FOLLOWBOT

Group 6

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Motivation

- The FollowBot was a creation of our desire to make travel easier and streamlined
- Airports, grocery stores, indoor malls, and beaches alike beckon for an easy to use motorized assistant
- The search for convenience for the lazy and ability for the disabled brought abot the design and product choices we made
- After careful considerations to each market, we specifically chose and implemented several technologies specifically built for indoor tracking and use

Project Goals & Objectives

- Cart to be able to autonomously follow User
- Be able to detect objects or obstructions and stop (collision detection)
- Mobile application to interface with cart via Bluetooth
- The most accurate Bluetooth Localization possible

SPECIFICATIONS AND REQUIREMENTS

Component	Parameter	Design Specification
Collision Detection	Range	3 feet
Motors	Speed	>1.5 mph
Battery	Charge Time	3 hours
Battery	Discharge Time	5 hours
Positioning	Accuracy	<1.5 meter
Chassis	Weight	<30 lbs
Motors	Carry Weight	<10 lbs

DISTRIBUTION OF WORK

TASK	Primary	Secondary
Bluetooth Localization(Positioning)	David	Abhinav
Object Avoidance & Pathing	Abhinav	David
PCB Design & Circuitry	Adil	Carlos
Construction & Motor System	Carlos	Adil

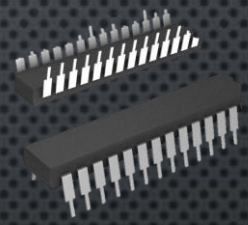
Part Selection

- Movement Systems: Motors, Wheels, Motor Controllers
- Collision Detection: Sensors
- Positioning: Bluetooth Modules, Beacons
- Power System: Battery
- Main: Microcontroller

MICROCONTROLLER CHOICE

MCU Solution	Cost	Active Power Consumption	Bluetooth?	Community	Development
MSP 432	~$10	80uA/MHz	Add-on	Good	Fair
ATMega328p	~$25	20mA/MHz	Add-on	Excellent	Quite Easy
BB Black	~$55	460mA/MHz	Onboard	Average	Easy
Raspberry Pi 2	~$40	240mA/MHz	Onboard	Excellent	Easy

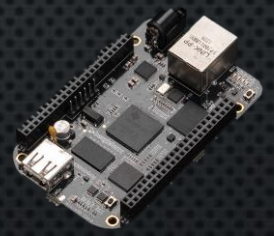
ATMega328p



TI MSP432

Raspberry Pi 2

BeagleBone Black



Microcontroller Choice (Continued)

- Came down to two major microcontrollers (ATMega328p & MSP432)
- Both offered efficient and effective solutions to our design
- Chose a more reliable microcontroller (ATMega) for our software development path to ensure better code and stability
- Arduino offers plenty of online resources which make development as well as debugging much easier for the programmers

ULTRASONIC SENSORS

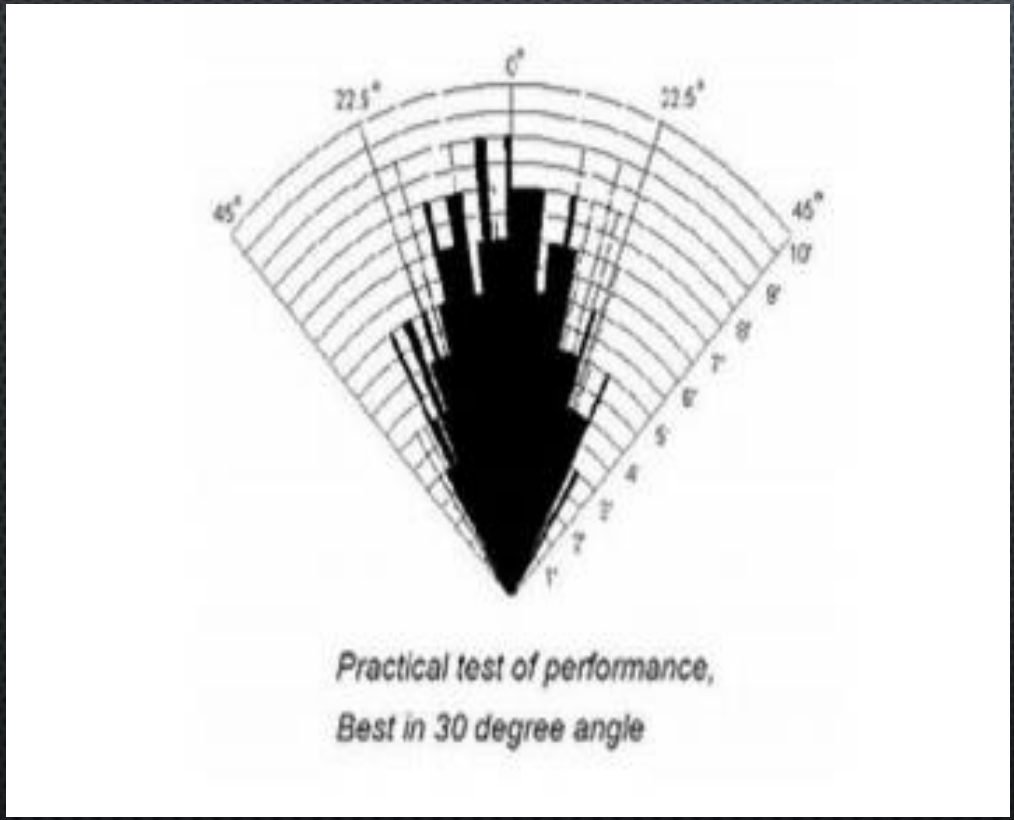
Sensor	Range	Cost	Resolution	Support
HC-SR04	2cm – 400cm	$2.95	4cm	Little to none
LV-EZ3	0cm – 645cm	$24.95	2.5cm	Good
**PING))) **	2.5cm – 304cm	$29.99	4cm	Excellent

WHY ULTRASONIC?

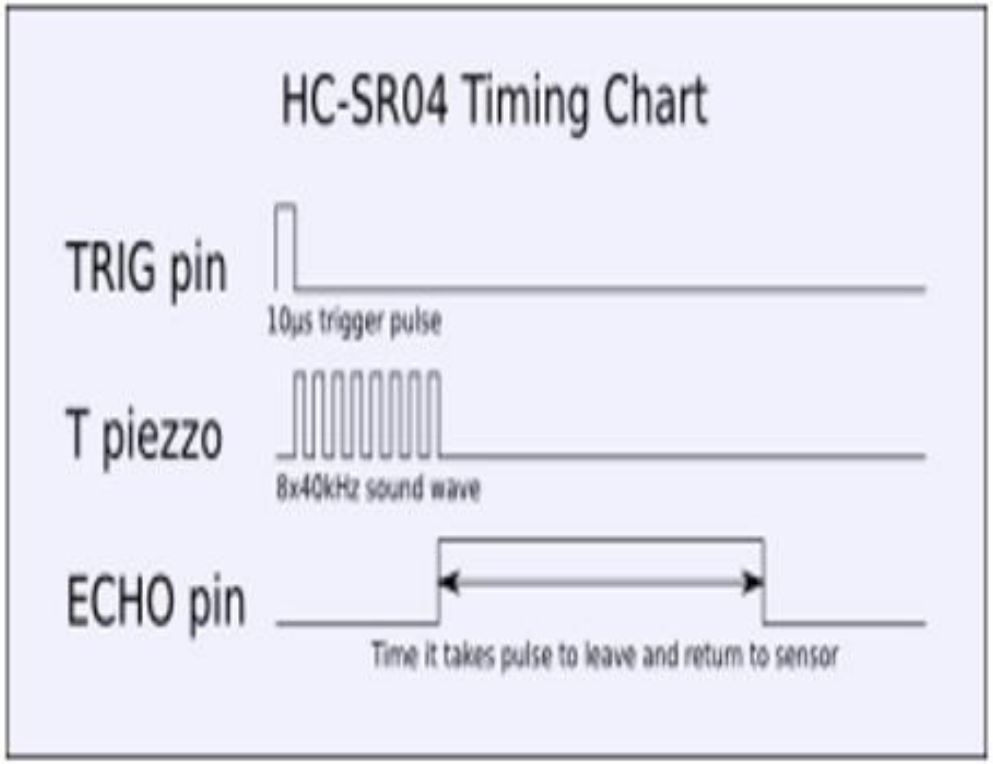
- OPTICAL PHOTOTRANSISTOR ARE CHEAPER HOWEVER, THEY SUFFER FROM SHADOW INTERFERENCE AND HAVE LOWER SENSITIVITIES
- INFRARED SENSING SUFFER FROM ERROR BASED ON MATERIAL
- LIDAR SENSORS HAVE THE BENEFIT OF INCREDIBLY LARGE RANGE BUT ARE ALSO VERY EXPENSIVE.
- ULTRASONIC OFFERS THE BEST PRICE TO PERFORMANCE RATIO WITH ADEQUATE RANGE AND RELATIVELY LOW COST

