Sumo Robots Project Report

Mechatronics – ME 353

Spring 2023

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1. Introduction

Sumo wrestling is a traditional Japanese contact sport where competitors aim to force their opponent out of a circular ring. The sport is highly regulated with strict traditions, rituals, and a ranking system. Sumo Robotics is a modern adaptation of the traditional sport, where autonomous robots push, lift, or maneuver their opponent. The competitions have rules in place to ensure fair play and safety. For example, robots must comply with size and weight limitations, operate autonomously, and have a time limit. They are also not allowed to intentionally damage the opponent robot and have specific electrical requirements such as battery chemistry, motor power draw, and sensor types.

In this version of the sumo robot competition, the objective is for the robot to push its opponent outside of the designated 3ft by 3ft neoprene rubber ring. However, this competition differs from typical sumo robot competitions in several ways. The ring is square instead of circular, and there are three positions in which robots must face each other within the ring. The robots have one minute to locate and push the other robot outside of the ring or agree on a draw.

There are additional constraints specific to this competition, such as a $200 budget limit, a size limitation of 10"x10"x6", and a weight limit of 5 lbs. The robots must also adhere to specific electrical constraints, such as a motor stall current of no more than 4.5A each, battery chemistry of NIMH, NICD, or Alkaline, and a maximum of 14V from AAA, AA, or C cells. The robots are controlled by one or more ATMega8P chips, and external control is prohibited.

The most critical constraints for this competition are the cost and weight restrictions. The cost limit ensures fair competition and prevents any manufacturing related advantages. Meanwhile, the weight restrictions level the playing field by preventing the use of heavier robots and stronger/heavier motors and batteries. Further, motor selection requires a careful balance between having enough power to push opponents while maintaining a lightweight robot.

2. Body

a. Strategy/Design Overview

The general strategy of this sumo robot is to always find and face its opponents with a wedge shape, and then be able to reliably push opponent robots out of the ring. To achieve this, the robot's wedge needs to have near zero clearance between it and the ground. Further, the design specifications regarding power and traction need to be optimized without exceeding weight limits. The goal is to make the most powerful, robust, and reliable robot possible in every aspect. This will involve pushing the limits of power delivery requirements, traction, and wedge design.

To make the most powerful robot, a hefty high power, high current drawing, and high capacity battery is necessary. A NIMH battery pack is the most reliable battery type between the allowable battery chemistries (also rechargeable), and it can supply high amperage without a considerable voltage drop. This means this battery can supply current reliably to all of the motors and electronics, even when motors stall. Thus, to meet the desired power requirement, the robot is powered by two parallel 10 packs of NIMH cells, supplying a nominal 12v.

Another way to push the power limit is to use the highest torque and RPM motors available without surpassing amps, weight, and budget limits. Motors that support 300 or 500RPM are ideal as they will allow the robot to travel around 2-3 feet per second (given 2 inch diameter wheels) while maintaining torque. The 5020 motor, which runs on 12v 500RPM and has a torque at stall of 2kg/cm, satisfies both the RPM and Torque requirement for this robot.

Figure 1: 5020 motor

Maximizing traction is essential for the robot, and to get the most traction, four motors will be used instead of the standard two motors. This means higher traction, but considerably more weight, power usage, and more stress on the chassis. A considerable portion of the budget is reserved to order custom, wide 2 inch Urethane wheels to ensure the best traction possible.

Figure 2: Urethane Wheels

The front of the robot must have the perfect wedge design to ensure it can attack the opponent robot reliably. To maintain a robust and strong structure, the outer frame and chassis are made from thin aluminum sheet metal and light-weight aluminum composite, respectively. The robot must have very little clearance between the ground in the case where both robots are facing each other. To achieve this, a hinge design is applied where constant down force is applied to the beveled hinge (using internal springs) to ensure there is very little clearance between it and the ground. To make sure the robot is always facing the opponent robot with the front wedge, ultrasonic sensors are used to locate the other robot.

b. Mechanical Design

i. Fabrication

Preparations:

The base plate is CNC cut from the 1/8 inch aluminum composite plate and the outer frame parts are laser cut from 22 gauge aluminum sheet metal. Sheet metal joint sections are bent to 90 degrees for the side, front, back, and top plates. The long rectangular pieces are also bent 90 degrees and used as mating surfaces to attach the finished outer frame to the base plate of the chassis. Excessive material is removed from the motor mount steel hinges by center drilling 1.2 inch holes on the steel motor-mount hinges.

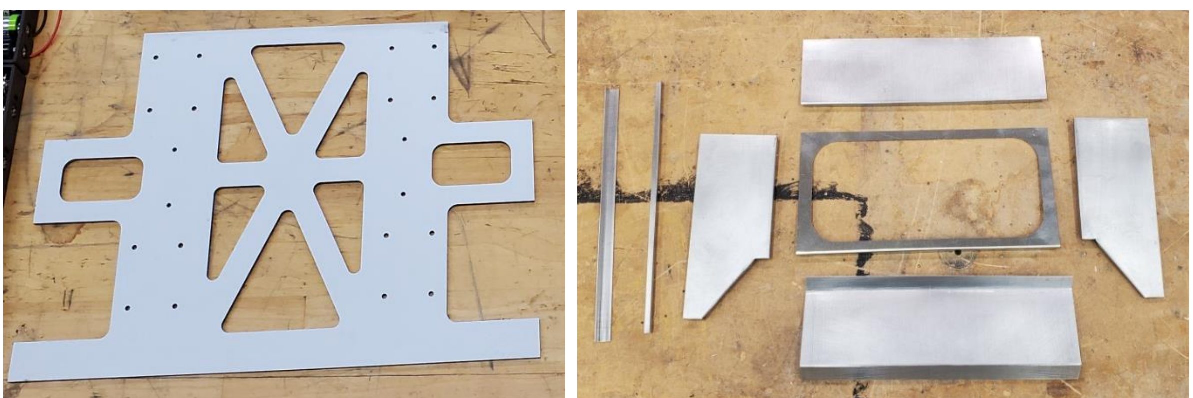
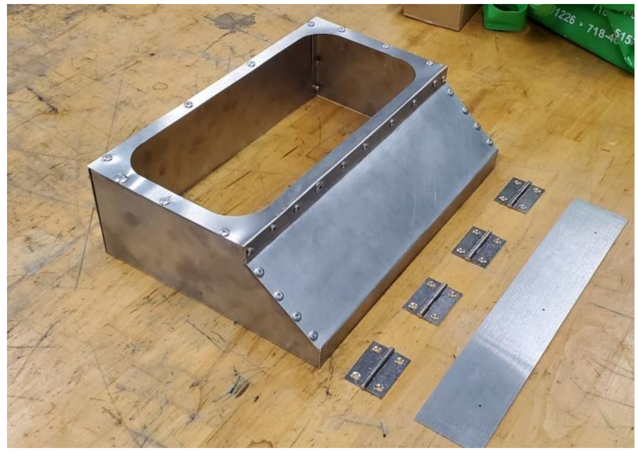
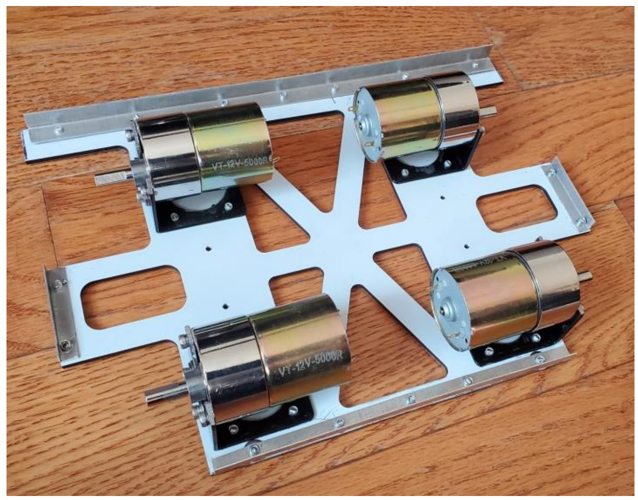


