California State University Long Beach
College of Engineering
Department of Electrical Engineering

µBiPedProject – CDR

- Project Manager & Control and Image Processing:

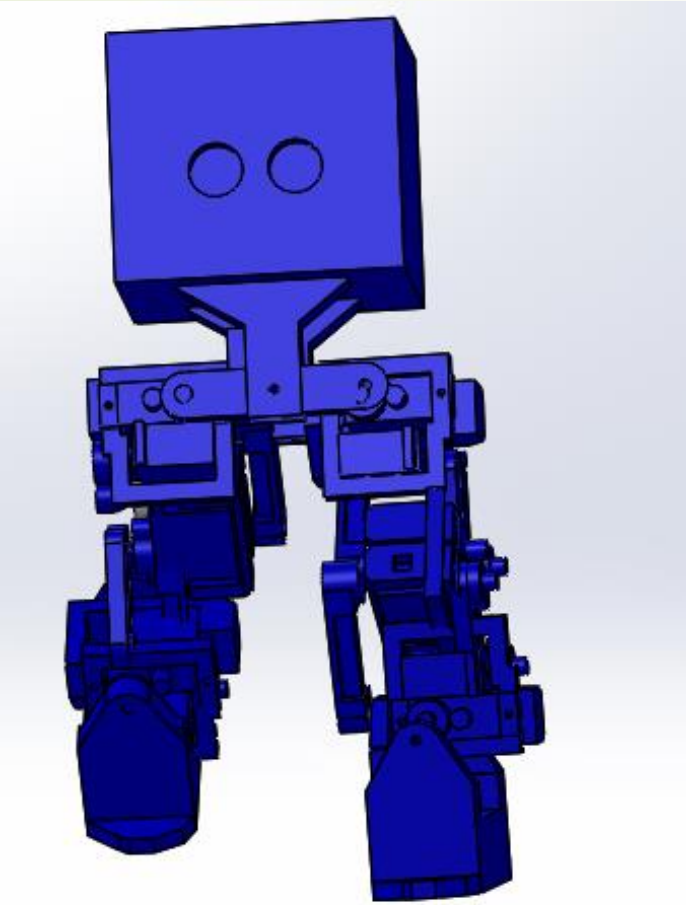
  Tate McGeary

  - Coding on for µBiPed
  - Help were necessary
- Systems and Test Engineering: Mesfer Aldosari
  - Prototyping
  - Troubleshooting
  - Arxterra
  - Battery choice
- Sensors, Actuators, and Power: Ameen Alattas
  - Checking components
  - How to integrate the system
  - Power budget
- 3D Printing and Manufacturing: Yakub Dure
  - Designing components
  - Manufacturing components
  - Material decision

Mission Objective

- The project mission is inspired by the BiPed designed by Jonathan Dowdall of Project Biped, completed in previous semesters of EE 400D. The goal is to scale down the BiPed design by changing standard servos to micro servos to yield the µBiPed, which will result in design changes to the robot. The robot must be able to communicate and be controlled by the Axterra™ application. The final deliverable of this project is to have the µBiPed maneuver through an obstacle course, while being able to resist outside disturbances.

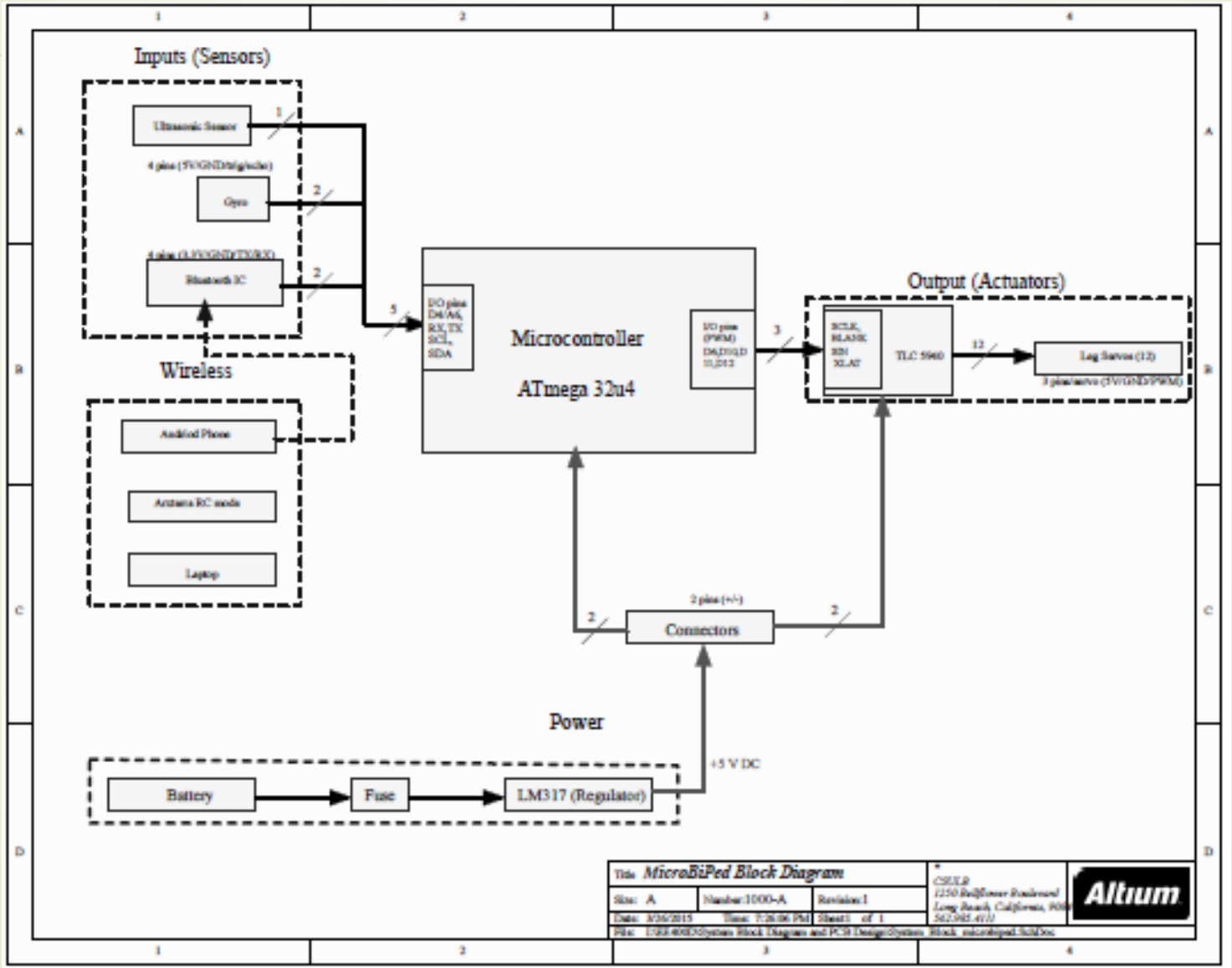
Design of µBiPed



Differences:

Height from Shoulder: 165.862 mm
Uses micro-servos
23x12.5x28 mm

System Block diagram



PolyFuse

Operations

- operation voltage
- holding current
- trip current

Features

Operations obtain from uk.farnell.co.uk

- Over current protection
- Low base resistance
- Short time to trip
- Lifetime up to 10 times longer
- Internationally standardized and approved

[9]

Trade off Study (batteries)

Nickel-Metal hydride (NiMH) obtained from batteryspace.com

1- **advanages:**

- Wide operating temperature range about -10 to 65 C
- Safer than LiPO
- High self discharge

2- disadvantages

Capacity 200 mA

Lithium Polymer (LiPo) obtained form batteryspace.com

1- Advantages:

- More efficient than NiMH
- has a higher specific energy than NiMH
- High self discharge
- High energy density

2- disadvantages

Expensive

[8,11]

NiMH Cylindrical battery

Features:

- Provide enough voltage 9 v
- Light its weight is 43 g
- Small 48 mm
- Capacity 250 mAh
- High rate discharge
- Self discharge

Operations obtain from batteryspace.com

Battery Life = Battery Capacity in Milli amps per hour / Loc

[Battery capacity(mAh)/device consuption(mA)]*0.7

(250/750)*0.7= 0.23

0.23*2*60=28minutes

So 28 minutes is our battery last long.

[8,12]

LM317 Voltage Regulator

obtained from reuk.co.uk

Advantages:

- Internal short current circuit limiting constant with temperature.
- Output current in excess of 1.5 A
- Eliminates stocking many fixed voltages
- Output adjustable voltage between 1.2 V up to 37 V
- internal thermal overload voltage
- Protect components

Torque Calculations

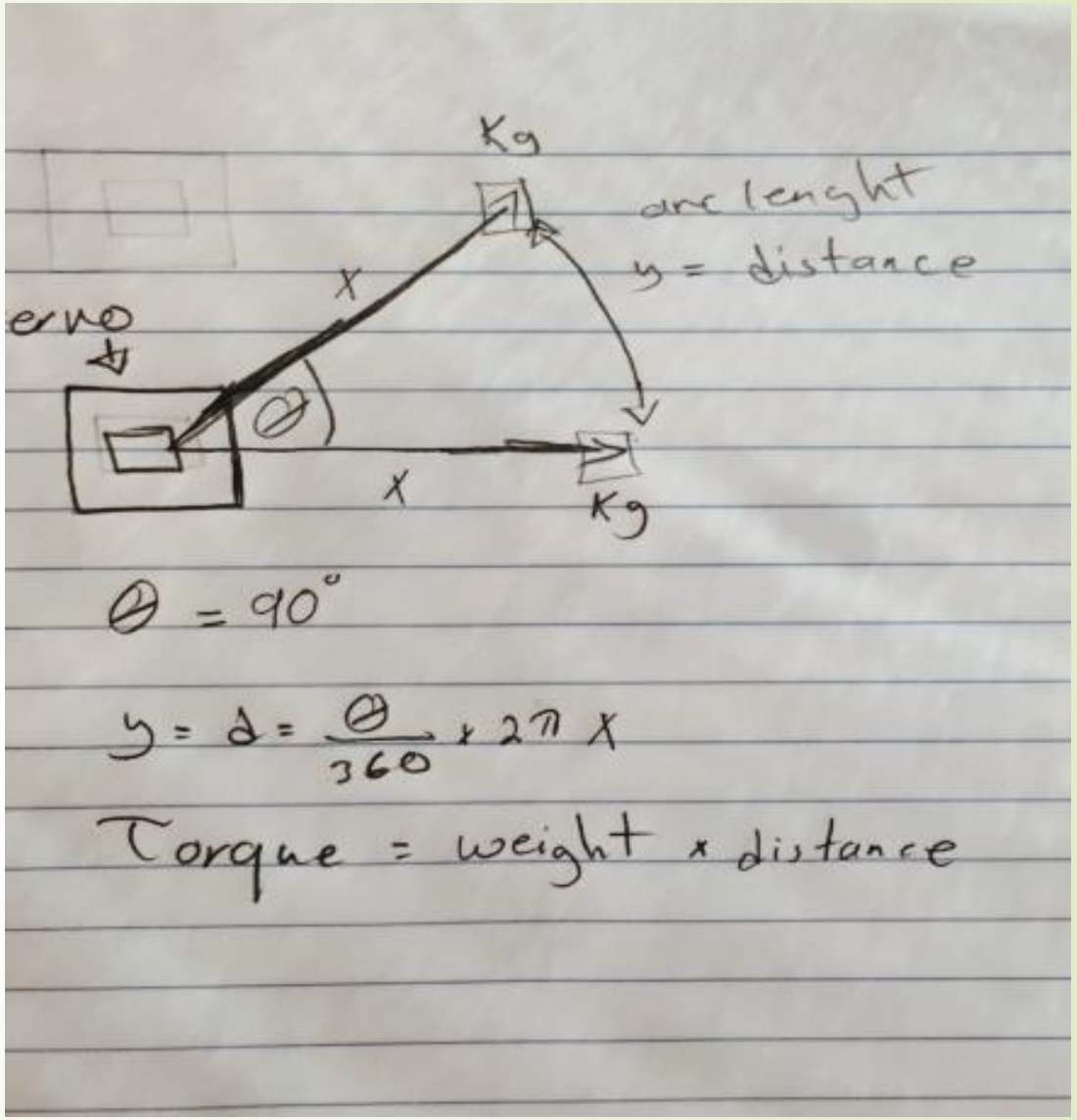
C= 2 pi X

D= theta/360 *2 pi x

X(cm)=5,10,15,20,25

Y is the Distance (m)