Sensor Type	Sensing Range	Unit Price	Unit Size
Optical	0.5-15 cm	$0.95	30mmx10mmx10mm
Lidar	0.1 cm to 40 m	$119.67	48mm x 40mm x 20mm
Ultrasonic	2 cm to 4 m	$3.95	45mmx20mmx15mm

ULTRASONIC SENSING PROCEDURE



Practical test of performance,
Best in 30 degree angle



BLUETOOTH ADAPTER

Modules	RN4020	RN52	CC2564MODA	HM-10
Operating Voltage	1.8 V to 3.6 V	3.0 V to 3.6 V	2.2 V to 4.8 V	3.6 V to 6 V
Size	11.5x19.5x2.5 mm	13.4x25.8x2.4 mm	7.0x7.0x1.4 mm	12.7x27x1.5 mm
Power Consumption (Idle)	<1.5 mA	12 mA	40 uA	3 mA
Power Consumption (Active)	16 mA	40 mA	41.2 mA	~32 to 50 mA
Bluetooth Version	4.1	2.1	4.1	4.1
Operating Range	100 meters	10 meters	10 meters	10 meters

Positioning

- Most common positioning tool is GPS due to its high accuracy and widespread availability
- Indoor Positioning currently utilizes either Bluetooth or Wifi (Chronos)
- Indoor Positioning is relatively new and upcoming

Bluetooth Beacons

- Three major types of Beacons:
- iBeacon
- URLBeacon
- Eddystone
- We are utilizing the Estimote Beacons for Ios and utilizing an iphone as an estimate sticker

BATTERY TYPE

Battery Type	NiCd	NiMH	Lead Acid	Lithium Ion
Charging Time	~1 hour	3 hours	8-16 hours	2-4 hours
Discharge Cycles	1500	300 to 800	500 to 800	500 to 1000
Temperature Range(C.)	-40 to 60	-20 to 60	-20 to 60	-20 to 60
Storage Temperature	-20 to 45	-20 to 45	<10	-20 to 25
Energy Density (Wh/kg)	45-80	60-120	30-50	110-160
Cutoff Voltage (V)	0.9 to 1.05	0.9 to 1.05	0.9	2.5
Cost per Cycle	$0.04	$0.12	$0.10	$0.14
Discharge Rate Per Month*	10%	13.9 to 70.6%	3%	8%

HARDWARE – MOTOR SELECTED

Magnolora 12V DC 25MM 120RPM Powerful High Torque Motor

Characteristics:

- Used in applications such as robotics, household appliances, electric tools, etc.

Specifications:

- Nominal Voltage: 12 V
- No Load RPM: 120 RPM (Rotations Per Minute)
- Stall Current: 1.8 A
- Stall Torque: 111 oz-in = 8 kg-cm
- Shaft Diameter: 4 mm
- Shaft Length: 12 mm
- Shaft Type: D-Shaped
- Size: 25D x 52L mm
- Weight: 100 g

Questions/Concerns:

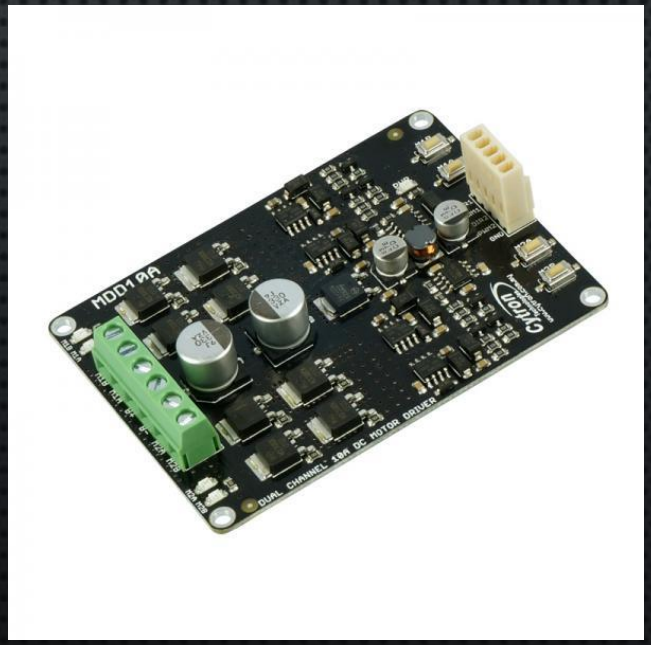
- Will it be able to handle a large amount of weight (Spur)?

- Will a 120 RPM motor be able to keep up with the user while moving load?

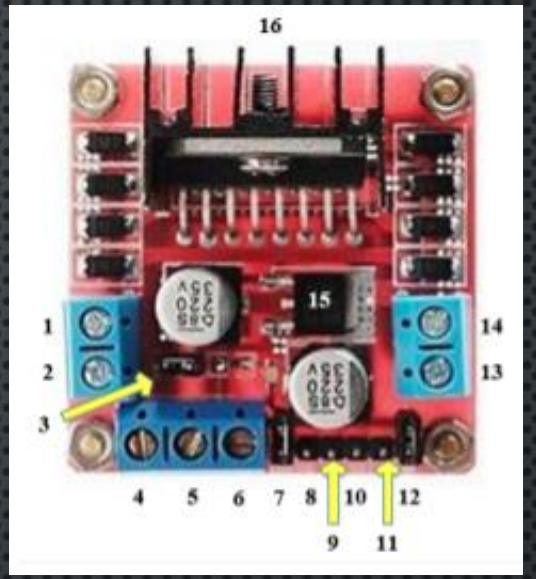
MDD10A Dual Channel DC Motor Driver Controller

Specifications:

- Operates two brushed DC motors
- Supports PWM signal
- NMOS H-Bridge for great efficiency and requires no heat sink
- Sign-magnitude and locked-antiphase PWM operations are supported
- Obtains solid state components for faster response time and minimize tear from mechanical relay
- Push button is on the board to manually operate the motor
- Drive voltage: 5V-25V
- Max PWM frequency is 20kHz (Hertz)
- Max continuous current up to 10A and 30A peak for each channel