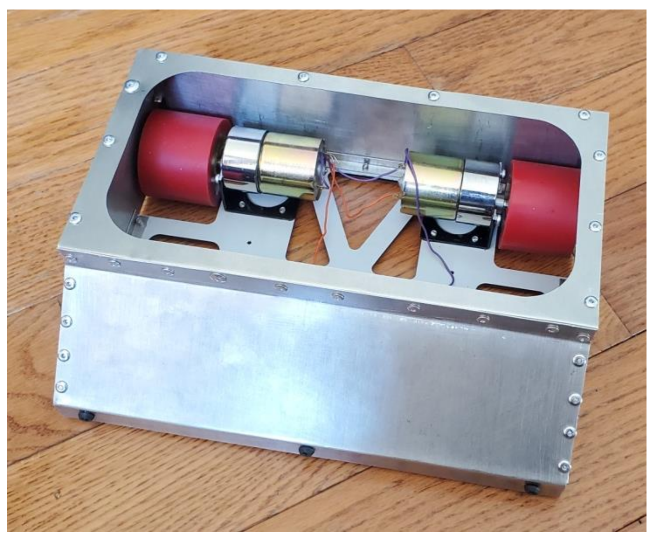
Figure 3: Top left to bottom right: CNC cut base plate, Laser cut and bent sheet metal, original steel brackets, modified steel brackets

Assembly:

The bent laser cut material for the outer frame is assembled using 1/8 inch aluminum rivets. The side panels are riveted together with the front and back frame using 4 equally spaced rivets on each side. The top panel is then riveted to the rest of the robot using 10 equally spaced rivets on the front, 3 equally spaced rivets on each side, and 4 equally spaced rivets on the back.

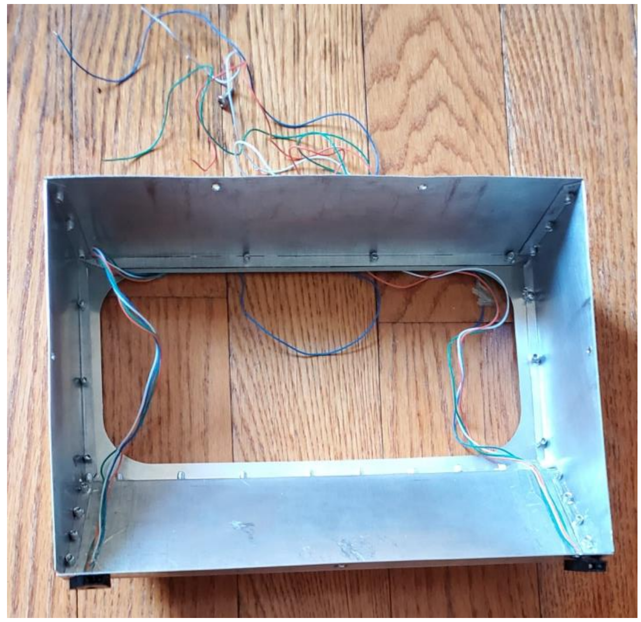




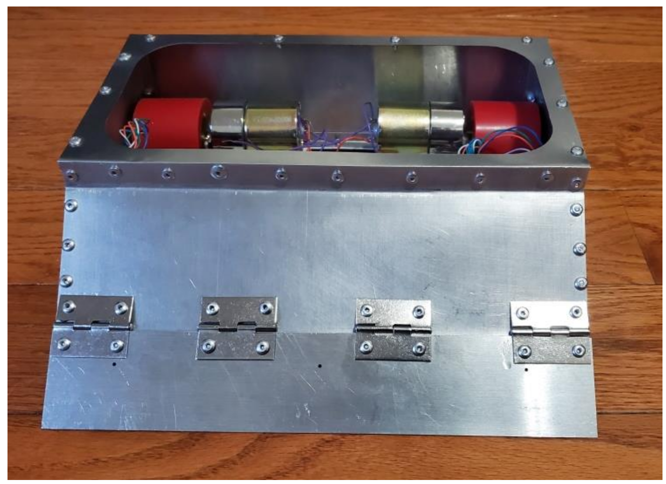


For the chassis base plate construction, the motor mounts are aligned and riveted into the CNC'd holes. Each motor is mounted with four M3 screws to the mount. The long rectangular aluminum pieces fabricated from the 22 gauge sheet metal are cut to size and riveted to the base plate. Their purpose is to add structural strength to the chassis and to provide an attachment point for the outer frame to mate with the chassis. The thicker piece is riveted to the front and thinner to the back since the front is expected to handle more loads. The front bar is riveted with seven rivets equally spaced, while the back uses five. The leftover thin pieces are riveted to the sides of the base plate using two rivets.

Once the chassis and outer frame are constructed, the four urethane wheels are mounted and tightened with a 1/16 inch hex key to the motor shaft keyways. The outer frame is then fixed to the chassis using serrated framing screws instead of rivets in the case where the frame may need to be removed for easy access to chassis. Three equally spaced screws are used on the front, then one on left and right side, and two equally spaced screws on the back.

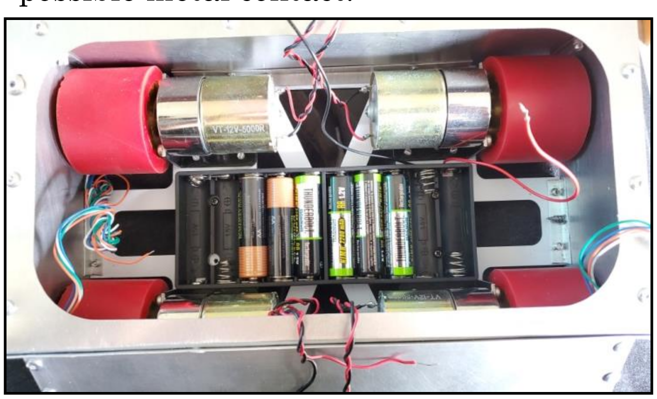


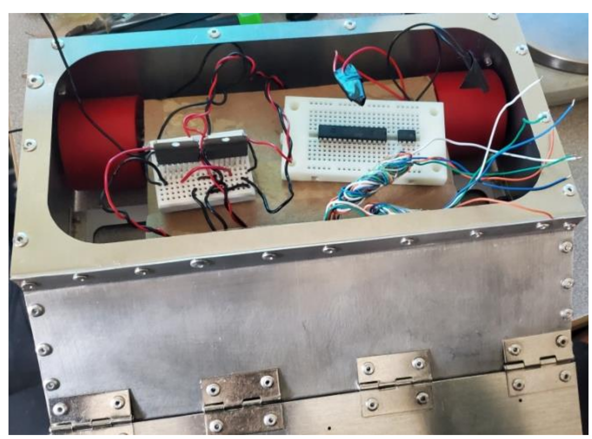
Finally, the front hinged bevel is attached. Before the hinged bevel can be riveted into place, the front left/right IR sensors must be mounted first. Sensors are mounted with screws, and wires are routed through a hole drilled into the frame. Tape is used to secure sensor wires.