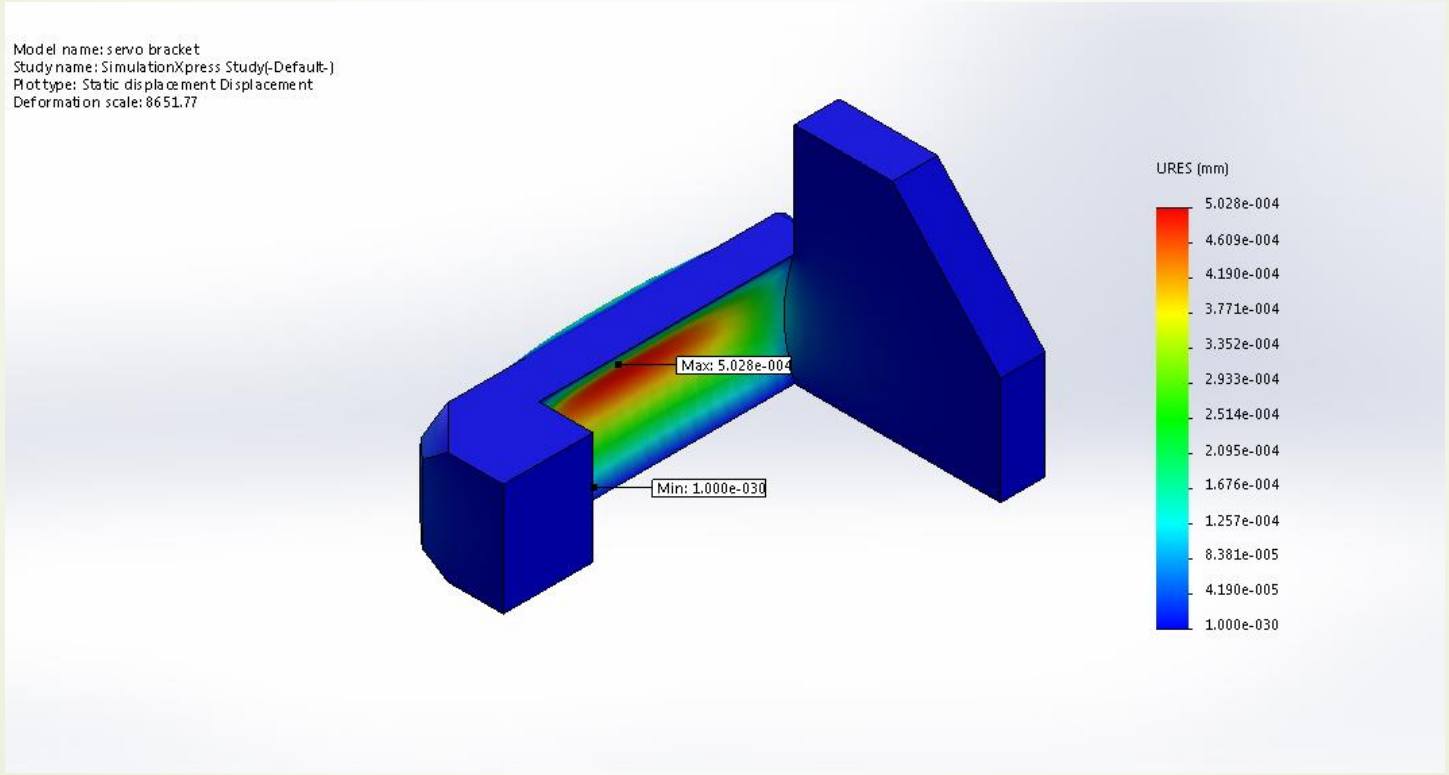
Torques= weight * distance*9.8



Experiment calculations:

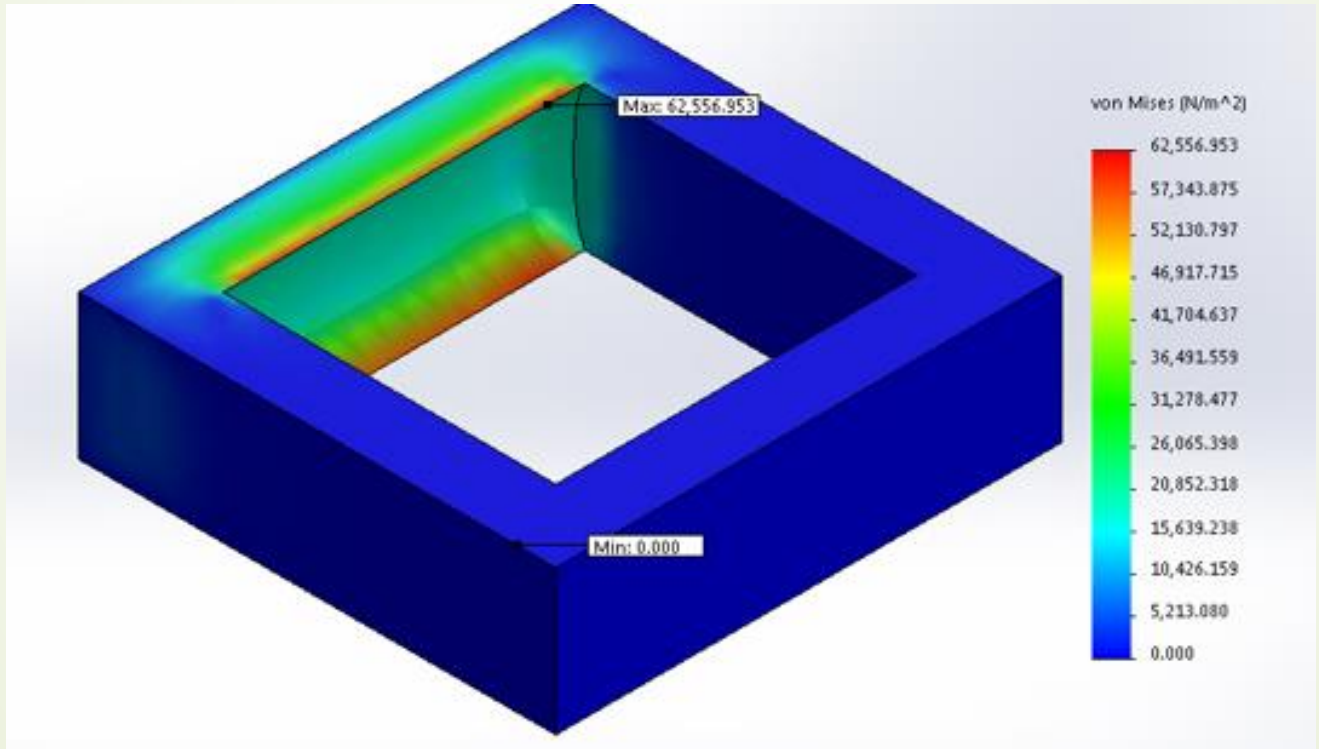
Weight (kg)	X(cm)	Y(m)	Torque (n/m)
0.1	5	0.078	0.076
0.25	5	0.078	0.19
0.5	5	0.078	0.38
1.0	5	0.078	0.76
1.5	5	0.078	1.15
2.0	5	0.078	1.53
0.1	10	0.157	0.154
0.25	10	0.157	0.385
0.5	10	0.157	0.78
1.0	10	0.157	1.54
1.5	10	0.157	2.31
2.0	10	0.157	3.1
0.1	15	0.235	0.23
0.25	15	0.235	0.575
0.5	15	0.235	1.15
1.0	15	0.235	2.3
1.5	15	0.235	3.45
2.0	15	0.235	4.6
0.1	20	0.314	0.31
0.25	20	0.314	0.77
0.5	20	0.314	1.54
1.0	20	0.314	3.1
1.5	20	0.314	4.62
2.0	20	0.314	6.2
0.1	25	0.392	0.38
0.25	25	0.392	0.96
0.5	25	0.392	1.9
1.0	25	0.392	3.8
1.5	25	0.392	5.76
2.0	25	0.392	7.6

Stress Testing



Name	Type	Min	Max
Stress	VON: von Mises Stress	3.67665e-006 N/m^2 Node: 10843	231671 N/m^2 Node: 10315

Obtained from SolidWorks™



Name	Type	Min	Max
Stress	VON: von Mises Stress	3.52872e-008 N/m^2 Node: 12252	62557 N/m^2 Node: 11842

Obtained from SolidWorks™

Comparison of materials

ABS

- Criss-crossed structure
- Made of styrene and acrylonitrile
- Bends
- More suitable for making bracelets or other flex plastics

PLA

- Can be homogeneous or heterogenous
- Made in a matrix form
- Sturdier
  - Better for load based parts
- Less likely to bend

Standard Plastic

- Can be linear, branched or network structures
  - Provides stronger item
- Drawback: have to use in molding process
  - Longer to obtain parts

[4,5,6]

Pros and Cons 3-D printing vs Molding

3-D Printing

- Advantages:
  - Easier to produce
  - Provides wide variety of customization
  - Cheaper
- Disadvantages:
  - Material used not strong
  - Limited materials
  - Temp. fluctuation can deform
  - Limited in size

Molding

- Advantages:
  - Much strong than 3D printed material
  - Can last a long time
  - Not effected by temp. fluctuation
- Disadvantages:
  - More expensive
  - Time consuming to produce
  - Harder to customize

[4,5,6]

Material and method chosen:

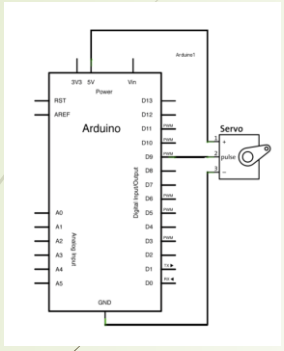
- PLA plastic is favored
- 3-D printing
- ABS can be too flexible
  - Means the robot can collapse on its own weight
- Standard Plastic
  - Too time consuming because of molding
  - More expensive

[8]

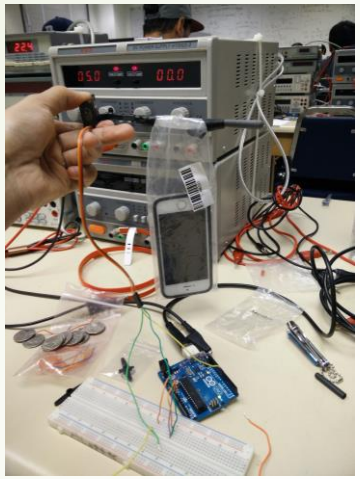
MG90S Test

Obtained from
http://www.nacrc.com/

- Set-up:



Obtained from
http://www.arduino.cc



- Actual voltage and current have been calculated
- Testing the maximum load the servo could carry
  - Table 1a add weight to servo
  - Table 1b adding 8cm object and attaching weight to it

- Code was taken from http://arduino.cc/en/Tutorial/sweep

Table 1A

Weight (g)	Current (mA)
100	236
200	300
321	372
400	400
448	448 (stall)

Table 1B

Weight (g)	Current (mA)
70	256
90	324
120	388
148	448 (stall)

