A.

Member
Gold Peak Group

Manufacturer reserves the right to alter or amend the design, model and specification without prior notice.

Appendix G3: NiMH battery MSDS

GP Batteries

Material Safety Data Sheet For NiMH Batteries

Section V – Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	

Incompatibility (Materials to Avoid)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry	Inhalation?	Skin?	Ingestion?
	N.A.	N.A.	N.A.

Health Hazard (Acute and Chronic) / Toxiclogical information

In case of electrolyte leakage, skin will be itchy when contaminated with electrolyte.

In contact with electrolyte can cause severe irritation and chemical burns.

Inhalation of electrolyte vapors may cause irritation of the upper respiratory tract and lungs.

Section VII – First Aid Measures

First Aid Procedures

If electrolyte leakage occurs and makes contact with skin, wash with plenty of water immediately.

If electrolyte comes into contact with eyes, wash with copious amounts of water for fifteen (15) minutes, and contact a physician.

If electrolyte vapors are inhaled, provide fresh air and seek medical attention if respiratory irritation develops. Ventilate the contaminated area.

Section VIII - Fire and Explosion Hazard Data

Flash Point (Method Used)	Ignition Temp.	Flammable Limits	LEL	UEL
N.A.	N.A.	N.A.	N.A.	N.A.

Extinguishing Media

Carbon Dioxide, Dry Chemical or Foam extinguishers can be used for battery BUT water extinguisher is not suitable.

Special Fire Fighting Procedures

N.A.

Unusual Fire and Explosion Hazards

Do not dispose of battery in fire - may explode.

Do not short-circuit battery - may cause burns.

GP Batteries

Material Safety Data Sheet For NiMH Batteries

Section IX – Accidental Release or Spillage

Steps to Be Taken in Case Material is Released or Spilled

Batteries that are leakage should be handled with rubber gloves.

Avoid direct contact with electrolyte.

Wear protective clothing and a positive pressure Self-Contained Breathing Apparatus (SCBA).

Section X – Handling and Storage

Safe handling and storage advice

Batteries should be handled and stored carefully to avoid short circuits.

Do not store in disorderly fashion, or allow metal objects to be mixed with stored batteries.

Never disassemble a battery.

Do not breathe cell vapors or touch internal material with bare hands.

Keep batteries between -20°C and 35°C for prolong storage.
When the cells are closed to fully charged, the storage temperature should be between -20°C and 30°C and should be controlled at 10-20˚C during transportation and packed with efficient air ventilation.

Section XI – Exposure Controls / Person Protection

Occupational Exposure Limits: LTEP		STEP
N.A.		N.A.
Respiratory Protection (Specify Type)		
N.A.		
Ventilation	Local Exhausts	Special
	N.A.	N.A.
	Mechanical (General)	Other
	N.A.	N.A.
Protective Gloves		Eye Protection
N.A.		N.A.
Other Protective Clothing or Equipment		
N.A.		
Work / Hygienic Practices		
N.A.		

Section XII – Ecological Information

N.A.

Section XIII – Disposal Method

Dispose of batteries according to government regulations.

Member
Gold Peak Group

Manufacturer reserves the right to alter or amend the design, model and specification without prior notice.

GP Batteries

Material Safety Data Sheet For NiMH Batteries

Section XIV – Transportation Information

GP batteries are considered to be "Dry cell" batteries and are unregulated for purposes of transportation by the U.S. Department of Transportation (DOT), International Civil Aviation Administration (ICAO), International Air Transport Association (IATA) and International Maritime Dangerous Goods Regulations (IMDG). The only DOT requirement for shipping these batteries is special provision 130 which states: "Batteries, dry are not subject to the requirements of this subchapter only when they are offered for transportation in a manner that prevents the dangerous evolution of heat (For example, by the effective insulation of exposed terminals). The only requirements for shipping these batteries by ICAO and IATA is Special Provision A123 which states : "An electrical battery or battery powered device having the potential of dangerous evolutions of heat that is not prepared so as to prevent a short-circuit (e.g. in the case of batteries, by the effective insulation of exposed terminals; or in the case of equipment, by disconnection of the battery and protection of exposed terminals) is forbidden from transportation." The international Maritime Dangerous Goods Code (IMDG) regulate them for ocean transportation under Special Provision 304 which says : Batteries, dry, containing corrosive electrolyte which will not flow out of the battery if the battery case is cracked are not subject to the provision of this Code provided the batteries are securely packed and protected against short-circuits. Example of such batteries are: alkali-manganese, zinc-carbon, sliver oxide, nickel metal hydride and nickel-cadmium batteries which are non-dangerous goods. Such batteries have been packed in inner packaging in such a manner as to effectively prevent short circuit and movement that could lead to short circuit.

Section XV – Regulatory Information

Special requirement be according to the local regulatories.

Section XVI – Other Information

The data in this Material Safety Data Sheet relates only to the specific material designated herein.

Section XVII – Measures for fire extinction

In case of fire, it is permissible to use Carbon Dioxide, Dry Chemical or Foam extinguishers on these batteries or their packing material. Cool exterior of batteries if exposed to fire to prevent rupture.

Fire fighters should wear self-contained breathing apparatus.