Four equally spaced silver hinges are then riveted to the leading edge of the bevel on the outer frame, followed by the laser cut rectangular flange, which is riveted to the four hinges. Three springs are riveted to the hinged flange and then secured to the bottom side of the body of the frame using the 3 serrated screws that also hold the frame to the chassis. This gives constant down force to the hinged flange to ensure zero clearance.

In the final touches, a battery holder box is screwed in place to the base using pre CNC'd holes, and the second battery box is stacked/mounted on top with screws. The ultrasonic sensor is mounted to the front of the robot, and a piece of 5"x8" cardboard is added to insulate electronics from moving parts and possible metal contact.

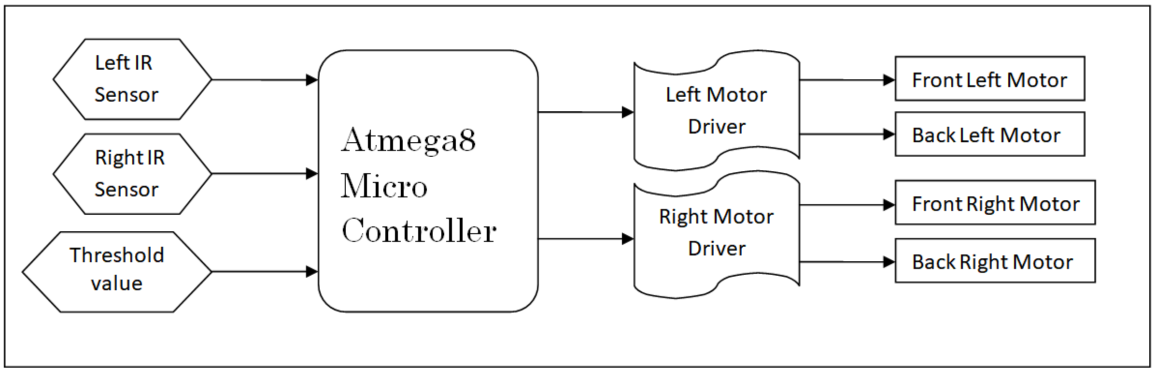




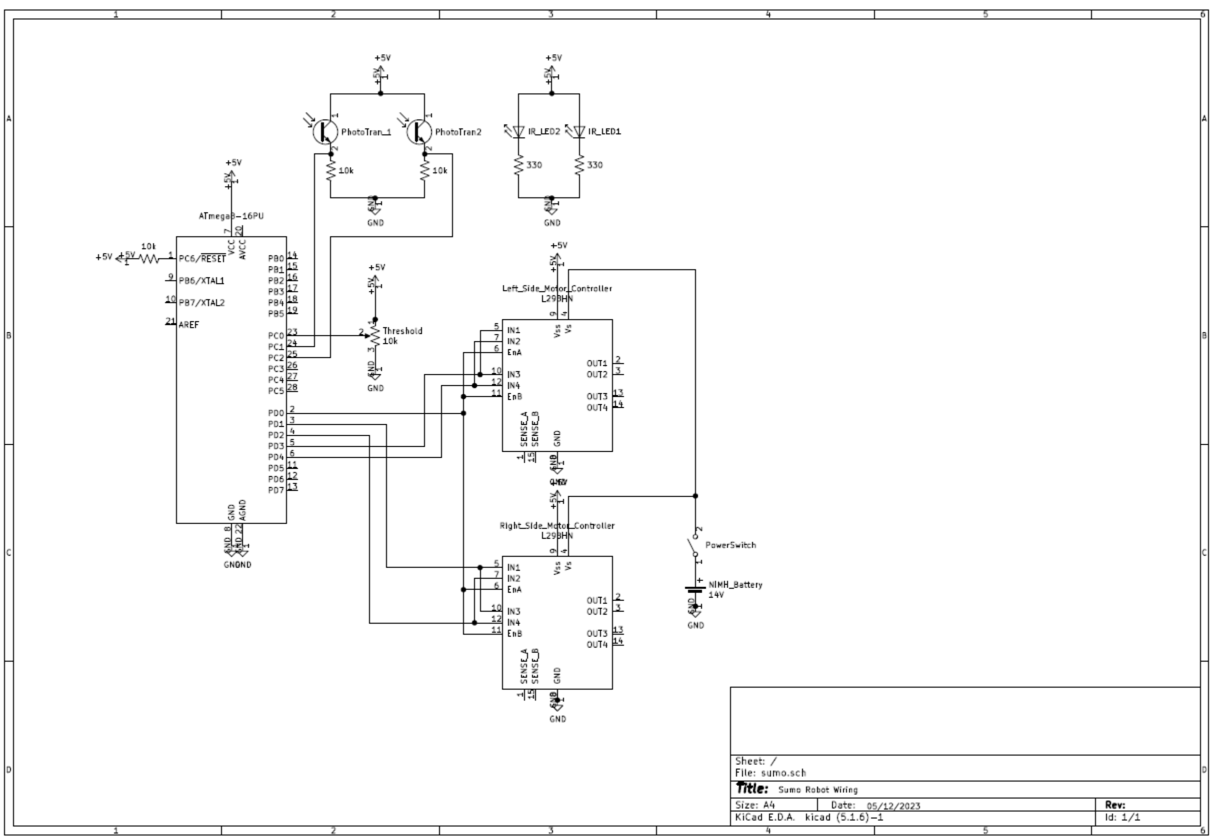
c. Electronics

i. System overview

Below is a block diagram describing the transmission and communication of electrical signals of the sumo robot. The Atmega8 microcontroller listens to input from the left and right IR sensors along with the voltage of the threshold value. Using this, the Atmega8 processor makes the decision of what the binary data to output on PORTD, which is sent to input pins of the Motor Drivers which will either drive their corresponding motors forward, reverse, or brake. Note that each motor driver controls two motors which are either the left or right two motors.