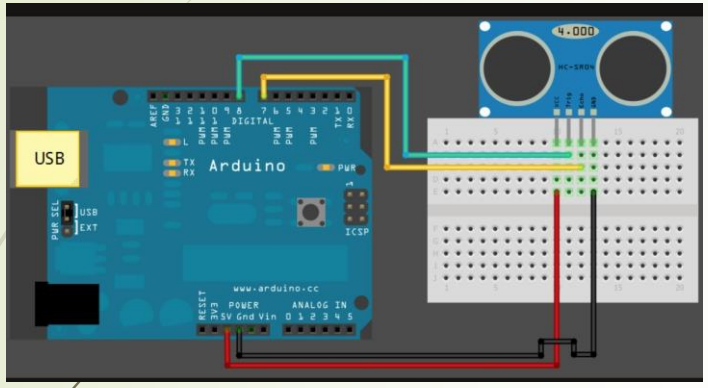
HC-SR04 Test

Set-up:

result:

Test

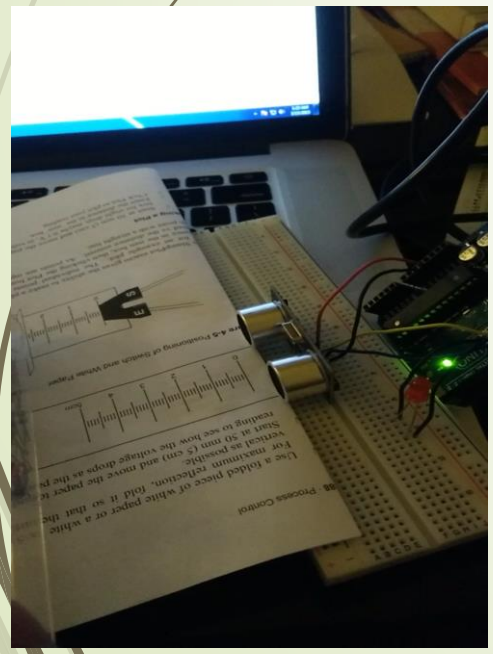
Obtained from arduinobasics.blogspot.com

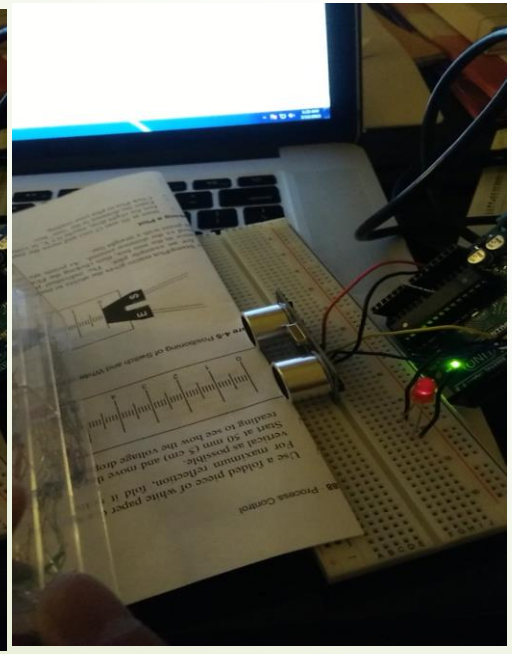


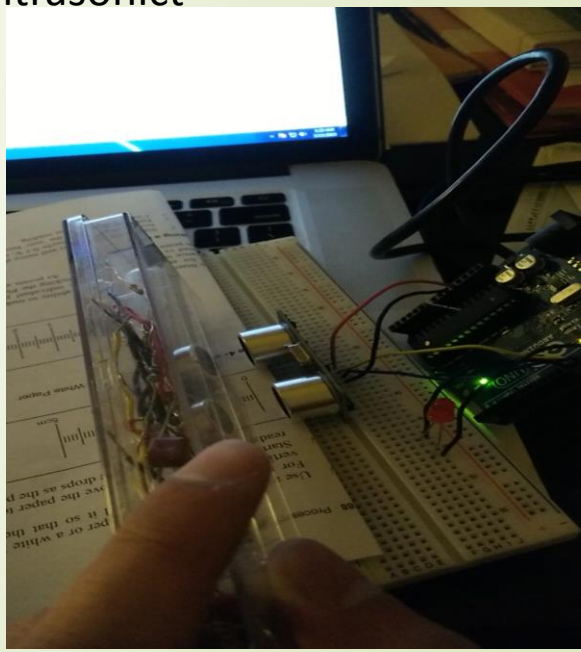
- Range: 2cm - 396 (4m)
- Sense an obstacle within 5 cm
- Measuring angle 15 degree
- Operating current is 15mA

Code taken: (See appendix D)

http://treehouseprojects.ca/ultrasonictutorial/







L3GD20 Test

Obtained from
http://nicegear.co.nz/

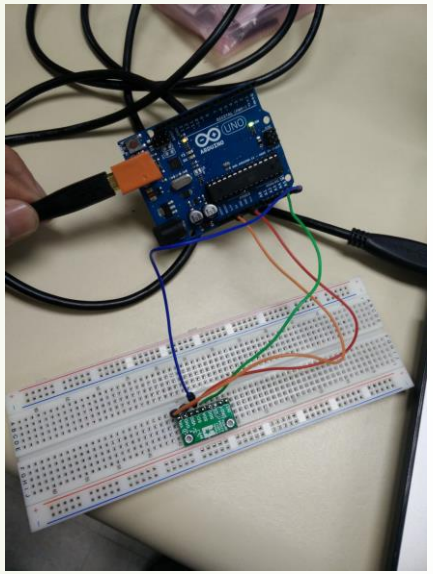
Set-up:

Arduino Micro

Arduino		L3G board
5V	->	VIN
GND	->	GND
2	->	SDA
3	->	SCL

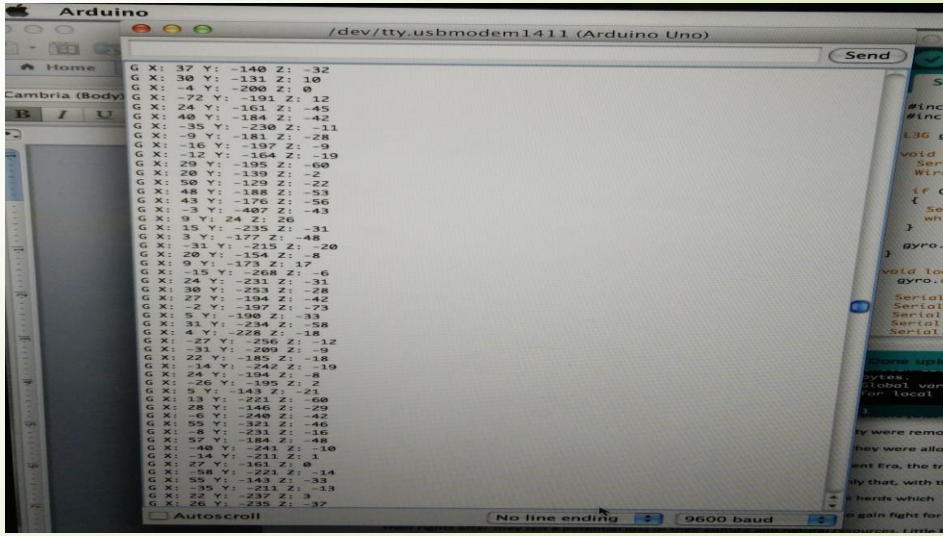
Arduino Uno (up to R2), Duemilanove,

Arduino		L3G board
5V	->	VIN
GND	->	GND
A4	->	SDA
A5	->	SCL



Test Result:

- Axis Counter-clockwise resulting in positive value, and clockwise resulting in negative value
- Code Could be found at: https://github.com/pololu/l3g-arduino

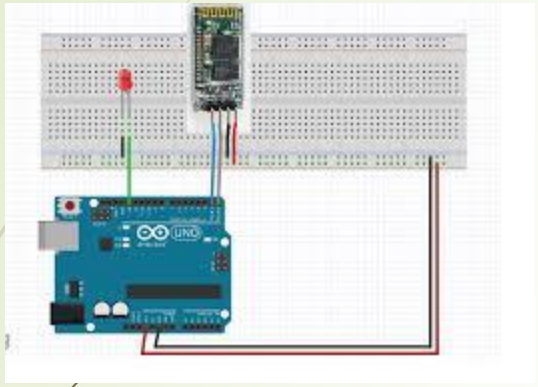


L3GD20 in balance system:

- The gyroscope will provide the current orientation of the BiPed to the microcontroller, which in return will be able to keep the BiPed standing in its natural standing position.

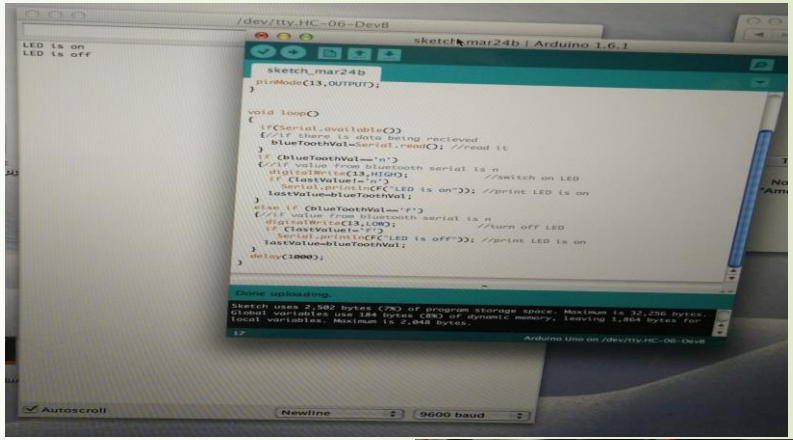
HC-06 Test

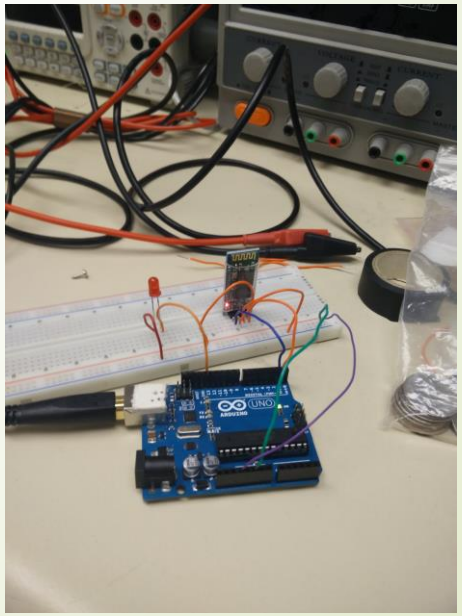
Set_up:

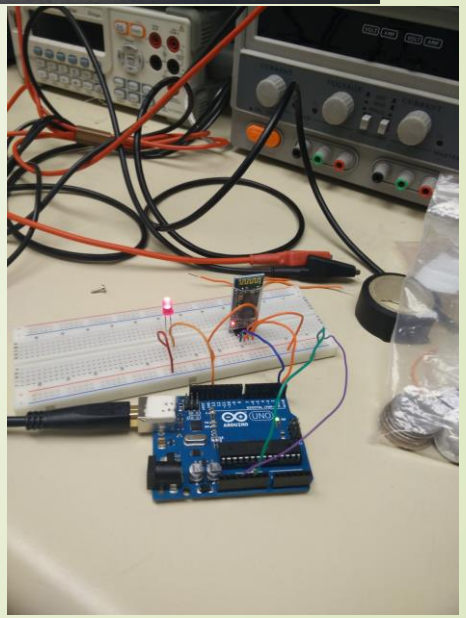


Obtained from http://www.arduino-hacks.com/

Test result:







Note:

- Password:1234
- Disconect whatever pin is connected RXD pin_0 in the arduino before uploading the code
- Code could be found

Microcontroller

Crumbuino Mega

- ATmega 2560
- Enough PWM pins
- Enough resources for code

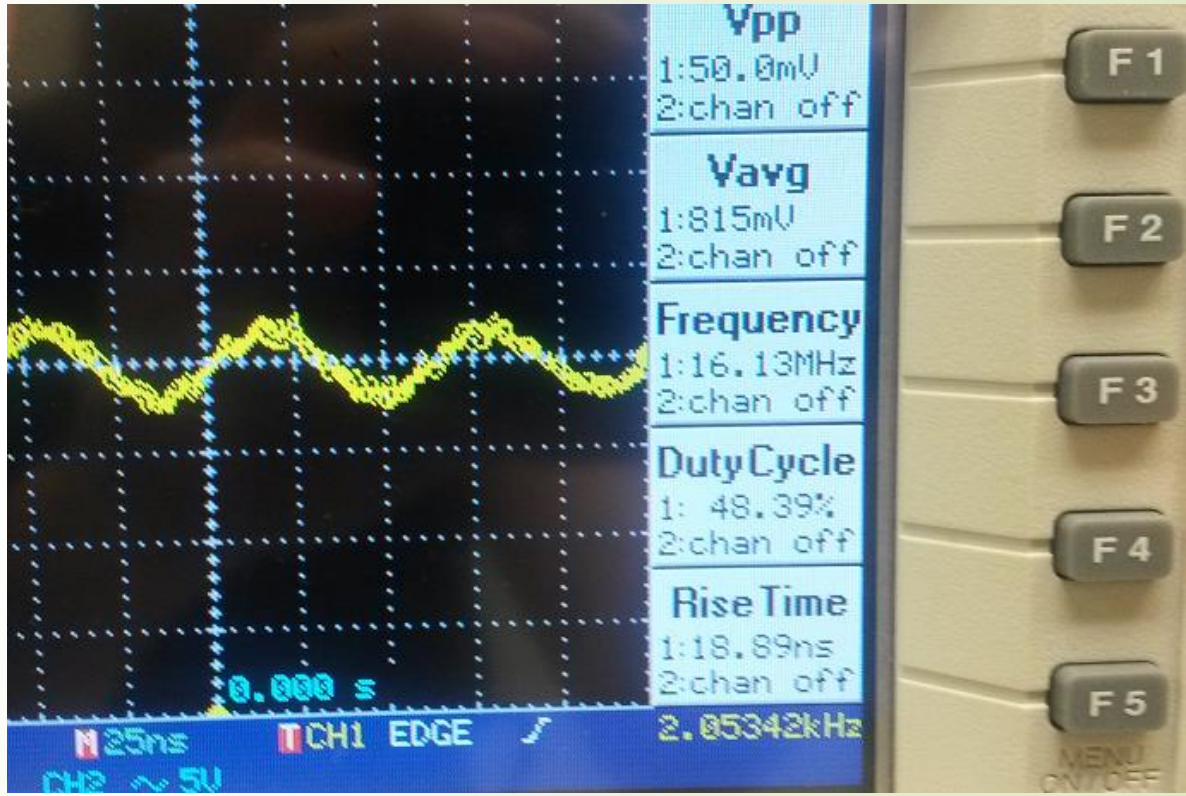
Arduino Micro

- ATmega 32u4
- Not enough PWM pins
  - Only 7
- Not enough resources for code

[15,16]

Problems with Crumbuino Mega

- Get a timeout error in Arduino IDE
  - Error means anything can be wrong
    - EG:
      - Bad Bootloader
      - Bad components
      - Bad BAUD rate
- Problem with board?
  - Checked continuity of components
  - Checked crystal
  - Checked Vbus



Obtained from GwInstek GDS-2062

Solutions:

Crumbuino Mega

- Order new one
- Reload bootloader

Arduino Micro

- Most resources used in:
  - Applycalibrate()
  - Calibrate servos on separate program
  - Store tables in FLASH
- PWM pins
  - Use TLC5960 or 74VHC164

Interface Definition

ARDUINO MICRO PIN CONNECTIONS

PIN	STMBOL	FUNCTION
1	MOSI	MASTER OUT SLAVE IN
2	SS	SLAVE SELECT
3	TX	TRANSMIT / DIGITAL PIN 1
4	RX	RECEIVE / DIGITAL PIN 0
5	RST	RESET
6	GND	GROUND
7	D2	DIGITAL PIN 2 / SERIAL DATA LINE
8	D3	DIGITAL PIN 3 / SERIAL CLOCK LINE / PWM
9	D4	DIGITAL PIN 4 / ANALOG 6
10	D5	DIGITAL PIN 5
11	D6	DIGITAL PIN 6 / ANALOG 7 / PWM
12	D7	DIGITAL PIN 7
13	D8	DIGITAL PIN 8 / ANALOG 8
14	D9	DIGITAL PIN 9 / ANALOG 9 / PWM
15	D10	DIGITAL PIN 10 / ANALOG 10 / PWM
16	D11	DIGITAL PIN 11 / PWM
17	D12	DIGITAL PIN 12 / ANALOG 11
18	D13	DIGITAL PIN 13 / PWM
19	3V3	+3.3 V
20	REF	ANALOG REFERENCE
21	A0	ANALOG 0
22	A1	ANALOG 1
23	A2	ANALOG 2
24	A3	ANALOG 3
25	A4	ANALOG 4
26	A5	ANALOG 5
27	NC	NOT CONNECTED
28	NC	NOT CONNECTED
29	5V	+5.0 V
30	RST	RESET
31	GND	GROUND
32	VIN	VOLTAGE IN (7-12 V)
33	MISO	MASTER IN SLAVE OUT
34	SCK	SYNCHRONOUS CLOCK

HC-SR04

PIN	STMBOL	FUNCTION
1	VCC	VOLTAGE SOURCE
2	TRIG	TRIGGER INPUT
3	ECHO	ECHO OUTPUT
4	GND	GROUND

HC-06 BLUETOOTH V2 CLASS 2.0

PIN	STMBOL	FUNCTION
1	VCC	VOTLAGE SOURCE
2	GND	GROUND
3	TXD	TRANSMITE
4	RXD	RECEIVE

L3GD20

PIN	STMBOL	FUNCTION
1	GND	GORUND
2	VCC	VOLTAGE SOURCE
3	SCL	SERIAL CLOCK LINE
4	SDA	SERIAL DATA LINE
5	SDO	SERIAL DATA OUTPUT
6	CS	SPI ENABLE
7	INT2	PROGRAMMABLE INTERRUPT
8	INT1	PROGRAMMABLE INTERRUPT

SERVO

WIRE COL	STMBOL	FUNCTION
ORANGE	O	PWM INPUT
BROWN	B	GROUND
RED	R	VOLTAGE SOURCE

TLC5940

PIN	STMBOL	FUNCTION
1	OUT1	Constant Current Output
2	OUT2	Constant Current Output
3	OUT3	Constant Current Output
4	OUT4	Constant Current Output
5	OUT5	Constant Current Output
6	OUT6	Constant Current Output
7	OUT7	Constant Current Output
8	OUT8	Constant Current Output
9	OUT9	Constant Current Output
10	OUT10	Constant Current Output
11	OUT11	Constant Current Output
12	OUT12	Constant Current Output
13	OUT13	Constant Current Output
14	OUT14	Constant Current Output
15	OUT15	Constant Current Output
16	XERR	Error output
17	SOUT	Serial data output
18	GSCLK	Reference clock for grayscale PWM
19	DCPRG	Switch DC data input
20	IREF	Reference current terminal
21	VCC	Power supply voltage
22	GND	Ground
23	BLANK	Blank all outputs
24	XLAT	Level triggered latch signal
25	SCLK	Serial data shift clock
26	SIN	Serial data input
27	VPRG	Multifunction input. (GND,VCC)
28	OUT0	Constant Current Output

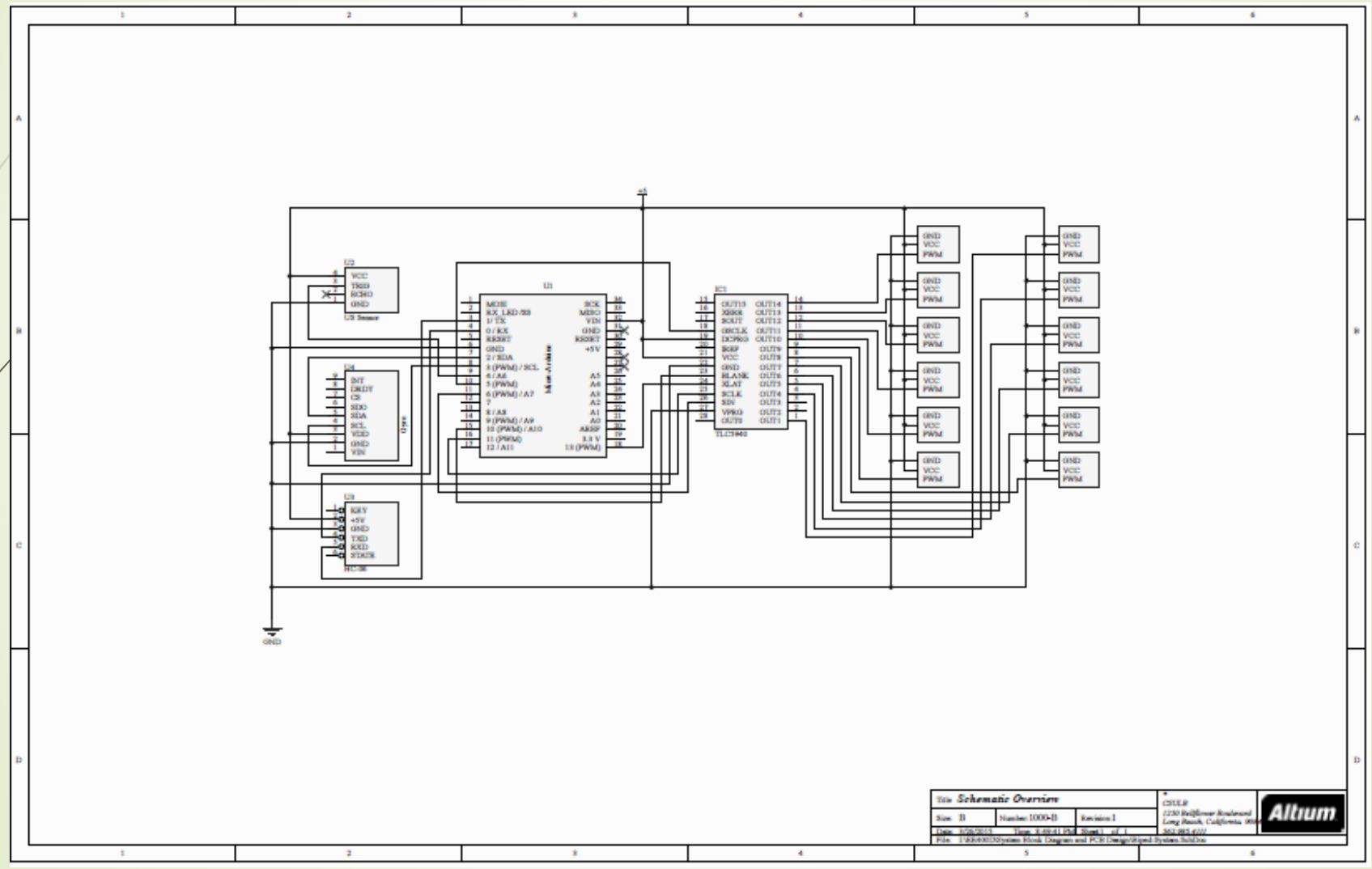
Pin connections

HC-SR04		TO	ARDUINO MICRO	
PIN	SYMBOL		PIN	SYMBOL
1	VSS	⟷	29	5V
2	TRIG	⟷	9	D4
3	ECHO	⟷	-	-
4	GND	⟷	6	GND
HC-06				
1	VCC	⟷	19	3V3
2	GND	⟷	6	GND
3	TXD	⟷	4	RX
4	RXD	⟷	3	TX
L3G4200D				
1	GND	⟷	6	GND
2	VCC	⟷	19	3V3
3	SCL	⟷	8	D3
4	SDA	⟷	7	D2
5	SD0	⟷	19	3V3
6	CS	⟷	-	-
7	INT2	⟷	-	-
8	INT1	⟷	-	-