L298N Dual H-Bridge DC Stepper Motor Controller



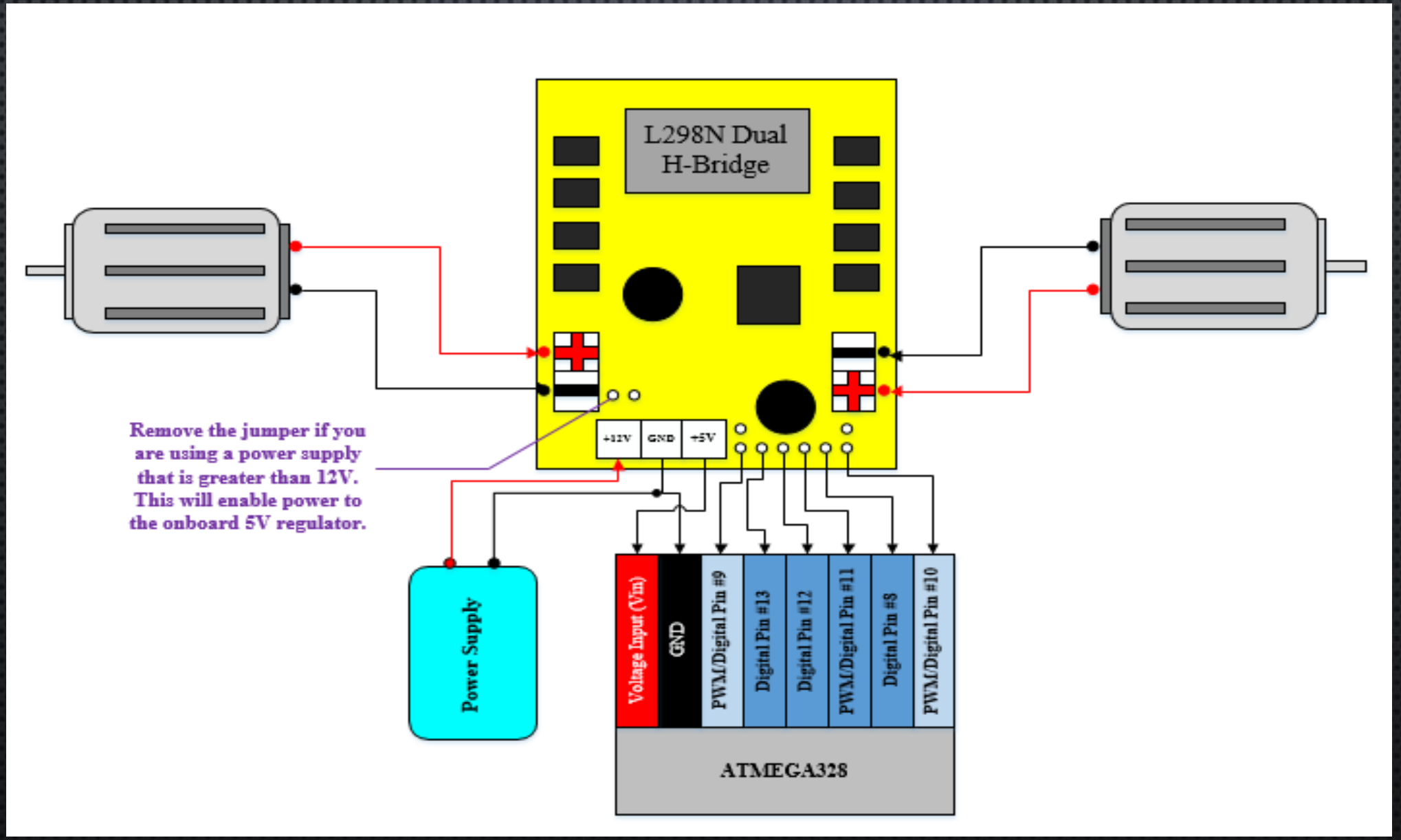
Components:

1. OUT1 (Motor A)
2. OUT2 (Motor A)
3. 12V Jumper: Removed if supply voltage > 12V
4. Supply Voltage
5. GND
6. 5V input/output voltage regulator
7. PWM signal for Motor A
8. IN1
9. IN2
10. IN3
11. IN4
12. PWM signal for Motor B
13. OUT3 (Motor B)
14. OUT4 (Motor B)
15. Internal 5V voltage regulator
16. L298N Dual H-Bridge

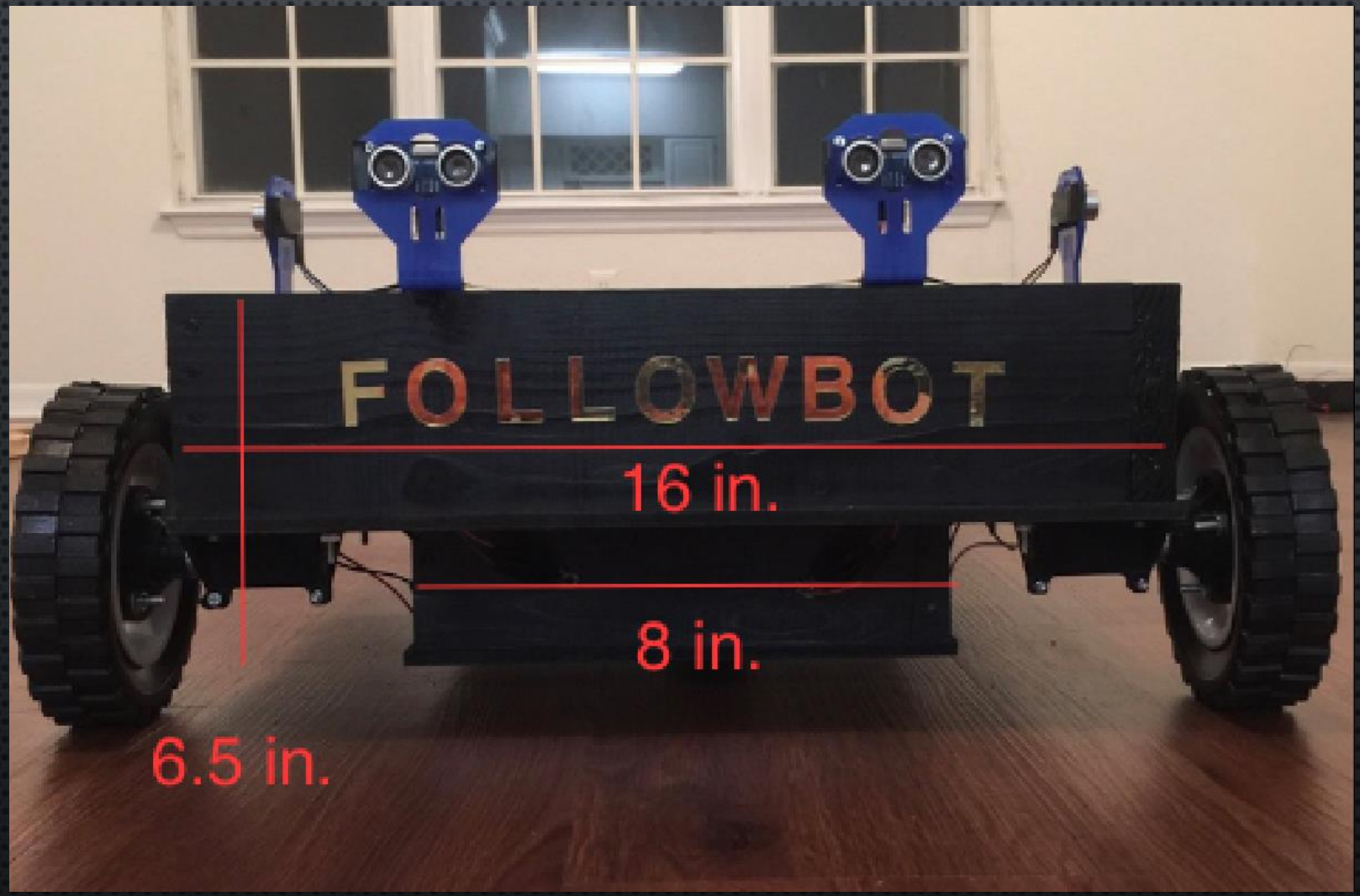
Specifications:

- **Drive Voltage: 5 - 35V**
- **Maximum Stall Current: 3A**
- **Able to drive 2-phase stepper motors, 4-phase stepper motor, or DC motors**
- **Supports PWM signal**
- **Max power: 25W**

HARDWARE – MOTION SYSTEM DESIGN

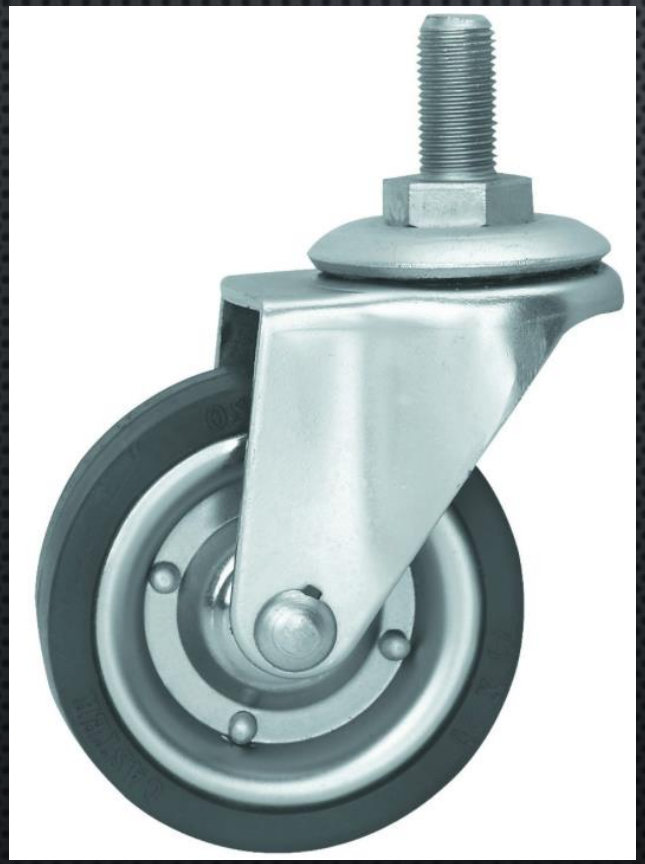


FINAL PRODUCT



HARDWARE – WHEELS

3 in. Hard Rubber Light Duty Swivel Caster



Characteristics:

- Solid rubber for durability and smooth movement.
- 360 degree rotation
- Includes double ball bearings and a zinc plated steel frame for more durability.