ii. Circuit layout



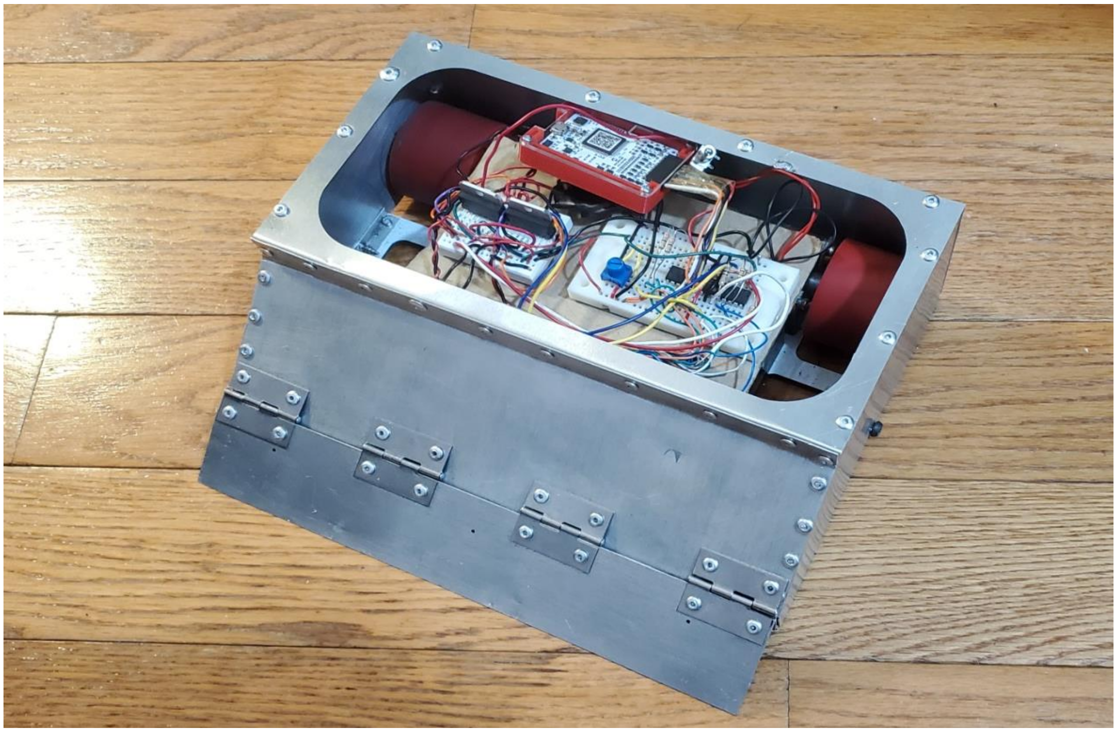


Figure 4: Completed Sumo Robot with Electronics

iii. Algorithm and programming

The code is written in C language and designed to control a sumo robot using only two IR sensors. Therefore, the sumo robot is missing the feature to detect another robot, which is not idea and will be later implemented before competition when time permits.

```c
unsigned int get_ADC( unsigned char );
int main(void){
    unsigned int right_sensor,left_sensor, threshold;
    DDRD = 0xFF;
    PORTD = 0b00001011;//move forward
    threshold = get_ADC(0);

    while(1){
        right_sensor = get_ADC(1);
        if( right_sensor > threshold){
            PORTD = 0b00010101; //move robot backwards momentarily
            _delay_ms(300);
            PORTD = 0b00001101;  //turn left
            _delay_ms(300);
        }

        left_sensor = get_ADC(2);
        if( left_sensor > threshold){

            PORTD = 0b00010101; //move robot backwards momentarily
            _delay_ms(300);
            PORTD = 0b00010011;  //turn right
            _delay_ms(300);
        }
        else {
            PORTD = 0b00001011; //continue forward
            _delay_ms(5);
        }
    }
}
unsigned int get_ADC( unsigned char channel ) {
    ADCSRA = (1<<ADEN)|(1<<ADPS2)|(1<<ADPS1)|(1<<ADPS0);
    ADMUX = (1<<REFS0);
    ADMUX = (ADMUX & 0xF8)|(channel);
    ADCSRA |= (1<<ADSC);
    while( ADCSRA & (1<<ADSC) );
    return ADC;
}
```

Before the main function, the `get_ADC` function is declared which is a function which accepts an ADC channel and returns a 10bit value representing the analog to digital conversion of the channel. The function begins by initializing the ADC by setting the prescaler to 128 (ADPS2:0 bits) and enabling the ADC (ADEN bit). It also sets the reference voltage to AVCC with external capacitor at AREF pin (REFS0 bit) and selects the analog channel by updating the ADMUX register. After starting the ADC conversion by setting the ADSC bit in ADCSRA, the function waits for the conversion to complete by checking the ADSC bit. Finally, it returns the 10-bit ADC result.

The main function starts with initializing the DDRD register to set all pins as output, and then sets the initial direction of the robot to move forward. The threshold value is calculated using the `get_ADC` function, which takes an analog channel number (0 in this case) as input and returns the ADC value.

In the infinite while loop, the code reads the analog values from the right and left IR sensors using the `get_ADC` function and stores them in the `right_sensor` and `left_sensor` variables, respectively. If the value of `right_sensor` is greater than the threshold, it means the robot has reached the edge of the ring on the right side. In this case, the robot backs up by setting `PORTD` to 0b00010101 and waits for 300ms using the `_delay_ms` function. Then it turns left by setting `PORTD` to 0b00001101 and waits for another 300ms.

If the value of `left_sensor` is greater than the threshold, it means the robot has reached the edge of the ring on the left side. In this case, the robot backs up by setting `PORTD` to 0b00010101 and waits for 300ms. Then it turns right by setting `PORTD` to 0b00010011 and waits for another 300ms.

If neither `right_sensor` nor `left_sensor` is greater than the threshold, it means the robot is still within the ring. In this case, the robot continues to move forward by setting `PORTD` to 0b00001011 and waits for 5ms.

Thus the general strategy of this robot is to stay within the ring, and hope that the other sumo robot will not attack, and when the trajectory is right, attack the other robot at random.

3. Discussion

Throughout the fabrication and testing of this robot, many things went to plan, but some things required an additional touch of improvisation and resilience. While build the robot, the first road block was that the weight of the robot was slowly exceeding expectations, so there was a need to use a light breadboard or connect wires directly, not ideal. In the end, we were to save over an ounce by using two smaller breadboards. During the wiring phase, we found that one of the IR sensors was not outputting enough voltage to go over the threshold value. Without knowing this, the robot was constantly triggering on either the left or right IR sensors. We fixed this by replacing the 10k with 15k resistors for the underperforming sensor, which improved the sensor gain substantially. While programming the robot, we found that the robot would over shoot edge boundary and turn back too late, we later diagnosed that the else statement gave too much time to "move forward" command (300ms) assuming no sensors were triggered, this meant each time the loop ran, it was only 300ms at a time. Another code performance fix was to do the ADC of right sensor followed by immediate testing of instead of running ADC of both left and right sensors at the same time, which are time heavy operations and slow down robot reaction time. The robot reaction time and code speed are very important considering the robot was the fastest robot in the ring. We were unable to implement ultrasonic sensor support but intend to do so before the competition.

4. Conclusions

Based on the design and strategy overview, as well as the mechanical design, the sumo robot performed well and met its target. The robot's wedge was designed to have near-zero clearance between it and the ground, ensuring that the robot could reliably push opponent robots out of the ring. The power delivery requirements, traction, and wedge design were optimized without exceeding the weight limits, ensuring that the robot remained within the competition's guidelines. The use of a NIMH battery pack and 5020 motor, along with the custom, wide 2 inch Urethane wheels, maximized the robot's power and traction. Additionally, the robot's front wedge had the perfect design, with a hinge design to maintain constant downforce so that it would not lose when it came to face to face combat. The mechanical design of the robot was well-executed, with the use of CNC and laser cutting and riveting to assemble the outer frame and chassis. Overall, the robot's performance in the competition demonstrated its ability to meet the design and task requirements, making it a success.