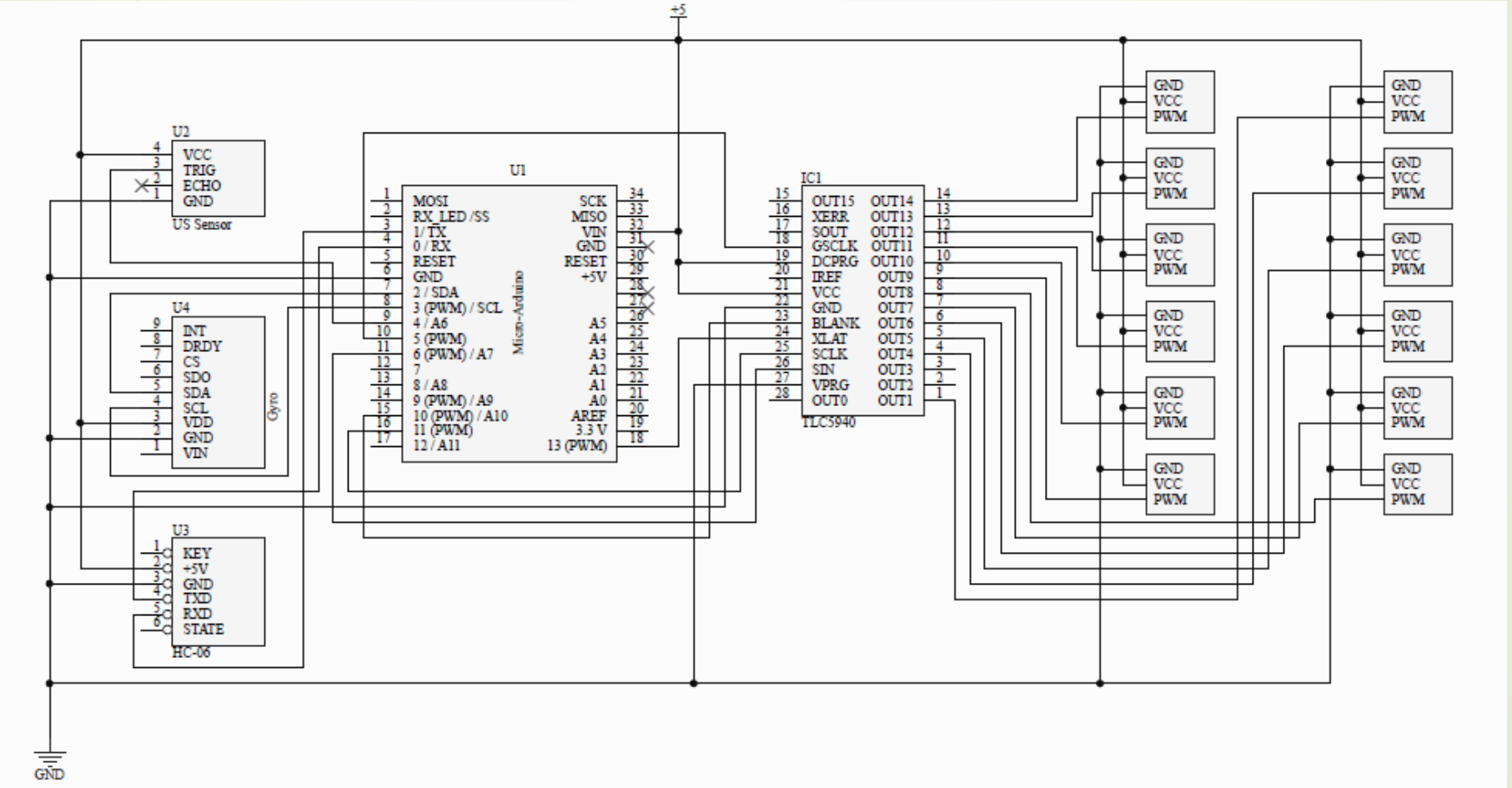
TLC5940				
1	OUT1	⟷	-	-
2	OUT2	⟷	-	-
3	OUT3	⟷	-	-
4	OUT4	⟷	-	-
5	OUT5	⟷	-	-
6	OUT6	⟷	-	-
7	OUT7	⟷	-	-
8	OUT8	⟷	-	-
9	OUT9	⟷	-	-
10	OUT10	⟷	-	-
11	OUT11	⟷	-	-
12	OUT12	⟷	-	-
13	OUT13	⟷	-	-
14	OUT14	⟷	-	-
15	OUT15	⟷	-	-
16	XERR	⟷	-	-
17	SOUT	⟷	-	-
18	GSCLK	⟷	10	D5
19	DCPRG	⟷	-	-
20	IREF	⟷	-	-
21	VCC	⟷	-	-
22	GND	⟷	-	-
23	BLANK	⟷	15	D10
24	XLAT	⟷	16	D13
25	SCLK	⟷	17	D12
26	SIN	⟷	-	-
27	VPRG	⟷	15	VPRG
28	OUT0	⟷	-	-

SERVOS			TLC5940	
ORANGE	O	⟷	OUT1	1
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT4	4
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT5	5
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT6	6
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT7	7
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT8	8
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT9	9
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT10	10
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT11	11
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT12	12
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT13	13
BROWN	B	⟷	-	-
RED	R	⟷	-	-
ORANGE	O	⟷	OUT14	14
BROWN	B	⟷	-	-
RED	R	⟷	-	-