Specifications:

- Tire size is 3 in.
- Maximum working load = 100 lbs.
- Weight = .90 lb.

6 in. Semi-Solid Tire with Polypropylene Hub

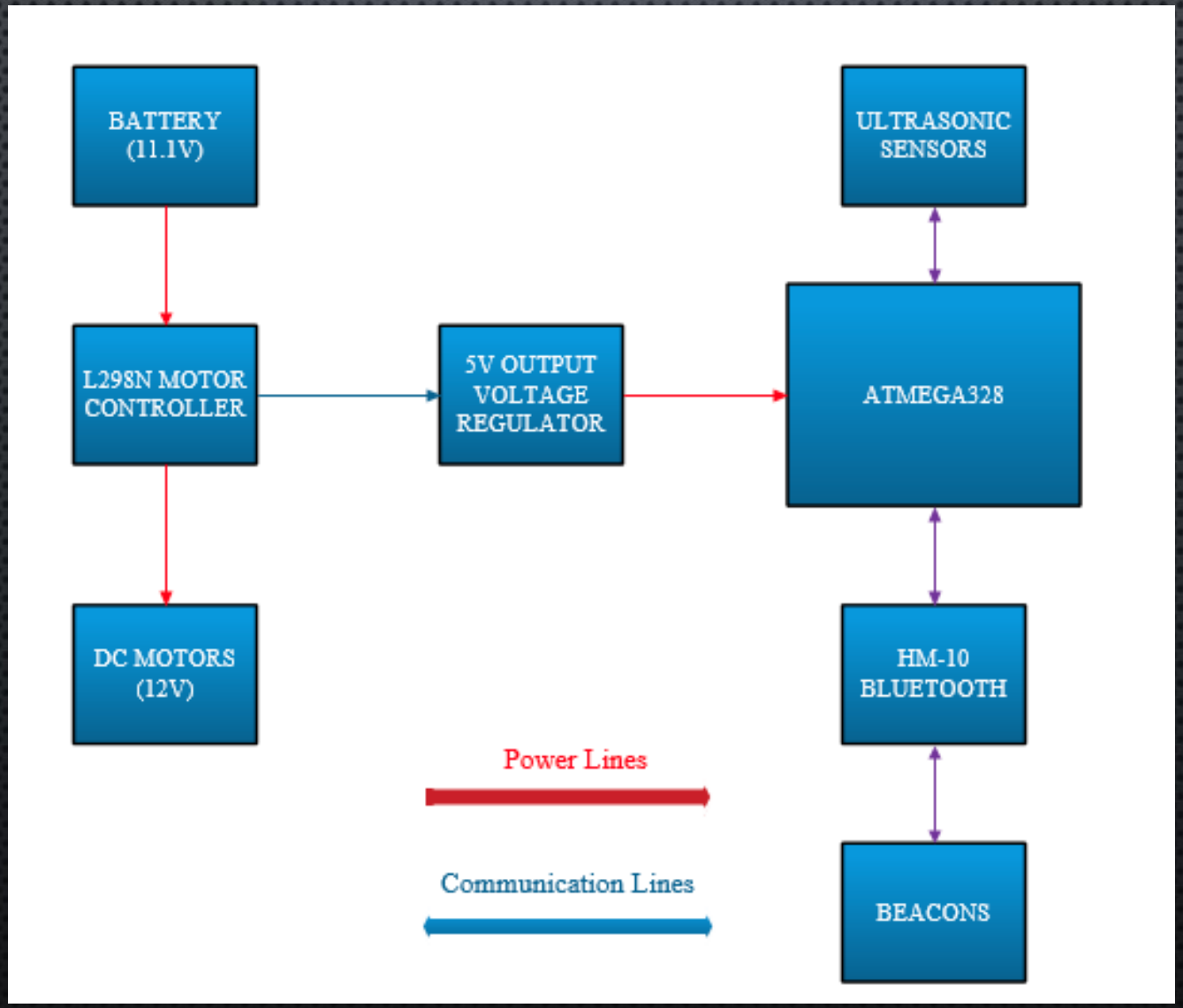
Characteristics:

- Puncture-proof semi-solid rubber tire.
- Strong weather resistant polypropylene inner hub.
- Excellent traction in any terrain.

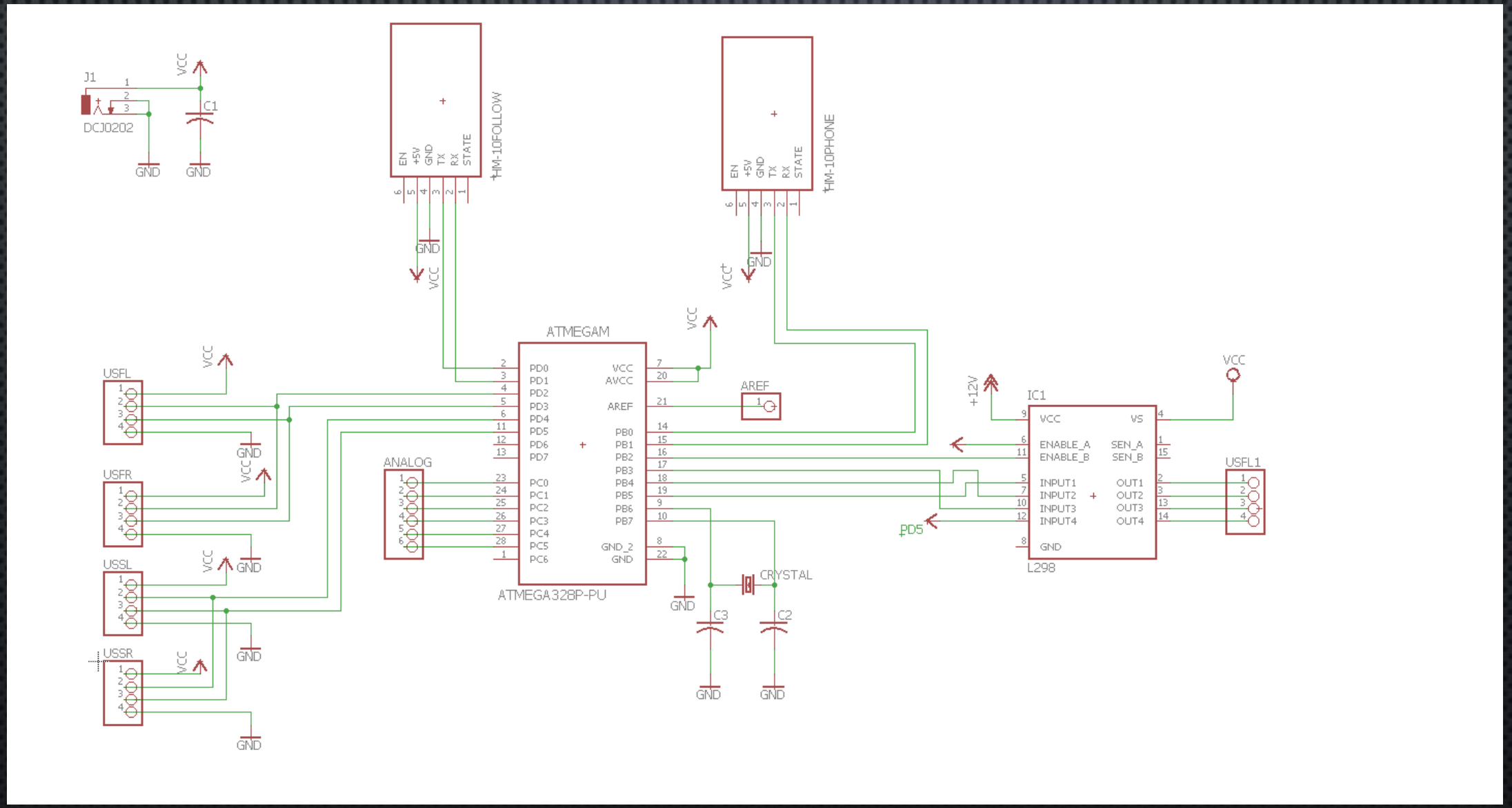
Specifications:

- Tire size is 6 in.
- Maximum working load = 94 lbs.
- Weight = 1 lb.