5. Appendices

i) Parts List

Items	Vender	Contact	Price
4	Amazon	www.amazon.com	77.47
4	FingerTech	www.fingertechrobotics.com	47.72
1	Harbor Freight	www.harborfreight.com	6.99
1	Home Depot	www.homedepot.com	6.92
1	SPSIndustrial	www.spsindustrial.com	11.40
		Total	150.50

ME 353 - Mechatronics
Cost Report: Amazon
Team Pencil-Pusher: Ahmad Malik

Vender	
	Amazon
	https://www.amazon.com/
	1-888-280-4331

Quantity	Part Number	Description	Price	Extension
1	B07TXZ2L2Q	Pxyelec 1.5 inch Stainless Steel Folding Butt Hinge	7.99	7.99
4	9123K31	520 High Torque Micro Brush DC Gear Reduction Motor Eccentric Shaft Gearbox Diameter 37 (12 Volt, 500RMP)	12.99	51.96
1	B07Z9ZB5NC	Rustark 4 Pcs 37mm Diameter DC Gear Motors Mounting Bracket Black Rust Resistance	10.98	10.98
2	BHAA10F	Jex Electronics Ten/10X AA DIY Flat Battery Holder Case Box Base 15V/12V Volt Bare Wire Ends, BHAA10F	2.39	4.78
1	B00004WLKB	Gardner Bender GSW-17 Electrical Toggle Switch, SPST, ON-OFF, 6 A/120V AC, Screw Terminal	1.76	1.76
1	B07QJ6YNS8	Arrow RSA1/8IP Short Aluminum 1/8-Inch Rivets, 100-Pack	6.48	6.48
			Total	77.47

ME 353 - Mechatronics
Cost Report: FingerTech
Team Pencil-Pusher: Ahmad Malik

Vender	
	FingerTech
	www.fingertechrobotics.com
	N/A

Quantity	Part Number	Description	Price	Extension
4	ft-sumo-wheel-2.00	FingerTech Urethane Sumo Wheel 2.00 inches	11.93	47.72
			Total	47.72

ME 353 - Mechatronics
Cost Report: Harbor Freight
Team Pencil-Pusher: Ahmad Malik

Vender	
	Harbor Freight
	https://www.harborfreight.com
	1 (800) 423-2567

Quantity	Part Number	Description	Price	Extension
1	64490	AA Alkaline Batteries, 24 Pack	6.99	6.99
			Total	6.99

ME 353 - Mechatronics
Cost Report: Home Depot
Team Pencil-Pusher: Ahmad Malik

Vender	
	Home Depot
	https://www.homedepot.com
	1 (800) 430-3376

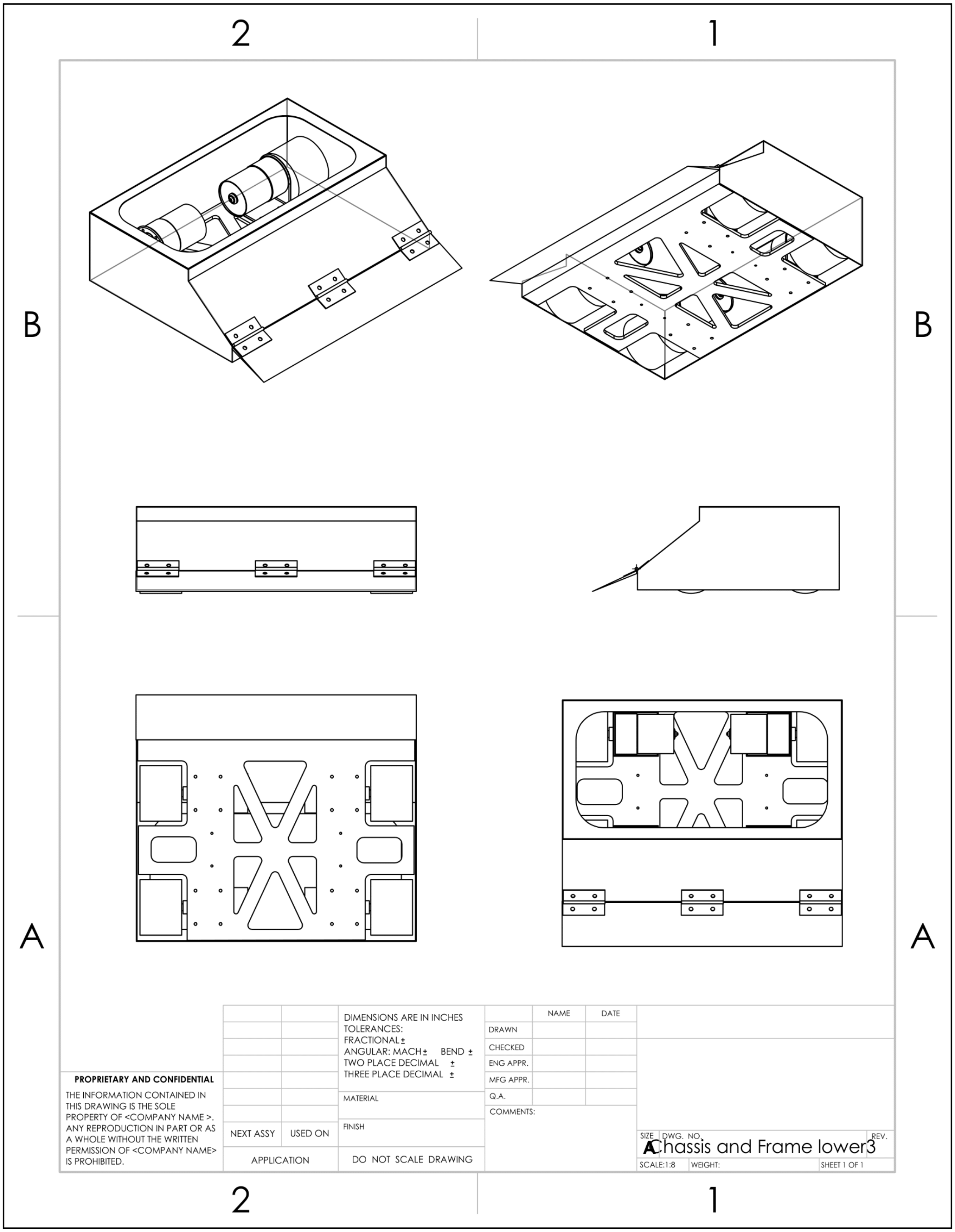
Quantity	Part Number	Description	Price	Extension
1	ACM-WT-1-8/1212	12 in. x 12 in. x 1/8 in. Thick Aluminum Composite ACM White Sheet	6.92	6.92
			Total	6.92

ME 353 - Mechatronics
Cost Report: SPSIndustrial
Team Pencil-Pusher: Ahmad Malik

Vender	
	SPSIndustrial
	www.spsindustrial.com
	321-251-8156

Quantity	Part Number	Description	Price	Extension
1	9426065	0.025 Inch Thick x 12 Inch Wide x 24 Inch Long, Aluminum Sheet	11.40	11.40
			Total	11.40

ii) CAD Drawings



iii)Circuitry Specifications

37GB-520-12V-500R

Product parameters			
Voltage	Deprating Range	V/DC	12V-24V
	Voltage	V/DC	12V
AT NO LOAD	Speed	r/min	500
	Current	A	0.3
AT MAXINUM EFFICENCY	Efficiency	%	no
	Speed	r/min	475
	Current	A	0.6
	Torque	g.cm	800
	Output	W	7
AT MAX POWER	Output	W	10
	Speed	r/min	7
	Current	A	1.5
	Torque	g.cm	1000
AT STALL	Torque	g.cm	2000
	Current	A	2.19

Figure 5: 5020 motor specifications

Motors

- Motors may not have a stall current of more than 4.5A (each).
  - **NOTE**: Stall current must be documented.