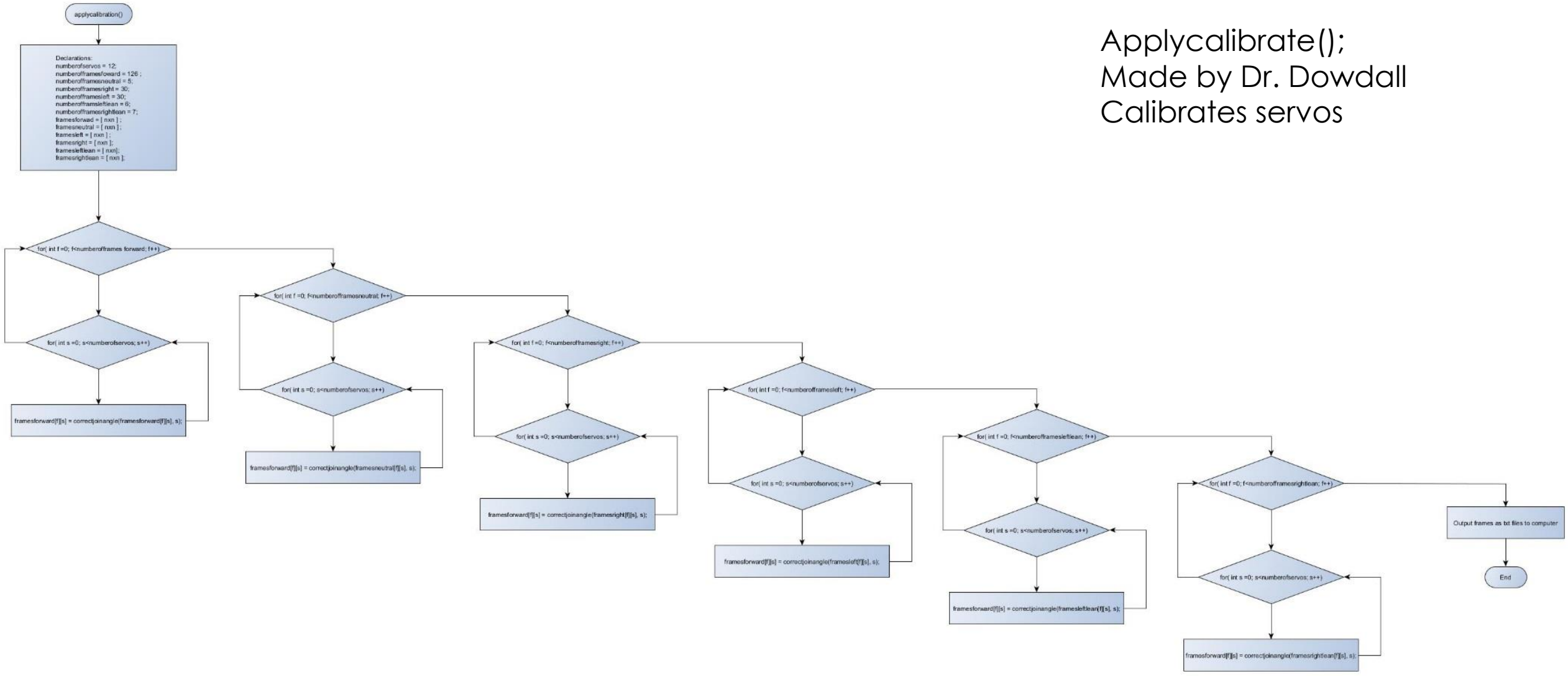
Circuit Definition



Closer view

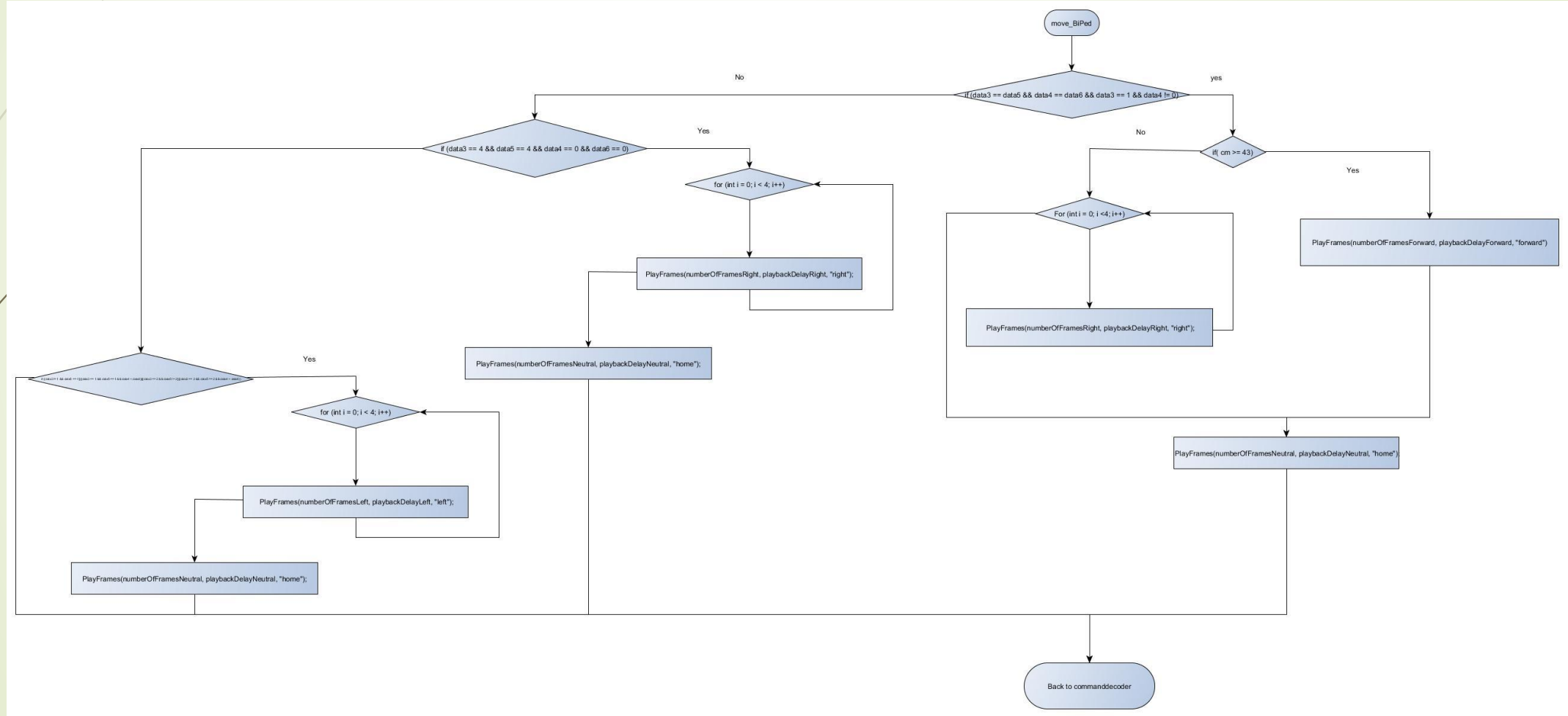

+5
U2
VCC
TRIG
ECHO
GND
US Sensor
U4
INT
DRDY
CS
SDO
SDA
SCL
VDD
GND
VIN
Gyro
U3
KEY
+5V
GND
TXD
RXD
STATE
HC-06
U1
MOSI
RX_LED /SS
1/ TX
0 / RX
RESET
GND
2 / SDA
3 (PWM) / SCL
4 / A6
5 (PWM)
6 (PWM) / A7
7
8 / A8
9 (PWM) / A9
10 (PWM) / A10
11 (PWM)
12 / A11
SCK
MISO
VIN
GND
RESET
+5V
A5
A4
A3
A2
A1
A0
AREF
3.3 V
13 (PWM)
Micro-Arduino
IC1
OUT15
XERR
SOUT
GSCLK
DCPRG
IREF
VCC
GND
BLANK
XLAT
SCLK
SIN
VPRG
OUT0
OUT14
OUT13
OUT12
OUT11
OUT10
OUT9
OUT8
OUT7
OUT6
OUT5
OUT4
OUT3
OUT2
OUT1
TLC5940
GND
VCC
PWM
GND

Flowcharts:

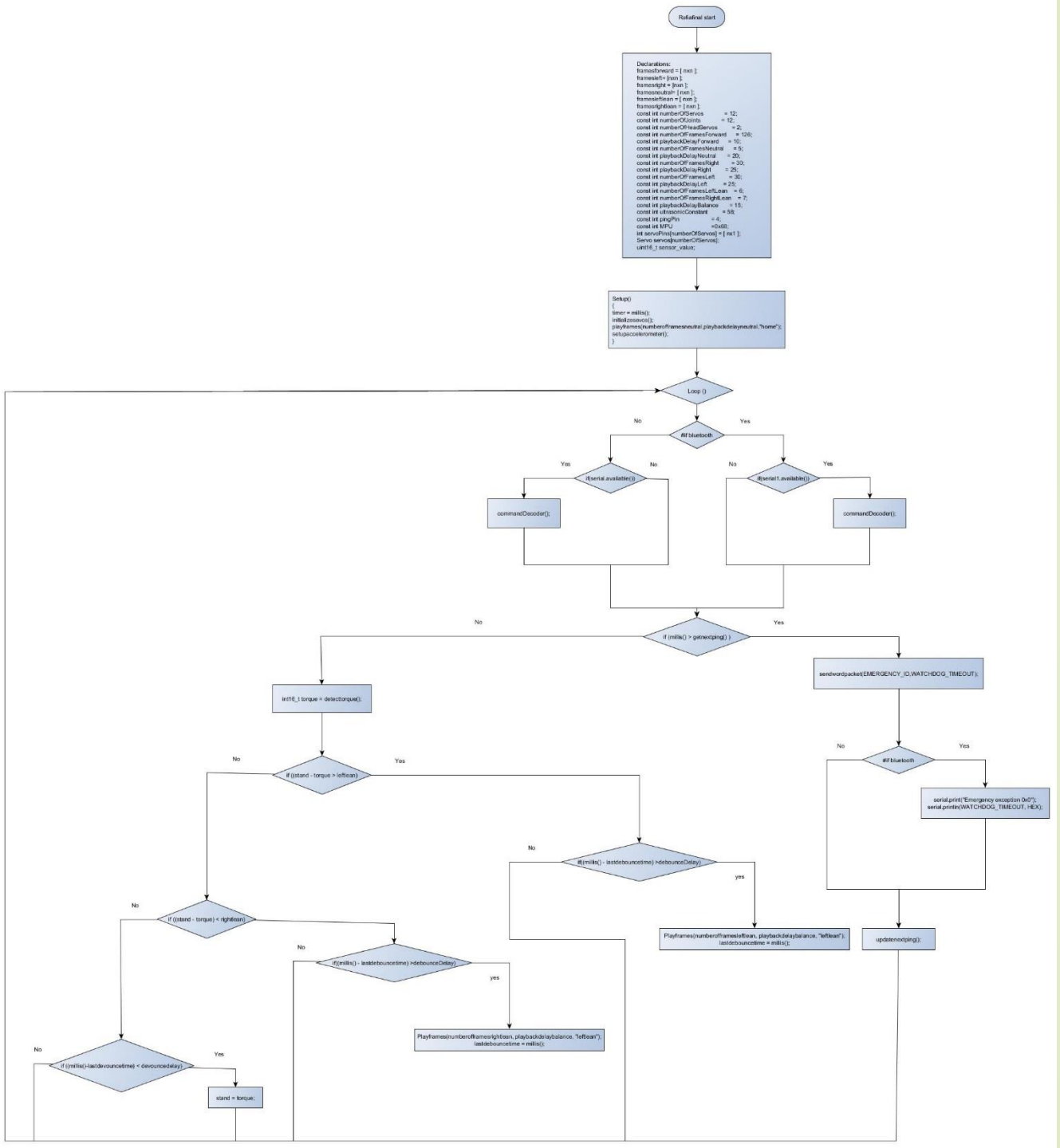


Applycalibrate();
Made by Dr. Dowdall
Calibrates servos

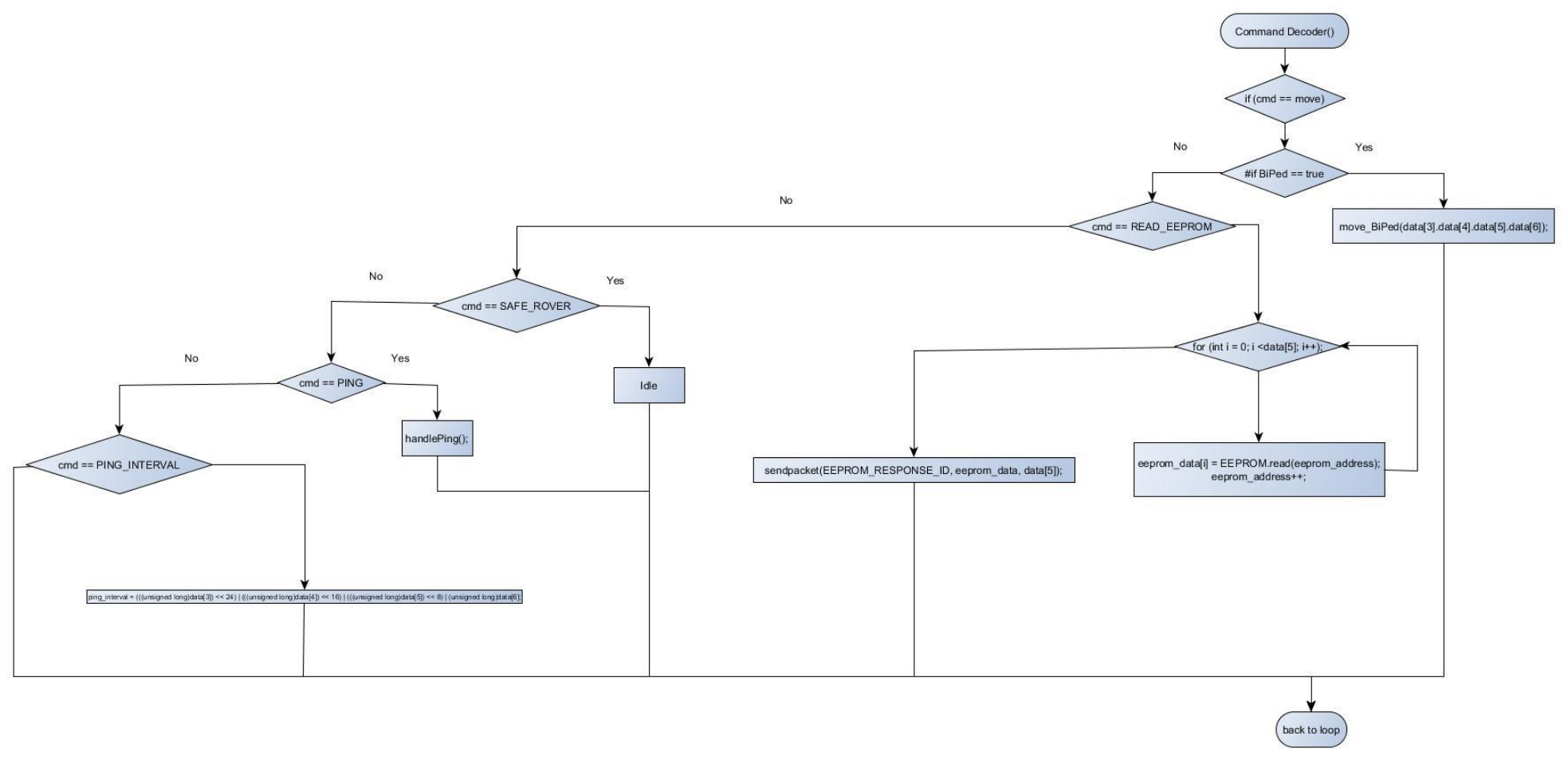
Move_BiPed();
Takes telemetry and decides what movement



Main loop();
Does force calculations and commands for BiPed



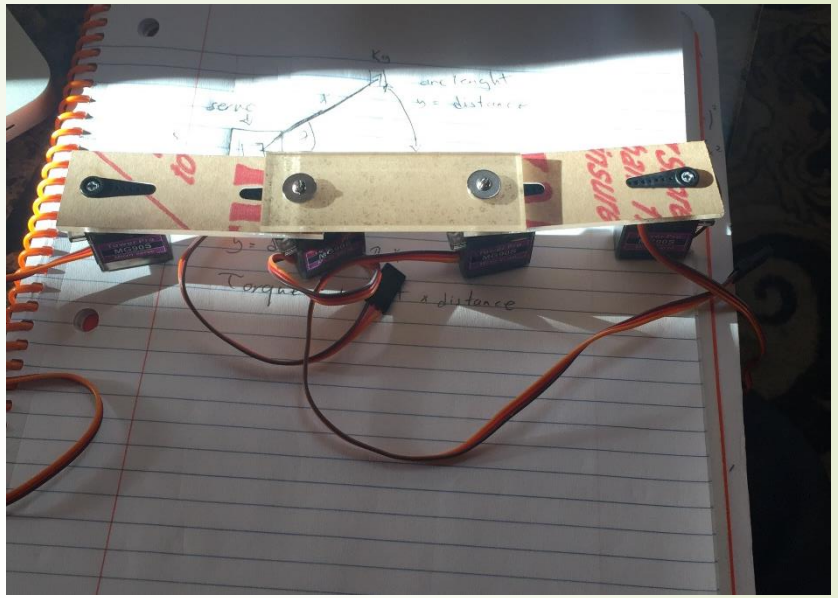
commanddecoder();
Reads commands from Arxterra