HARDWARE BLOCK DIAGRAM



SYSTEM SCHEMATIC



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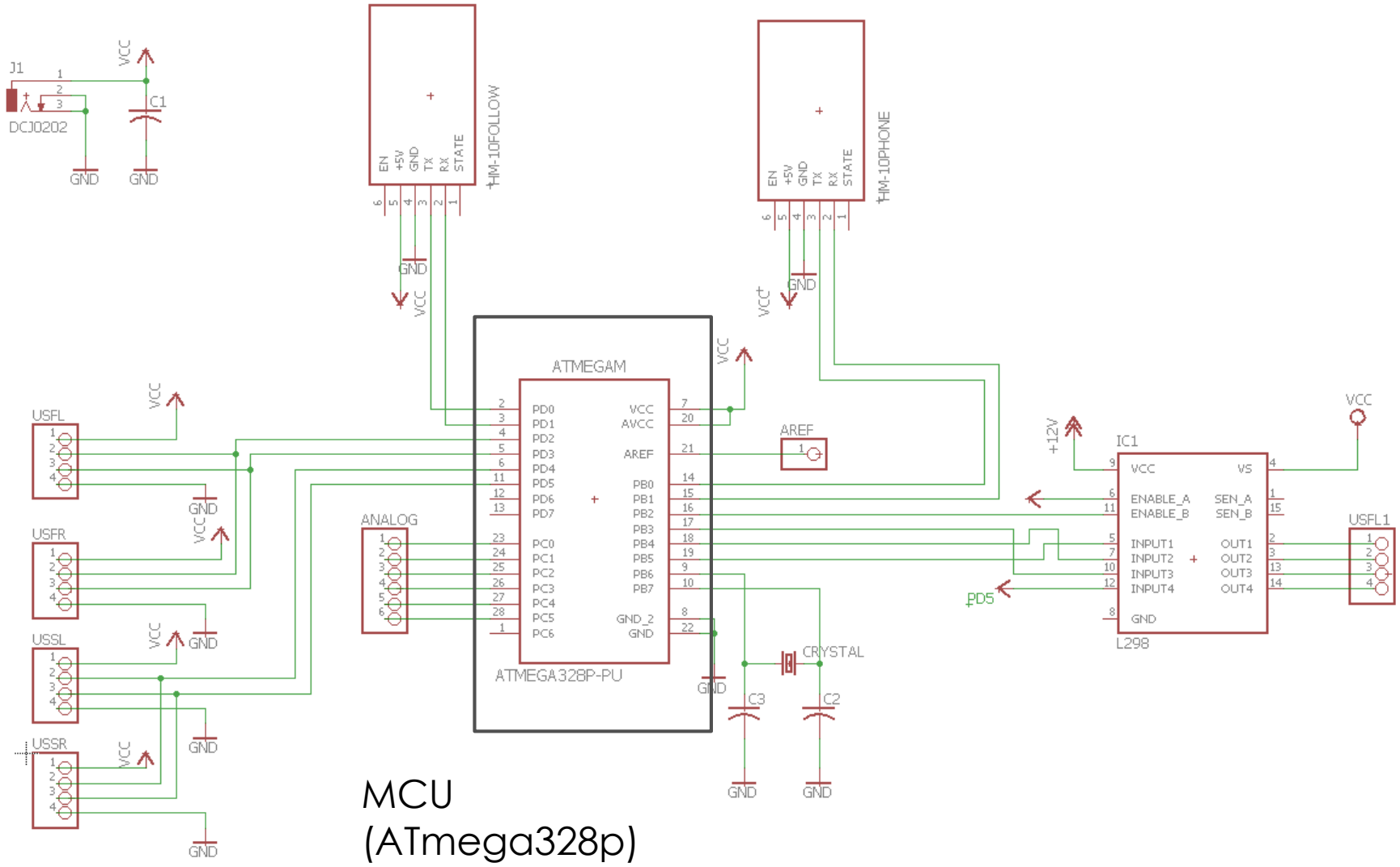
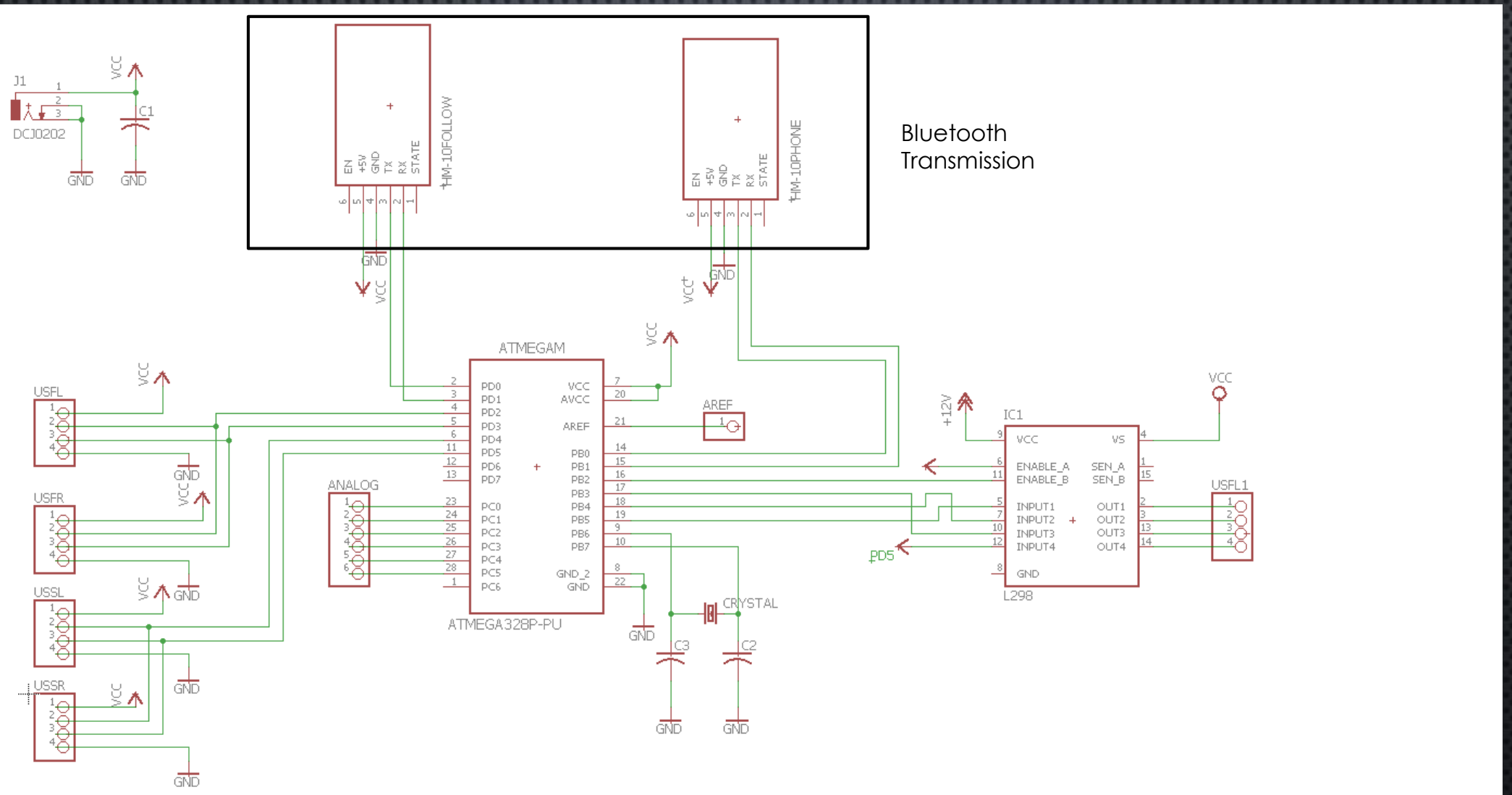
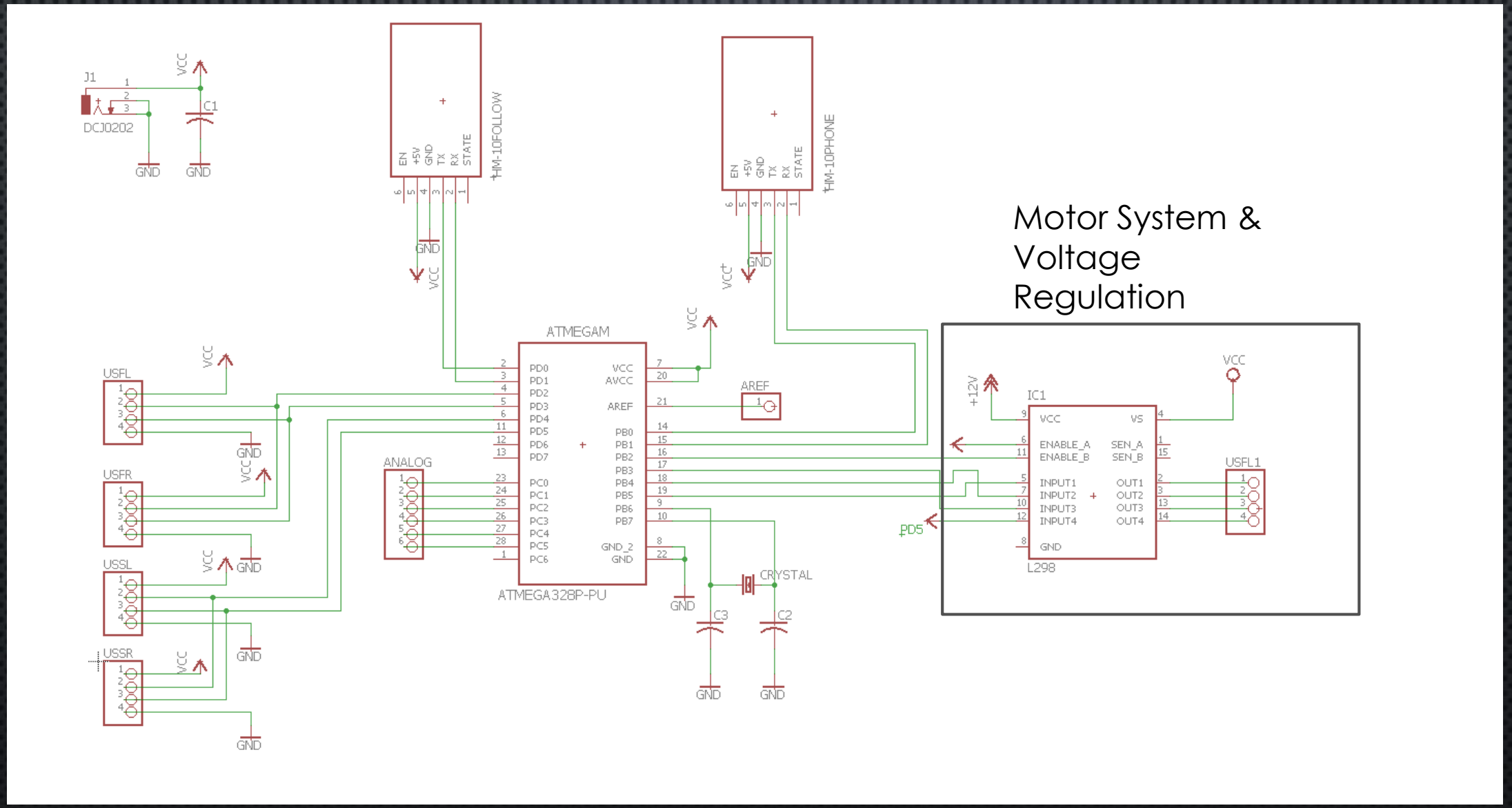