Power supply

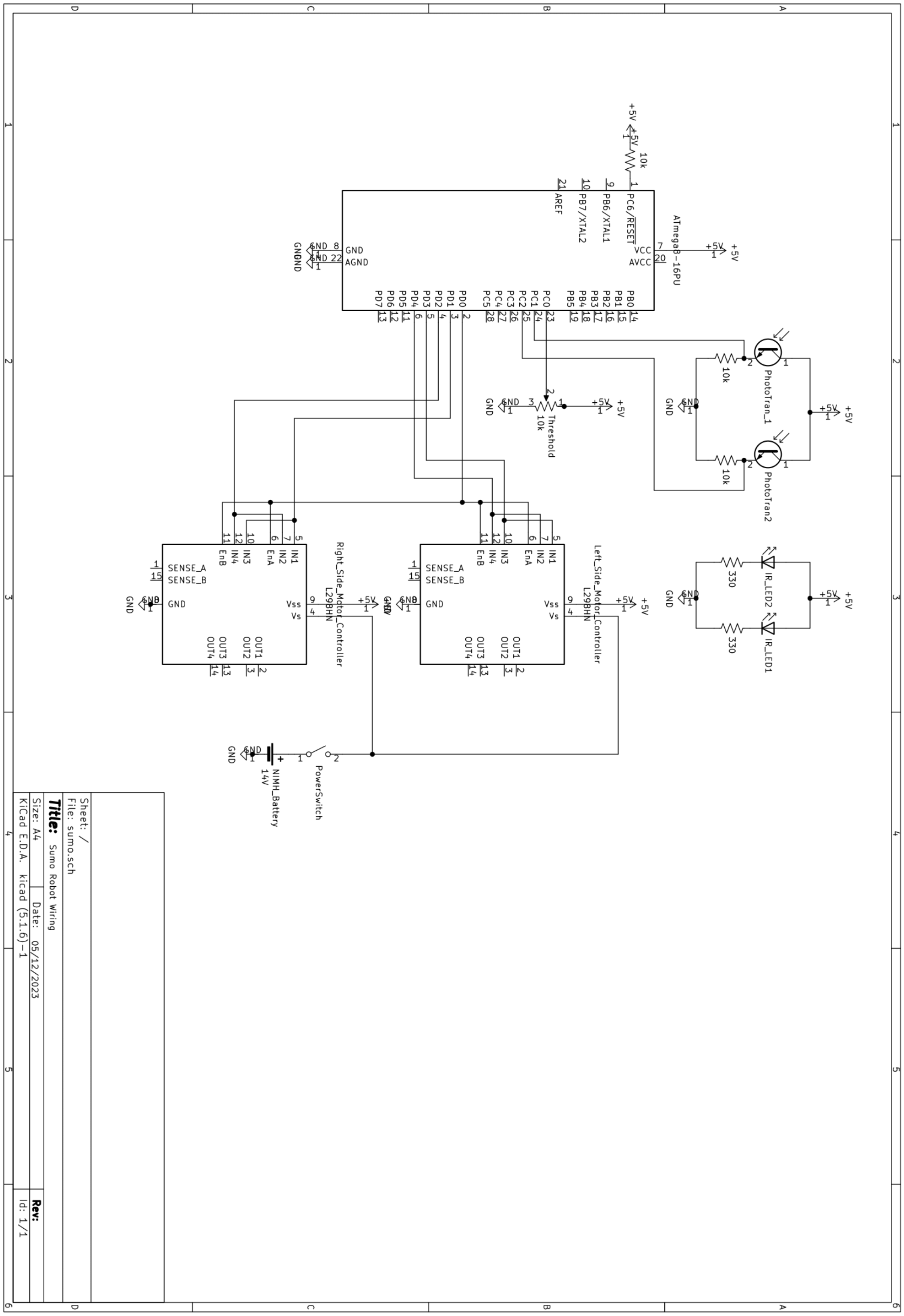
- The motor power supply must be a combination of AAA, AA or C cells, providing a maximum of 14V (they must be NiCd or NiMH).
- The power supply for electronics may be at the team's discretion, and may feed from the same power supply as the motors.

Electronics

- The robot must be controlled by one or more ATMega328P. No other programmable chip is allowed.
- The robot will sense the border of the ring with one or more supplied IR sensors.
- The robot may (though not necessarily) employ additional sensors, a LIDAR sensor will be included in the kits – any additional sensors must be accounted for in the total cost.
- No external control of any sort is allowed.
- The robot MUST have an easy to access kill-switch. This MUST cut ALL current to ALL parts (motors, electronics, logic etc.)

Figure 6: Electrical Restrictions for Sumo Robot

iv) Circuit Diagrams



v) Code

```
...s\Atmel Studio\7.0\XC8Application1\XC8Application1\main.c                    1
/*
 * main.c
 *
 * Created: 05/06/2023 6:48:27 PM
 *  Author: Ahmad M
 */


#include <xc.h>
#include <avr/io.h>
#include <util/delay.h>

unsigned int get_ADC( unsigned char );
int main(void){
    unsigned int right_sensor,left_sensor, threshold;
    DDRD = 0xFF;
    PORTD = 0b00001011;//move forward
    threshold = get_ADC(0);

    while(1){
        right_sensor = get_ADC(1);
        if( right_sensor > threshold){
            PORTD = 0b00010101; //move robot backwards momentarily
            _delay_ms(300);
            PORTD = 0b00001101;  //turn left
            _delay_ms(300);
        }

        left_sensor = get_ADC(2);
        if( left_sensor > threshold){

            PORTD = 0b00010101; //move robot backwards momentarily
            _delay_ms(300);
            PORTD = 0b00010011;  //turn right
            _delay_ms(300);
        }
        else {
            PORTD = 0b00001011; //continue forward
            _delay_ms(5);
        }
    }
}
unsigned int get_ADC( unsigned char channel ) {
    ADCSRA = (1<<ADEN)|(1<<ADPS2)|(1<<ADPS1)|(1<<ADPS0);
    ADMUX = (1<<REFS0);
    ADMUX = (ADMUX & 0xF8)|(channel);
    ADCSRA |= (1<<ADSC);
    while( ADCSRA & (1<<ADSC) );
    return ADC;
}
```

vi) MSDS.

Article Information Sheet (AIS)

DURACELL

This Article Information Sheet (AIS) provides relevant battery information to retailers, consumers, OEMs and others users requesting a GHS-compliant SDS. Articles, such as batteries, are exempt from GHS SDS classification criteria. The GHS criteria is not designed or intended to be used to classify the physical, health and environmental hazards of an article. Branded consumer batteries are defined as electro-technical devices. The design, safety, manufacture, and qualification of branded consumer batteries follow ANSI and IEC battery standards. This document is based on principles set forth in the following hazard communication approaches: ANSI Z-400.1, GHS, JAMP AIS, IEC 62474, and ANSI C18.4M.