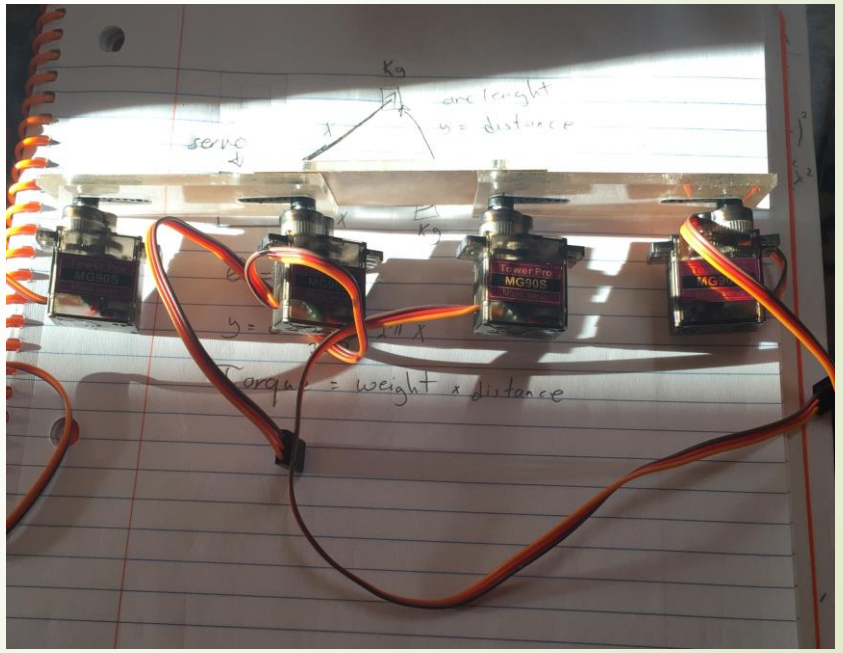


Prototype
For verification:

Used SolidWorks to prototype the leg of the micro Biped project. The type of plastic used is acrylic plastic 20”x21” sheet with 0.123” thickness.

Arnel Ignacio from design department helped in cutting it.





Mass Report

Values are measured

Mass report

Devices	Mass (g)	Quantity	Total Mass (g)
Arduino Micro Atmega 32u4	13	1	13
Micro Servos (MG905)	13.4	12	160.8
Sain Smart HC-SR04 Ultrasonic Sensor	8.5	1	8.5
L3G4200D	13	1	13
HC-06	1	1	1
Battery	43	2	86
Plastic	227	1	227
Total Mass			509

Power Break Down

Values are measured

Device	Quantity	Operating DC volt.(v)	Max Current (mA)	Operating Current (mA)	Total Current (mA)	Power (mW)
Micro Arduino	1	5	50	45	45	225
Servos	12	5	448(Stall)	120	1440	7200
HC-SR04	1	5	15	15	15	75
L3GD20	1	5	7	5.1	5.1	25.5
HC-06	1	5	45	40	40	200
TLC5940	1	5	120	60	60	300
Total					1605.1	8025.5

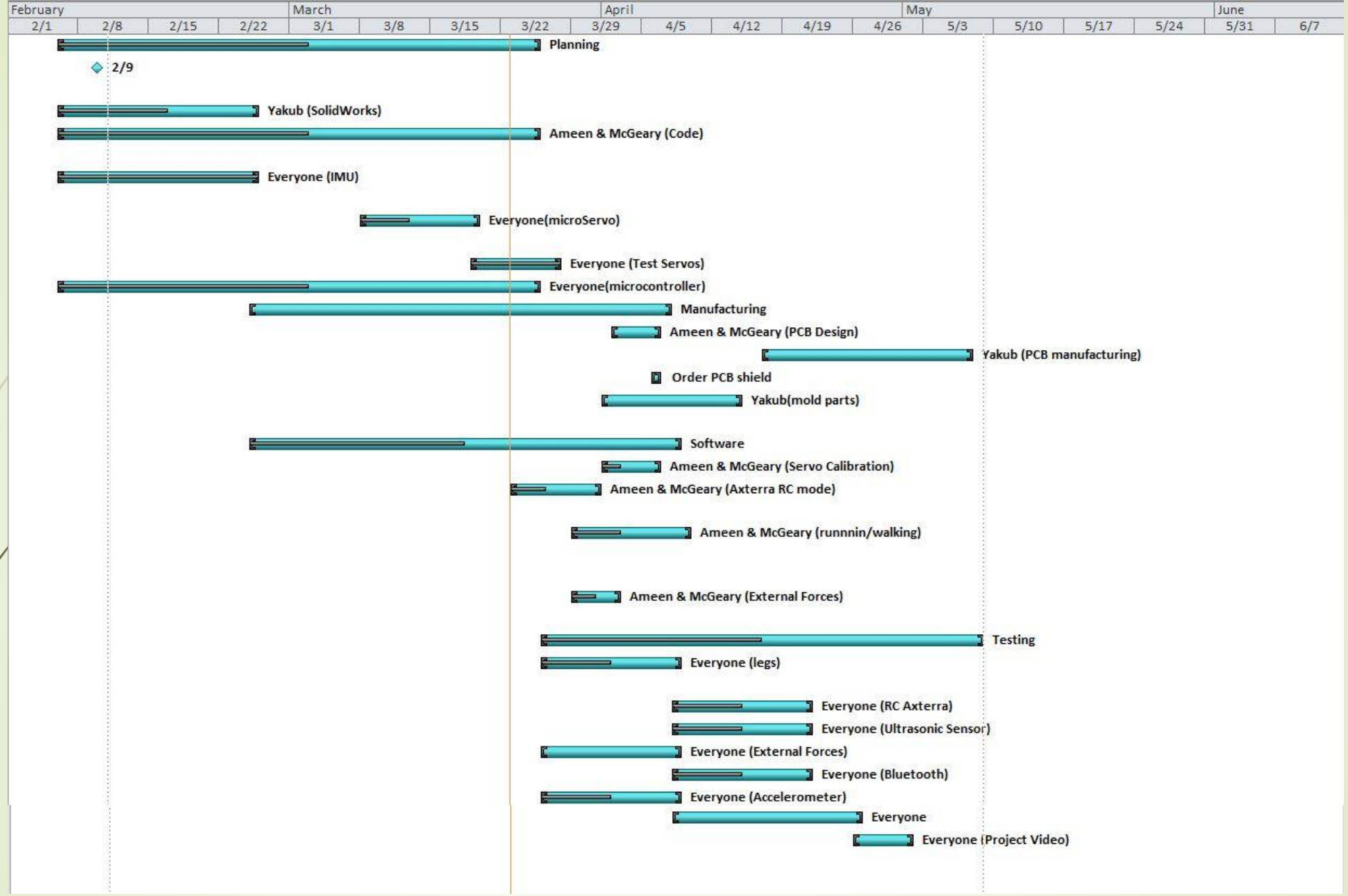
Updated Cost:

Parts	Quantity	Price	Subtotal	Margin (%)	Margin ($)
Microservo	12	$ 4.96	$ 59.52	15	$ 8.93
#1585 2 Layer PCB	1	$ 43.15	$ 43.15	15	$ 6.47
Battery charger	1	$ 15.00	$ 15.00	10	$ 1.50
Gyro	1	$ 9.96	$ 9.96	15	$ 1.49
Bluetooth	2	$ 4.50	$ 9.00	10	$ 0.90
Radio Shack Ping Ultra-Sonic Range Finder Distange Sensor by Parallax for Arduino and More 276-0031 28015	1	$ -	$ -	15	$ -
Battery	2	$ 4.30	$ 8.60	15	$ 1.29
Microcontroller	1	$ 17.99	$ 18.65	10	$ 1.87
Silicone Mold Maker	5	$ -	$ -	15	$ -
Casting Resin	5	$ -	$ -	15	$ -
Epoxy	1	$ -	$ -	15	$ -
A26509-40-ND CONN HDR BRKWAY	2	$ 1.82	$ 3.64	15	$ 0.55
CONN FEMALE 34POS	1	$ 1.53	$ 3.06	15	$ 0.46
S7004-ND CONN HEADER FEMALE 6POS	3	$ 0.68	$ 2.04	15	$ 0.31
S5520-ND CONN HEADER FEMALE 12POS	1	$ 1.53	$ 1.53	15	$ 0.23
Splitter Parallel Battery Connector	1	$ 5.99	$ 5.99	15	$ 0.90
Connector Adapter Plug Converter	1	$ 6.99	$ 6.99	15	$ 1.05
Crumbuino Mega 45	1	$ 52.00	$ 52.00	10	$ 5.20
TLC5940	1	$ 6.59	$ 6.59	10	0.659
Shipping Costs and Tax		$ 30.00	$ 30.00	15	$ 4.50
		All Parts	$ 275.72	Margin (+/-)	$ 36.30

Original budget $393.72; Current projected cost $275.72

New schedule

	Task Mode	Task Name	Duration	Start	Finish	Resource Names	% Complete
		Planning	**34 days**	**Fri 2/6/15**	**Wed 3/25/15**	**Planning**	**50%**
✓		Choose material for skeleton	0 days	Sat 2/7/15	Mon 2/9/15	Plastic (ABS)	100%
		SolidWorks Model	14 days	Fri 2/6/15	Wed 2/25/15	Yakub (SolidWorks)	50%
		Reviewing previous code	34 days	Fri 2/6/15	Wed 3/25/15	Ameen & McGeary (Code)	50%
✓		Accelerometer/Gyro IMU	14 days	Fri 2/6/15	Wed 2/25/15	Everyone (IMU)	100%
		Choose/buy microServos	10 days	Sun 3/8/15	Thu 3/19/15	Everyone(microSer	50%
✓		Test microServos	7 days	Thu 3/19/15	Fri 3/27/15	Everyone (Test Ser	100%
		Choose microcontroller	34 days	Fri 2/6/15	Wed 3/25/15	Everyone(microcor	50%
		Manufacturing	**30 days**	**Wed 2/25/15**	**Tue 4/7/15**	**Manufacturing**	**0%**
		PCB Design	3 days	Thu 4/2/15	Mon 4/6/15	Ameen & McGeary	0%
		PCB Manufacturing	15 days	Fri 4/17/15	Thu 5/7/15	Yakub (PCB manufa	0%
		Order/ship PCB shield	1 day	Mon 4/6/15	Mon 4/6/15	Order PCB shield	0%
		Print 3-D parts/Mold Parts	10 days	Wed 4/1/15	Tue 4/14/15	Yakub(mold parts)	0%
		Software	**31 days**	**Wed 2/25/15**	**Wed 4/8/15**	**Software**	**50%**
		Servo calibration/center	4 days	Wed 4/1/15	Mon 4/6/15	Ameen & McGeary	50%
		Interface Axterra RC mode	7 days	Mon 3/23/15	Tue 3/31/15	Ameen & McGeary (Axterra RC mode)	50%
		Modify Run/Walking code to allow for stepping over	10 days	Sun 3/29/15	Thu 4/9/15	Ameen & McGeary (runnnin/walking)	50%
		Modify external force code	5 days	Sun 3/29/15	Thu 4/2/15	Ameen & McGeary (External Forces)	50%
		Testing	**32 days**	**Thu 3/26/15**	**Fri 5/8/15**	**Testing**	**50%**
		Test leg with new microServos	10 days	Thu 3/26/15	Wed 4/8/15	Everyone (legs)	50%
		Test Axterra RC mode	10 days	Wed 4/8/15	Tue 4/21/15	Everyone (RC Axter	50%
		Test Ultrasonic Sensor	10 days	Wed 4/8/15	Tue 4/21/15	Everyone (Ultrason	50%
		Test External Forces	10 days	Thu 3/26/15	Wed 4/8/15	Everyone (External	0%
		Test Bluetooth	10 days	Wed 4/8/15	Tue 4/21/15	Everyone (Bluetoo	50%
		Test	10 days	Thu 3/26/15	Wed 4/8/15	Everyone	50%
		Trouble Shooting	14 days	Wed 4/8/15	Sun 4/26/15	Everyone	0%
		Create Project Video	6 days	Sun 4/26/15	Fri 5/1/15	Everyone (Project)	0%