MCU
(ATmega328p)

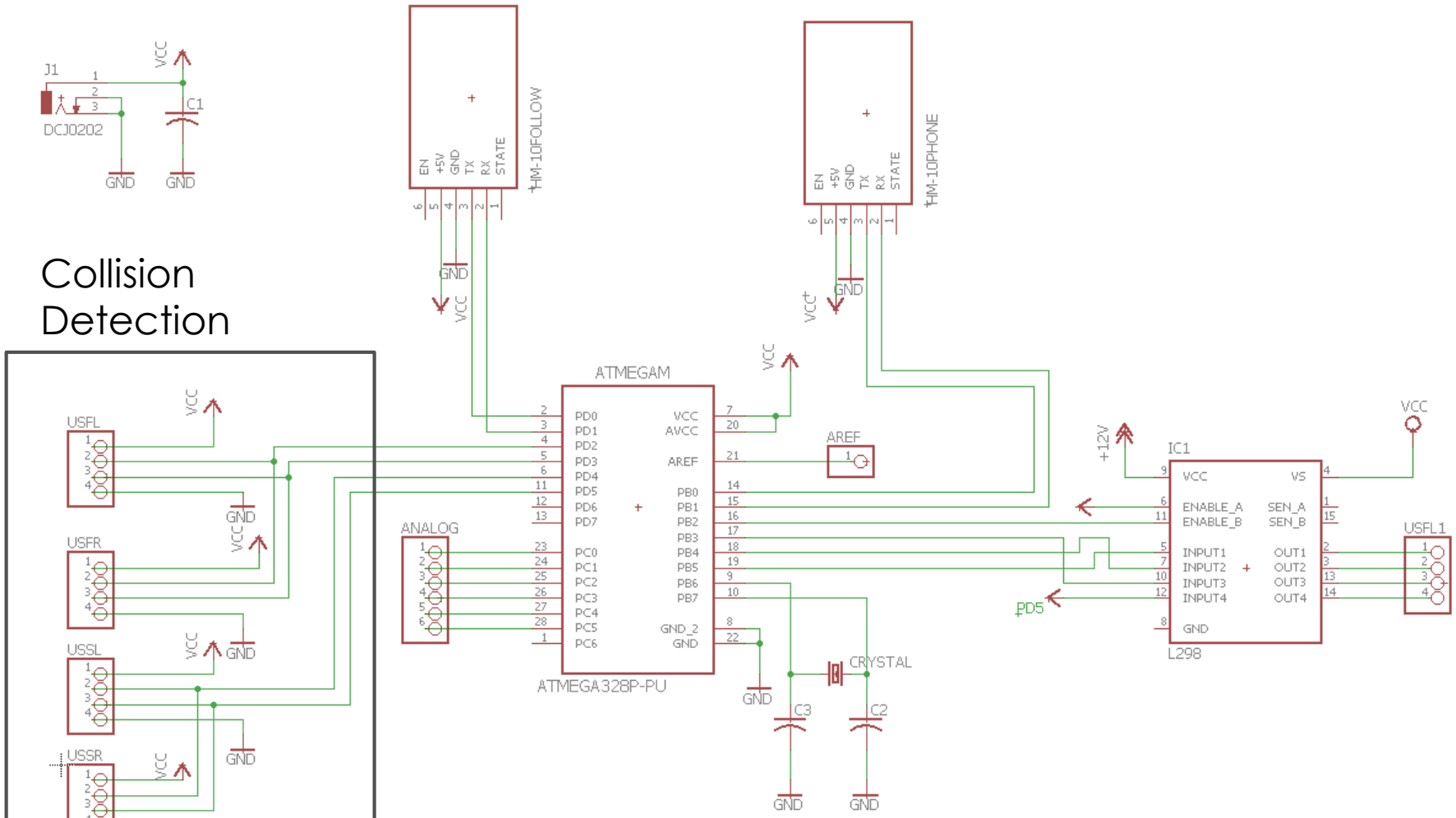
SYSTEM SCHEMATIC



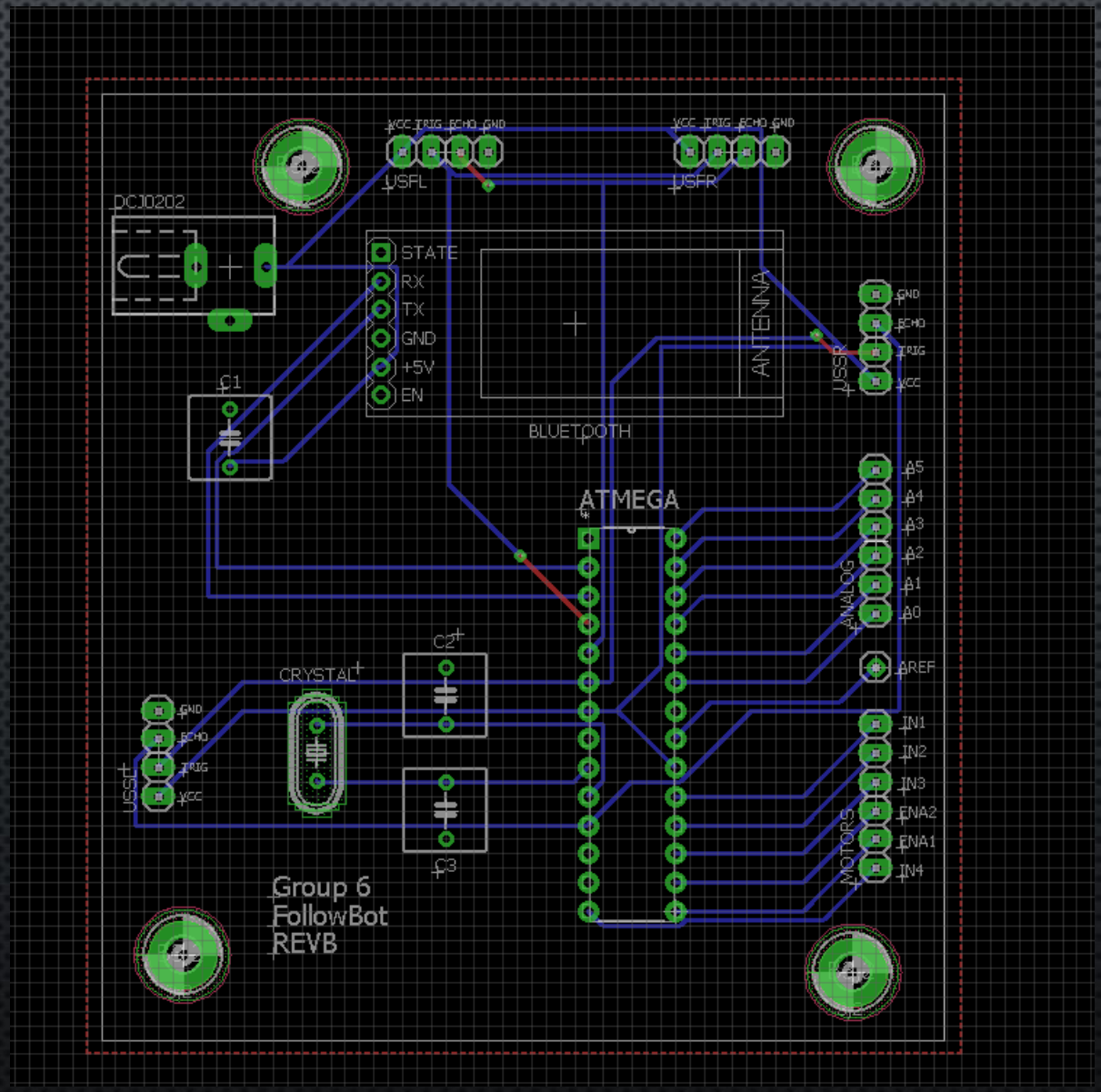
SYSTEM SCHEMATIC



SYSTEM SCHEMATIC

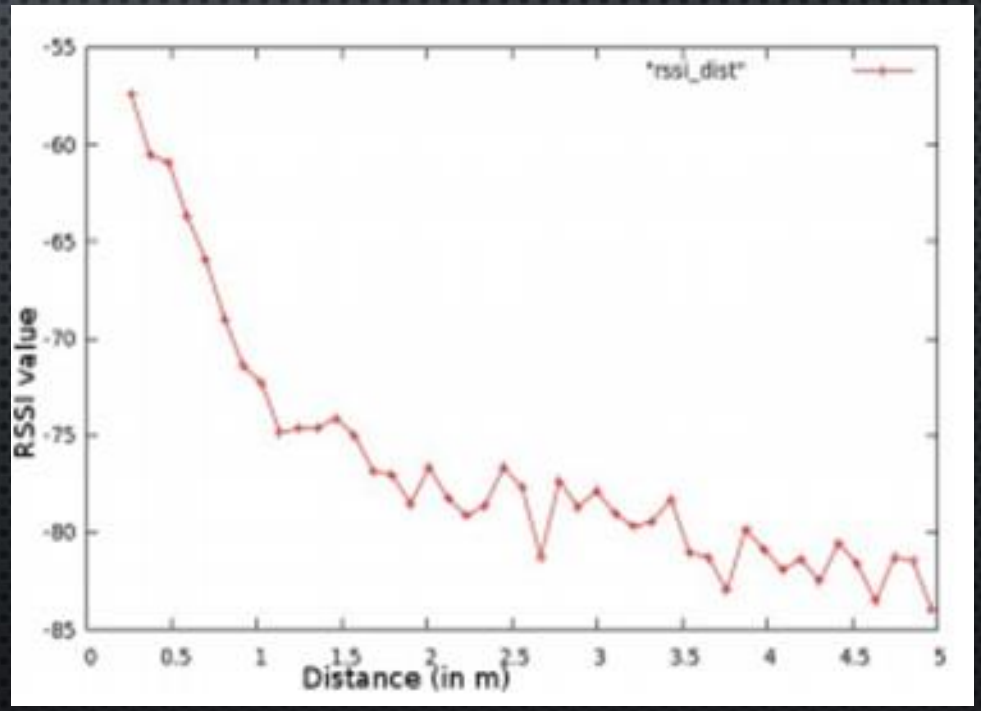


PRINTED CIRCUIT BOARD



RECEIVED SIGNAL STRENGTH INDICATION(RSSI)