1. Document Information	
Document Name	**Duracell Nickel Metal Hydride (NiMH) Rechargeable Batteries** **Duracell Nickel Metal Hydride (NiMH) Rechargeable Batteries packaged with/in equipment (Duracell chargers/devices)**
Document ID	AIS-NiMH
Issue Date	15-Jan-20
Version	6.a
Preparer	Product Safety & Regulatory
Last Revision	12/7/2022
Information Contact	SDS@duracell.com
2. Company Information	
NA Name & Address	Duracell US Operations, 14 Research Drive, Bethel, CT USA 06801. Duracell Batteries BV, Nijverheidslaan 7, 3200 Aarschot, Belgium. Duracell International Operations Sàrl, Rue du Pré-de-la-Bichette 1, CH-1202, Geneva, Switzerland.
Telephone	(203) 796- 4000
Global Website	www.duracell. com
Consumer Relations: NA	North America: 1-800-551-2355 (9:00 AM - 5:00 PM EST)
Consumer Relations	**Latin America** (Brazil)0800-727-1165, (Mexico) 1800-283-2901, (Chile)188-800-224 488, (Rest of Latin America) duracell.mx.help. **Europe** (UK) 0800 716434, (FR) 0800 346 790 (Service & appel gratuits), (IRL) 1 800 509 176, (DE) 800 101 2112, (AT) 0800 1025 1956, (CH) 0800 000 885, (BE) 0800 509 95, (NL) 0800 265 8616, (IT) 800 125 662, (ES) 900 800 522, (PT) 800 781 012, (GR) 210 66 75 000, (CY) 22-210900, (DK-FI-NO-SE) +46 8 799 1926, (NO) 63791957, (ZA) 0800980782, (RO) 021 3361915, (IS) +354 5222700, (MD) +373 0800700 88, (BG) 02 40 24 500, (BIH) 033756000, (MNE) 020261920, (PL) 00800 77628282, (LT) +370 656 40111, (LV) +371 670 48400, (EE) +3726505555, (CZ) +420 233 325 614, (SK) +42153419601, (HU) 0620 770 7099, (HR) 0800 0009, (SI) 01/588 6800, (AZ) 99412 5990511, (UA) +380444909771 (ПрАТ "САВ 92) & +380442476704 (ТОВ «ІНВЕСТКОМ»), (KZ) +7 727 250 05 50, (TM) 00865 530070, (KG) 0312 41 77 04 (Apple City International), (TR) 0 850 502 61 40, (BG)02/40 24 500, (BIH) 38733756000, (UZ) 998 900123313 **Asia** (CN) 4008850883, (HK) 800-969-950, (TW) 0800-251-122, (AU) 1-800-239901, (NZ) 0800-44-6869, (KP) 080-393-3000, (SG) 800-120-5608, (TH) 001 800 852 6595, (VN) 120 11543, (MY) 1-800-81-5379, (ID)001-803-0167294, (PH) 1-800-1110-1392, (IN) 1800-120-7897

AIS-NiMH 1 of 6

Article Information Sheet (AIS)

DURACELL

3. Article Information	
Description	Duracell branded consumer nickel metal hydride rechargeable batte
Product Category	Electro-technical device
Use	Portable power source for electronic devices
Global sub-brands (Retail)	**RECHARGEABLE**
Sizes	AA, AAA, C, D & 9V
IEC Designations	HR6, HR03, HR9V, HR14, HR20
Principles of Operation	A battery powers a device by converting stored chemical energy into electrical energy.
4. Article Construction	
Applicable Battery Industry Standards	ANSI C18.2M Part 1, ANSI C18.2M Part 2, ANSI C18.4, IEC 61951-2, IEC 62133
Electro-technical System	Nickel Metal Hydride
Anode (Electrode - Negative)	Metal hydride contains iron, nickel & cobalt
Cathode (Electrode - Positive)	Nickel hydroxide (CAS# 12054-48-7)
Electrolyte	Alkali Metal Hydroxide (aqueous potassium hydroxide - CAS # 1310-58-3)
Materials of Construction - Can	Nickel Plated Steel
Declarable Substances (IEC 62474 Criteria 1)	None - See Section 10b (EU REACH ANNEX XVII) of this document (page 4)
Mercury Free Battery (ANSI C18.4M <5ppm)	Yes
Small Cell or Battery (ANSI C18.1M Part 2; IEC 60086-5)	Size AAA fits inside a specially designed test cylinder 2.25 inches (57.1mm) long by 1.25 inches (31.70 mm) wide.
5. Health & Safety	
Ingestion/Small Parts Warning	Required for Battery Size AAA: Keep away from children. If swallowed, consult a physician immediately.
Normal Conditions of Use	Exposure to contents inside the sealed battery will not occur unless the battery leaks, is exposed to high temperatures, or is mechanically abused.
Note to Physician	A damaged battery will release concentrated and caustic potassium hydroxide.
First Aid - If swallowed	Do not induce vomiting. Seek medical attention immediately. For information on treatment, call 24-Hour National Battery Ingestion Hotline (telephone number below).
24-Hour National Battery Ingestion Hotline	USA/CANADA CALLS ONLY:: 800-498-8666
Poison Centers - World Directory	http://globalcrisis.info/poisonemergency.html#AAA
First Aid - Eye Contact	Flush with water for at least 15 minutes. Seek medical care if irritation persists.
First Aid - Skin Contact	Remove contaminated clothing. Wash skin with soap and water. Seek medical care if irritation persists.
First Aid - Inhalation	Remove to fresh air.

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Battery Safety Standards & Testing	Duracell batteries meet the requirements of ANSI C18. 2M Part 2; IEC 61951-2, and IEC 62133. These standards specify tests and requirements for alkaline batteries to ensure safe operation under normal use and reasonably foreseeable misuse. The test regimes assess three conditions of safety. These are: **1-Intended use simulation:** Partial use, vibration, thermal shock, and mechanical shock **2-Reasonably foreseeable misuse:** Incorrect installation, external short-circuit, free fall (user-drop), over-discharge, and crush **3-Design consideration:** Thermal abuse, mold stress
Precautionary Statements	(For AAA & Smaller) "CAUTION: Keep batteries away from children. If swallowed, consult a physician at once. For information on treatment, call (202) 625-3333 collect." (All sizes)" CAUTION: Never use different battery brands, types, capacities, or systems at the same time. For proper insertion, please observe pole indications (+/-). Duracell battery charger recommended. Keep batteries away from fire, or explosion may occur."
6. Fire Hazard & Firefighting	
Fire Hazard	Batteries may rupture or leak if involved in a fire.
Extinguishing Media	Use any extinguishing media appropriate for the surrounding area.
Fires Involving Large Quantities of Batteries	Large quantities of batteries involved in a fire will rupture and release caustic potassium hydroxide. Firefighters should wear self-contained breathing apparatus and protective clothing.
7. Handling & Storage	
Handling Precautions	Avoid mechanical and electrical abuse. Do not short circuit or install incorrectly. Batteries may rupture or vent if disassembled, crushed, recharged or exposed to high temperatures. Install batteries in accordance with equipment instructions.
Storage Precautions	Store batteries in a dry place at normal room temperature. Refrigeration does not make them last longer.
Spills of Large Quantities of Loose Batteries (unpackaged)	Notify spill personnel of large spills. Irritating and flammable vapors may be released from leaking or ruptured batteries. Spread batteries apart to stop shorting. Eliminate all ignition sources. Evacuate area and allow vapors to dissipate. Clean-up personnel should wear appropriate PPE to avoid eye and skin contact and inhalation of vapors or fumes. Increase ventilation. Carefully collect batteries and place in appropriate container for disposal. Remove any spilled liquid with absorbent material and contain for disposal.
8. Disposal Considerations (GHS Section 13)	
Collection & Proper Disposal	Dispose of used (or excess) batteries in compliance with federal, state/provincial and local regulations. Do not accumulate large quantities of used batteries for disposal as accumulations could cause batteries to short-circuit. Do not incinerate. In countries, such as Canada and the EU, where there are regulations for the collection and recycling of batteries, consumers should dispose of their used batteries into the collection network at municipal depots and retailers. They should not dispose of batteries with household trash.