February
March
April
May
June
2/1
2/8
2/15
2/22
3/1
3/8
3/15
3/22
3/29
4/5
4/12
4/19
4/26
5/3
5/10
5/17
5/24
5/31
6/7
Planning
2/9
Yakub (SolidWorks)
Ameen & McGeary (Code)
Everyone (IMU)
Everyone(microServo)
Everyone (Test Servos)
Everyone(microcontroller)
Manufacturing
Ameen & McGeary (PCB Design)
Yakub (PCB manufacturing)
Order PCB shield
Yakub(mold parts)
Software
Ameen & McGeary (Servo Calibration)
Ameen & McGeary (Axterra RC mode)
Ameen & McGeary (runnnin/walking)
Ameen & McGeary (External Forces)
Testing
Everyone (legs)
Everyone (RC Axterra)
Everyone (Ultrasonic Sensor)
Everyone (External Forces)
Everyone (Bluetooth)
Everyone (Accelerometer)
Everyone
Everyone (Project Video)

PROJECT OVERVIEW

FRI 2/6/15 - FRI 5/8/15

% COMPLETE

41%

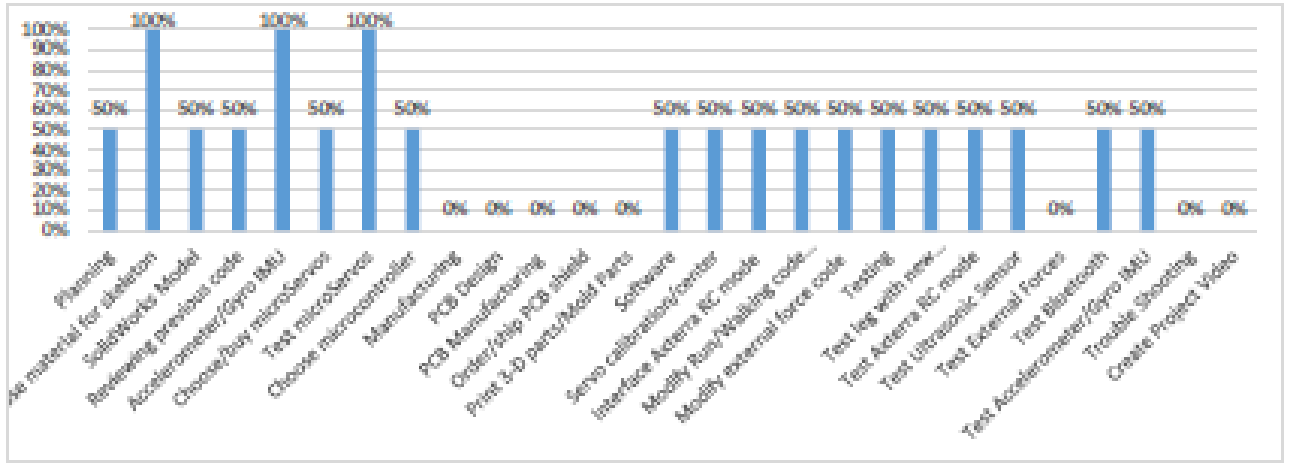
LATE TASKS

Tasks that are past due.

Name	Start	Finish	Duration	% Complete	Resource Names
Planning	Fri 2/6/15	Wed 3/25/15	34 days	50%	Planning
SolidWorks Model	Fri 2/6/15	Wed 2/25/15	14 days	50%	Yakub (SolidWorks)
Reviewing previous code	Fri 2/6/15	Wed 3/25/15	34 days	50%	Ameen & McGeary (Code)
Choose/buy microServos	Sun 3/8/15	Thu 3/19/15	10 days	50%	Everyone(microServo)
Choose microcontroller	Fri 2/6/15	Wed 3/25/15	34 days	50%	Everyone(microcontroller)
Manufacturing	Wed 2/25/15	Tue 4/7/15	30 days	0%	Manufacturing
Software	Wed 2/25/15	Wed 4/8/15	31 days	50%	Software

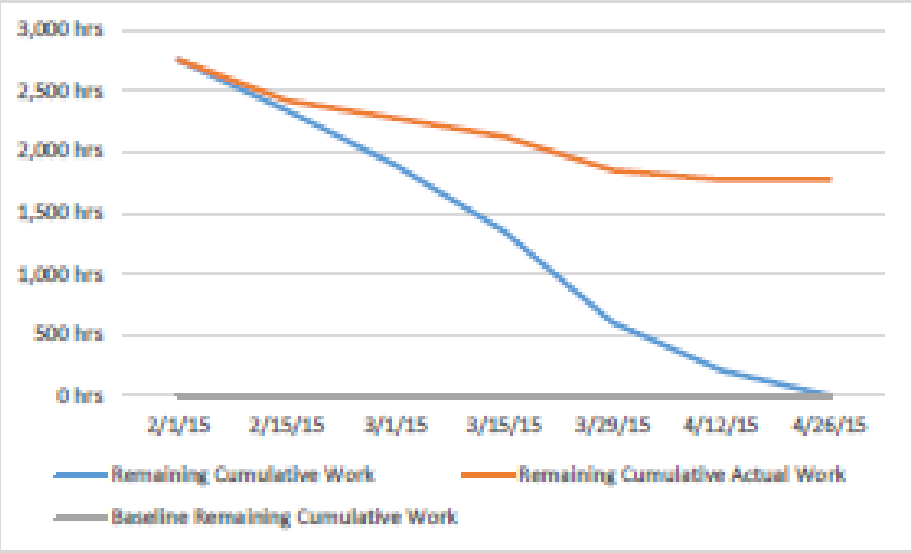
% COMPLETE

Status for all top-level tasks. To see the status for subtasks, click on the chart and update the outline level in the Field List.



Fri 2/6/15 - Fri 5/8/15

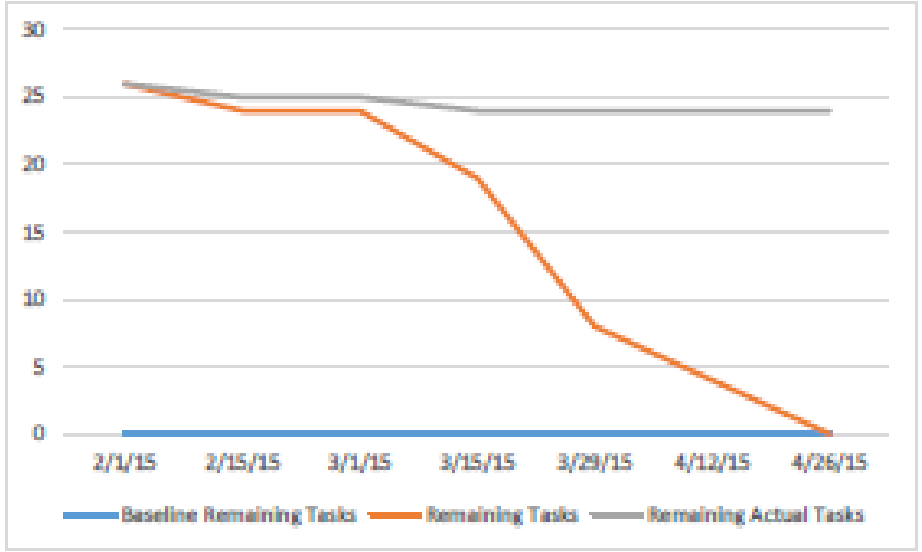
BURNDOWN



WORK BURNDOWN

Shows how much work you have completed and how much you have left. If the remaining cumulative work line is steeper, then the project may be late. Is your baseline zero?

Try setting a baseline



TASK BURNDOWN

Shows how many tasks you have completed and how many you have left. If the remaining tasks line is steeper, then your project may be late.

Learn more

Resources:

1. http://www.turbocad.com/Portals/1/Charts/PLA%20Uses.pdf
2. http://www.stratasys.com/~/media/en/Materials/FDM/PC%20ABS/pc_abs_spec_sheet.pdf
3. http://teststandard.com/data_sheets/ABS_Data_sheet.pdf
4. ABS. Stratasys Inc. (2007).
5. Imre, B. Renner, K. Pukanszky, B. "Interactions, Structure nad properties in poly(latic acid)/thermoplastic polymer blends." *eXPRESS Polymer Letters Vol. 8, No. 1 (2014) 2-14. WEB*
6. https://www.nde-ed.org/EducationResources/CommunityCollege/Materials/Structure/polymer.htm
7. http://makezine.com/2014/11/11/abs-or-pla-choosing-the-right-filament/
8. http://data.energizer.com/PDFs/nickelmetalhydride_appman.pdf
9. http://www.slideshare.net/khanpin2/polyfuse
10. http://www.st.com/web/en/resource/technical/document/datasheet/CD00000455.pdf
11. http://www.batteryspace.com/prod-specs/SPECIFICATION_9V250%5B1%5D_1.pdf
12. http://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-battery-life
13. http://treehouseprojects.ca/ultrasonictutorial/
14. http://arduinobasics.blogspot.com/2012/11/arduinobasics-hc-sr04-ultrasonic-sensor.html
15. https://www.chip45.com/products/crumbuino-mega_arduino_compatible_atmega2560_module_board_usb.php
16. http://arduino.cc/en/Main/arduinoBoardMicro

Appendix A:
ABS thermoplastic specifications

Property	English		Metric
Density	0.03757lb/inch^3		1.04g/cm^3
Tensile Strength/yield	4700/4500 psi		33/31MPA
Modulus Strength	320000psi		2200MPA
Tensile Elongation at Break/yield	6/2%		6/2%
Melting Point	220^0F		105^0C

[2,3]

Appendix B: PLA thermoplastic specifications

Property	English	Metric
Density	0.0448lb/inch^3	1.24g/cm^3
Tensile Strength/yield	21000/15000psi	144.5/103.2MPA
Modulus Strength	500000psi	3440MPA
Tensile Elongation at Break/yield	180/100%	180/100%
Melting Point	320^0F	160^0C

[1]

Appendix C:
Difference between NiMH and LiPO

NiMH Vs. LiPO

Feature	NiMH	LiPO
Weight	0.6 Wh/gram	0.132 Wh/gram
Rated Voltage	1.25 V	3.7 V
Safety	Save	Dangerous
Efficient	At high rate discharges	More efficient
Temperature	-10 to 65	-20 to 60

[8,11]

Appendix D:

Code

```
// Sweep
// by BARRAGAN <http://barraganstudio.com>
// This example code is in the public domain.


#include <Servo.h>

Servo myservo;  // create servo object to control a servo
                // a maximum of eight servo objects can be created

int pos = 0;    // variable to store the servo position

void setup()
{
  myservo.attach(9);  // attaches the servo on pin 9 to the servo object
}


void loop()
{
  for(pos = 0; pos < 180; pos += 1)  // goes from 0 degrees to 180 degrees
  {                                  // in steps of 1 degree
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
  for(pos = 180; pos>=1; pos-=1)     // goes from 180 degrees to 0 degrees
  {
    myservo.write(pos);              // tell servo to go to position in variable 'pos'
    delay(15);                       // waits 15ms for the servo to reach the position
  }
}
```

http://arduino.cc/en/Tutorial/sweep