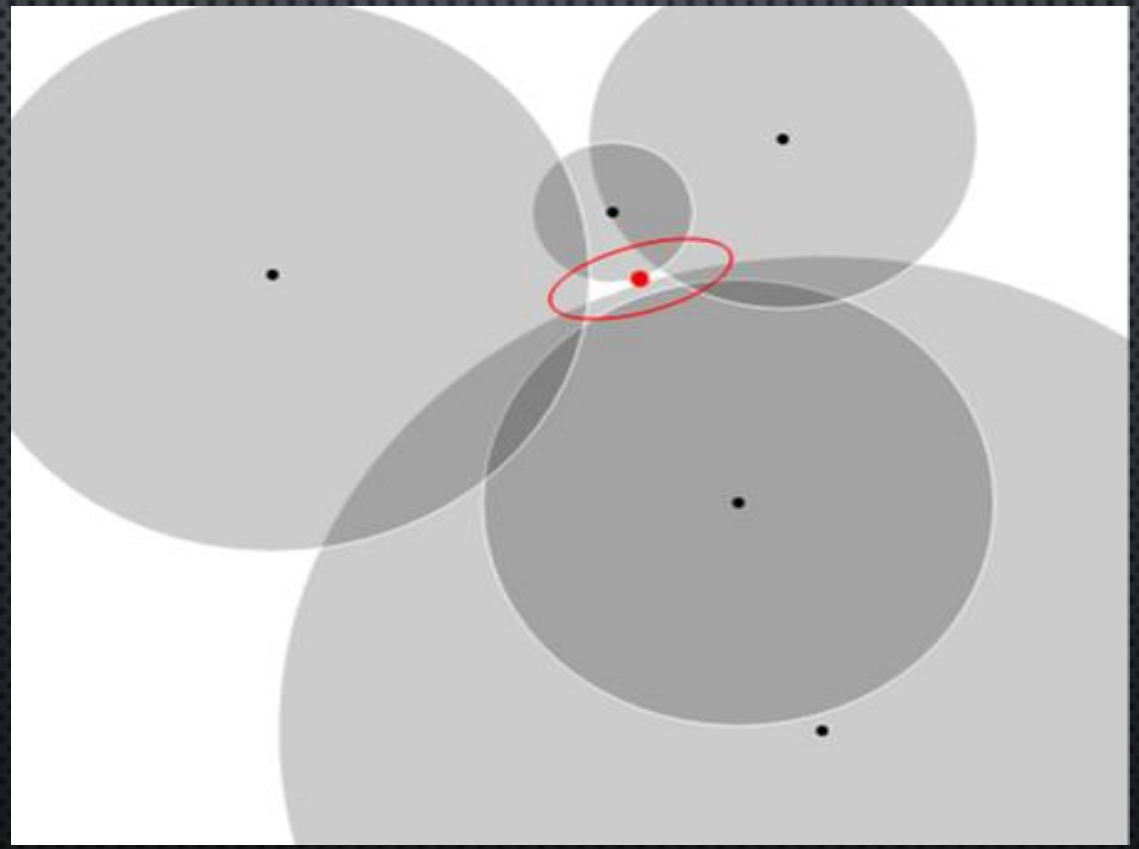
- BLUETOOTH BEACONS RETURN RSSI VALUES TO MODULE
- USING RSSI VALUES YOU CAN GET ROUGH ESTIMATES OF RANGE
- D = 10^((TXPOWER-RSSI)/(10*N)
- D= DISTANCE: TXPOWER = SET BROADCASTING POWER: N= ENVIRONMENTAL FACTOR(BETWEEN 1 AND 4)



Trilateration with range filter

- Strengths
  - Quick Approximation of BT modules location
  - Lot's of open source code available
  - Easy to implement
  - Could be integrated with a particle filter
- Weaknesses
  - More than a meter of inaccuracy for location of module
  - Due to inaccuracy of location, the estimated direction the bot faces will be inaccurate
  - Needs multiple access points

TRILATERATION



Particle Filtering with Range Filter

- Strengths
  - Very accurate after a certain period of time
  - Only needs a single access point to a Range Filter
  - Creates predicted path as the actual path is happening
- Weaknesses
  - Inaccurate for first several steps
  - If module moves around parameter of circle generated using Range Filter, the system will likely get confused.

Kalman Filter

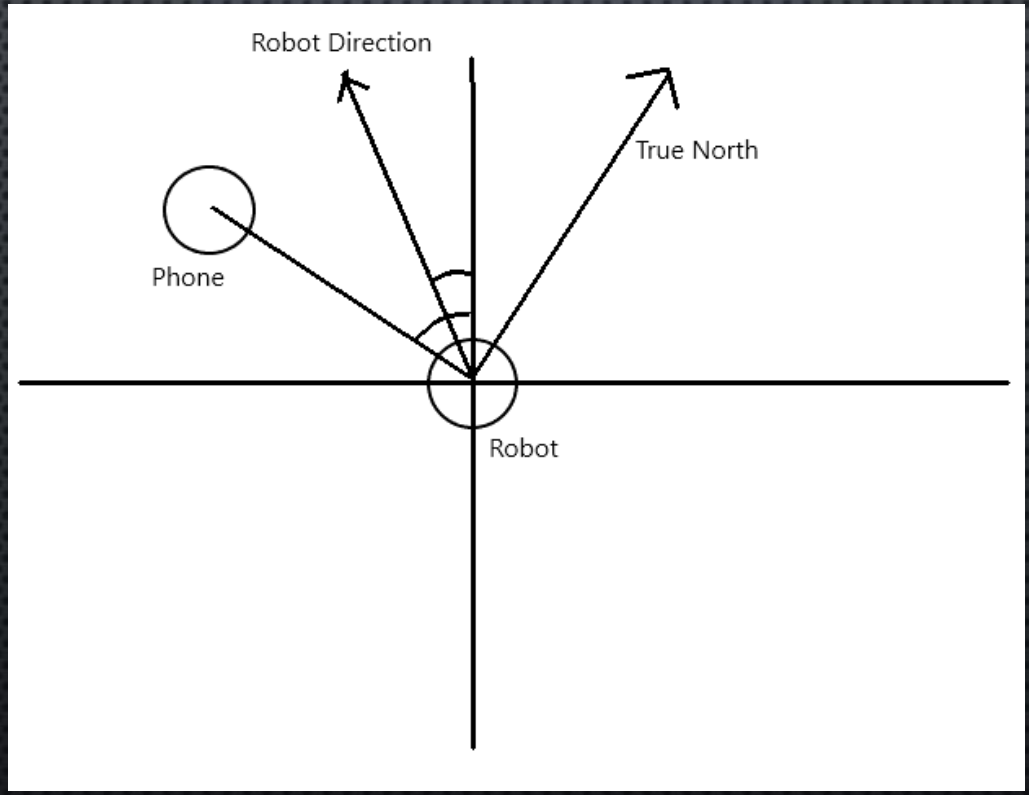
- Iterative approach to filtering. Highly efficient and used in military applications such as the Tomahawk missile
- Uses measurement uncertainty, Data interval, and averages a flow of number values
- Over time becomes more accurate by using previous estimate and a Estimation Uncertainty that it calculates dynamically

KALMAN FILTER

Pathing

- Followbot needs to know the angle it must turn and the distance it must cover.
- Distance is found using Pythagorean theorem between location of bot and phone
- Angle is found by finding the angle between the direction the followbot is facing and the y-axis and subtracting that from the angle created between y axis and the line between the followbot and the phone

PATHING



Reasons for Agile

- Highly Flexible
  - Weekly meetings with occasional emergency dailies for blockers
- Promotes ownership
  - Tasks assigned to individual team members
- Easy to track progress
  - With individuals owning parts of the software it easy to keep them accountable
- Keeps momentum going
  - With a task completed and win in hand at the end of each sprint it easy to keep morale high and work from stagnating

Sprints to Success

- Sprint 1(Oct 1-7) – Test Bluetooth accuracy for getAccuracy(), getDistance(), and getRSSI(). Build approximation infrastructure for mobile app and Atmega. Order rest of BT LE beacons. Finish and order PCB
- Sprint 2(Oct 8-14) – Build Full prototype, test effectiveness of simple motor control commands. Develop first phase of particle filter with unit tests. Start first phase of object avoidance and pathing software development.
- Sprint 3(Oct 15-21) – Finish particle filter and apply it to trilateration infrastructure. Finish object avoidance and pathing software. Begin design for final robot body and hardware enclosure.

Sprints to Success

- Sprint 4(Oct 22-28) – Install PCB into robot hardware enclosure. Run simple motor control command tests and the effect of weight on the robot. Make changes as necessary.
- Sprint 5(Oct 29-Nov4) – Burn final software onto the PCB. Finalize Assembly. Begin testing to verify simulations.
- Sprint 6 and 7(Nov 4-24) – Verify simulations and make final improvements.

BUDGET

Description	Manufacturer	Part Number	Quantity	Unit Cost	Total Cost
Microcontrollers	Arduino	ATmega328	3	$4.83	$14.49
Bluetooth Modules	HYY	HM-10	2	$6.5	$12.99
BLE Beacons	Lotton	B01MU7YC87	3	$22.99	$68.97
Ultrasonic Sensor	Elegoo	HC-SR04	5	$1.97	$9.86
Lead Acid Battery	ExpertPower	EXP1270	1	$16.94	$16.94
Battery Charger	UPG	D1761 SLA	2	$7.01	$14.02
Switching Regulators	Qunqi	MP1584EN	5	$1.80	$8.99
Motor Controllers	Daoki	L298N	5	$2.97	$14.98
Motors	Cytron	RB-Cyt-28	4	$14.61	$87.66
Wheels	Pololu	Dagu 120mm	4	$14.95	$29.9
PCB	TBD		2	$40	$80
Vehicle Design	TBD				$50
TOTAL					$408.80

QUESTIONS?