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USA EPA RCRA (40 CFR 261)	Nickel metal hydride rechargeable batteries are considered RCRA Universal Waste as long as they are recycled. In some states (California, New York, Minnesota, and Maine) Nickel metal hydride batteries must be recycled by state law.
California Universal Waste Rule (Cal. Code Regs. Title 22, Div. 4.5, Ch. 23)	California prohibits disposal of batteries as trash (including household trash).
9. Transport Information (GHS Section 14)	
Regulatory Status	NiMH cells and batteries are not listed or regulated as dangerous goods under IATA Dangerous Goods Regulations, ICAO Technical Instructions, UN Model Regulations, U.S. Hazardous Materials Regulations (49 CFR), and UNECE ADR.
UN Identification Number/ Shipping Name	UN3496 - Batteries, Nickel Metal Hydride
Special Provision (SP) Conformance	Special regulatory provisions require batteries to be packaged in a manner that prevents the generation of a dangerous quantity of heat and short circuits. Shippers can prepare batteries by taping the terminals, individually packaging batteries, or otherwise segregating the batteries to prevent risk of creating a short circuit. Batteries shipped in original unopened Duracell packaging is compliant.
Internation Maritme Dangerous Goods (IMDG)	CODE: UN-3496, SP-117 & SP-963 [2020 EDITION]
IMDG Packing Instructions	According to IMDG, NiMH batteries are not considered dangerous goods if the total gross weight of NiMH batteries charged in one transport unit is less than 100 kg. If the total gross weight of NiMH batteries loaded in one transport unit is 100 kg or more, the following requirements must be met: 1) A transport document for transportation of dangerous goods by sea (IMO declaration) must be issued and accompany the goods during sea transportation. 2) The goods must be described in the IMO declaration as follows UN3496 BATTERIES, NICKEL-METAL HYDRIDE, 9; EMS: F-A, S-I
US DOT SP	49 CFR 172.102 Special Provisions 130 and 340
AITA 64th Edition, ICAO - Air Transport (IATA/ICAO) SP	A123, A199
Emergency Transportation Hotlin	**CHEMTREC 24-Hour Emergency Response Hotline** **Within the United States call +703-527-3887** **Outside the United States, call +1 703-527-3887 (Collect)**
10. Regulatory Information (GHS Section 15)	
10a. Battery Requirements	
USA EPA Mercury Containing & Rechargeable Battery Management Act of 1996	During the manufacturing process, no mercury is added.

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EU Battery Directive 2006/66/EC & amendment 2013/56/EU	Compliant with marking and substance restrictions for mercury (<0.0005%); cadmium (<0.0020%)l and lead (<0.0040%). Global labels are marked with the special collection symbol and the EU qualifier in accordance with EU Battery Directive 2006/66/EC, Article 11, Paragraph 1 on batteries and accumulators and waste batteries and accumulators (Annex II).
10b. General Requirements	
USA CPSIA 2008 (PL. 11900314)	Exempt
USA CPSC FHSA (16 CFR 1500)	Consumer batteries are not listed as a hazardous product.
USA EPA TSCA Section 13 (40 CFR 707.20)	For customs clearance purpose, batteries are defined as an "Article
USA EPA RCRA (40 CFR 261)	Nickel metal hydride rechargeable batteries are considered RCRA Universal Waste as long as they are recycled. In some states (California, New York, Minnesota, and Maine) Nickel metal hydride batteries must be recycled by state law.
California Prop 65	No warning required per 3rd party assessment.
CANADA Products Containing Mercury Regulations SOR/20140254	Mercury free
EU REACH REGULATION (EC) NO. 1907/2006	Regulated as an "article." No listed substances are present (>0.1% w/w) in accordance with ECJ article definition of 10 September 2015. If needed, a declaration (DoC) confirming the current SVHC Candidate List can be downloaded from the Duracell web site (https://www.duracell.com/en-us/for-business/) Folder: "Environmental & Regulatory."
EU REACH Annex XVII	The use of nickel in batteries does not meet the conditions of restriction described for Annex XVII Item #27 - Nickel. The use restriction applies for articles intended to come into direct and prolonged contact with the skin, specifically pierced earring posts and other types of jewelry.
EU REACH Article 31	SDS is not required consumer alkaline batteries.
10c. Regulatory Definitions - Articles	
USA OSHA	29 CFR 1910.1200(b)(6)(v)
USA TSCA	40 CFR 704.3; 710.2(3)(c); and [19 CFR 12.1209a)]
EU REACH	Title 1 - Chapter 2 - Article 3(3)
GHS	Section 1.3.2.1
11. Other Information	
AIS Hazard Communication Approaches (consulted in developing this document):	
Globally Harmonized System (GHS)	GHS SDS requirements and classification criteria do not apply to articles or products (such as batteries) that have a fixed shape, which are not intended to release a chemical. The article exemption is found in Section 1.3.2.1.1 of the GHS and reads: ***The GHS applies to pure substances and their dilute solutions and to mixtures. "Articles" as defined by the Hazard Communication Standard (29 CFR 1900.1200) of the OSHA of the USA, or by similar definition, are outside the scope of the system."***

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Joint Article Management Promotion Consortium JAMP	JAMP is a Japanese Industry Association who developed the concept of an Article Information Sheet as a supply chain tool to share and communicate chemical information in articles. The AIS authoring process is based on "declarable" substances to meet global regulatory requirements as well as substances to be reported by GADSL, JIG, etc.
IEC 62474 Ed. 1.0 B:2012 Material Declaration for Products of and for the Electro-technical Industry	An international standard that came into effect in March 2012 concerning declaration for electrical and electronic products. IEC 6274 replaces the defunct Joint Industry Guide – Material Declaration for Electro-technical Products (JIG-101-Ed 4.1 (May 21, 2012)
IEC 62474 Database - Publically available online (maintained by TC11: Environmental Standardization for electrical and electronic products and systems.	The general principle for a substance to be included in the database as a declarable substance is: 1) existing national laws or regulations in an IEC member country that are relevant to Electro-technical products and that prohibit or restrict substances, or that have a labeling, communication, reporting or notification requirement, and 2) applying IEC 62474 criteria results in identification of declarable substance.
ANSI C18.4M-2017 Portable Cells and Batteries - Environmental	This standard provides regulatory guidance and a template to author an article information sheet for a portable consumer battery. See Annex (Informational) C.2 Safety Data Sheets and Annex E (Informative) E.2 General.
ANSI Z 400.1/Z19.1 (2010)	2.1 Scope: Applies to preparation of SDSs for hazardous chemicals used under occupational conditions. Does not address how the standard may be applied to articles. It presents basic information on how to develop and write a SDS. Additional information is provided to help comply with state and federal environmental and safety laws and regulations. Elements of the standard may be acceptable for International use.

DISCLAIMER: This AIS is intended to provide a brief summary of our knowledge and guidance regarding the use of this material. The information contained here has been compiled from sources considered by Duracell to be dependable and is accurate to the best of the Company's knowledge. It is not meant to be an all-inclusive document on worldwide hazard communication regulations. This information is offered in good faith. Each user of this material needs to evaluate the conditions of use and design the appropriate protective mechanisms to prevent employee exposures, property damage or release to the environment. Duracell assumes no responsibility for injury to the recipient or third persons or for any damage to any property resulting from misuse of the product.

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6. Bibliography

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