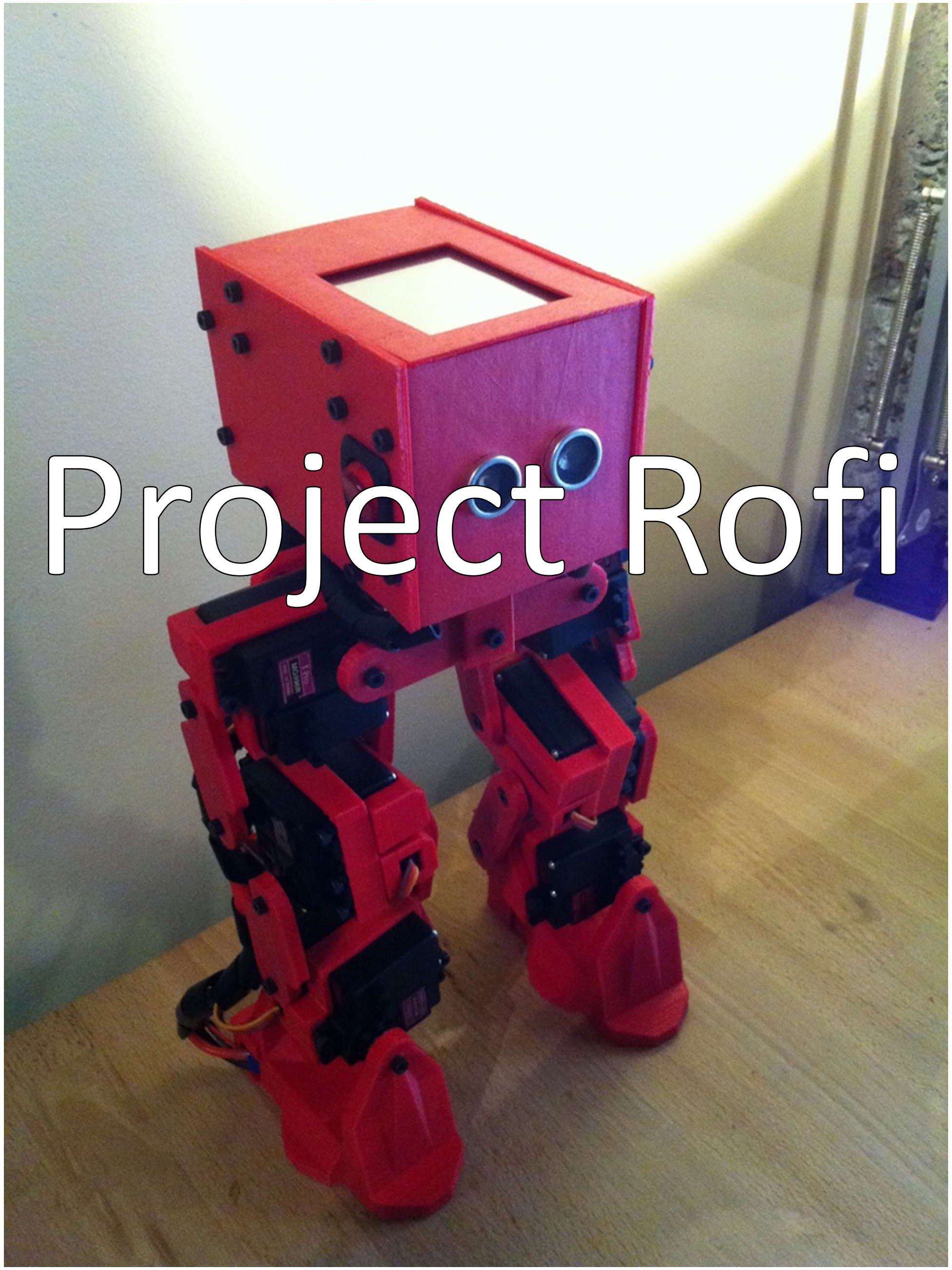

Project Rofi

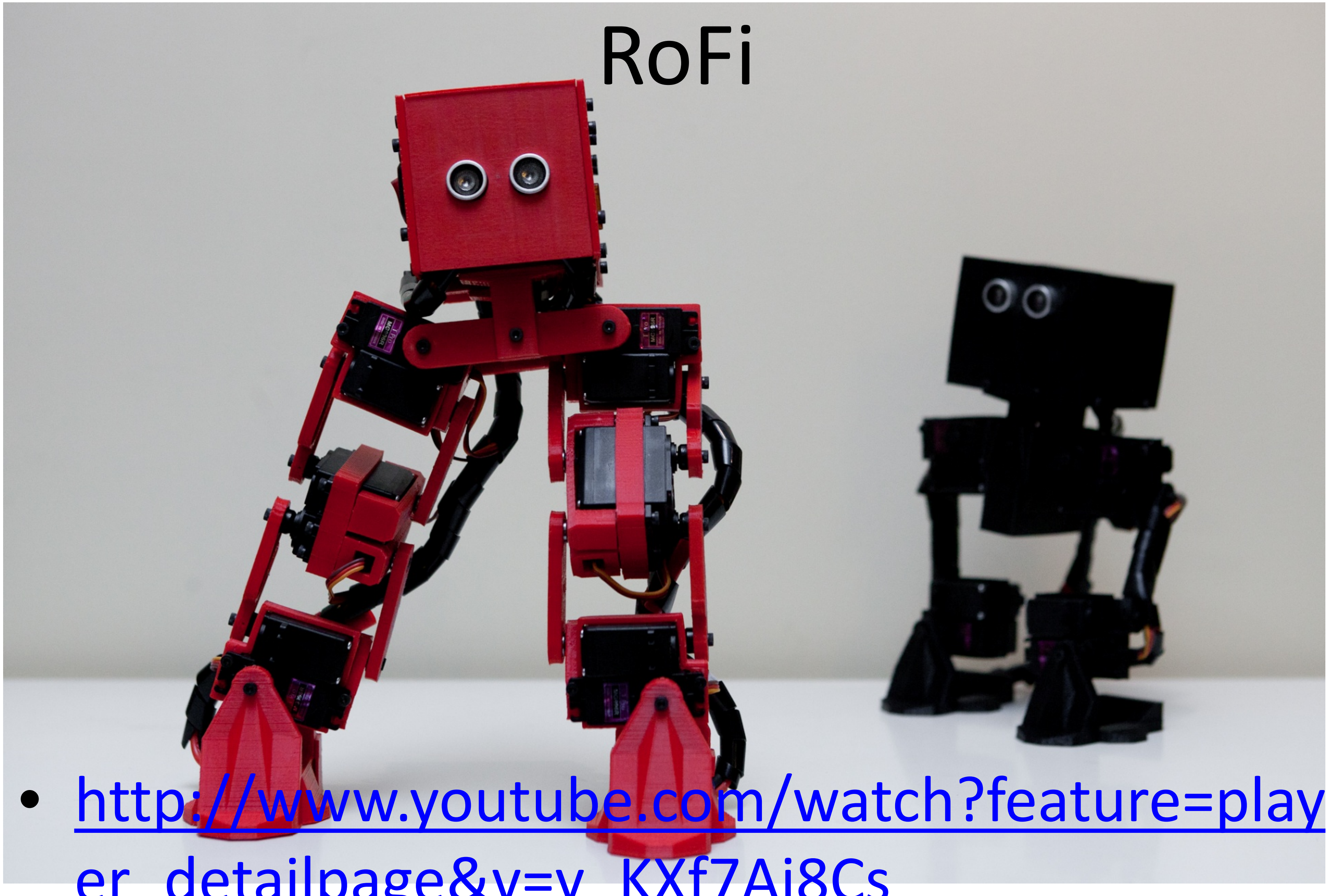
Research

- Project Biped by Jonathan Dowdall
  - Fobo and Foba : static balanced
  - Rofi: static but with accelerometer feedback to smooth walking
  - http://www.projectbiped.com

Rofi vs Fobo

	FoBo	Rofi
Static/Dynamic	Static	Partially Dynamic
FeedBack	None	Accelerometer
“Brain”	Arduino Uno	Android
Degrees of Freedom	8	12
Sensors	Ultrasonic Range	Ultrasonic Range, Accelerometer (Android)
Batteries	1 at center	2, one at each foot
Plastic	193cc, 206g (about 1/5 spool)	ABS plastic 1.75mm, 1kg
Build Time	18 hours: 16 hours printing + 2 hours assembly	30 hours: 25 hours printing + 5 hours assembly
Size	9.5cm x 15.25cm x 24cm (4.5” x 6” x 9.5”)	17.75cm x 11.45cm x 30.5cm (7” x 4.5” x 12”)

RoFi



- http://www.youtube.com/watch?feature=player_detailpage&v=y_KXf7Aj8Cs

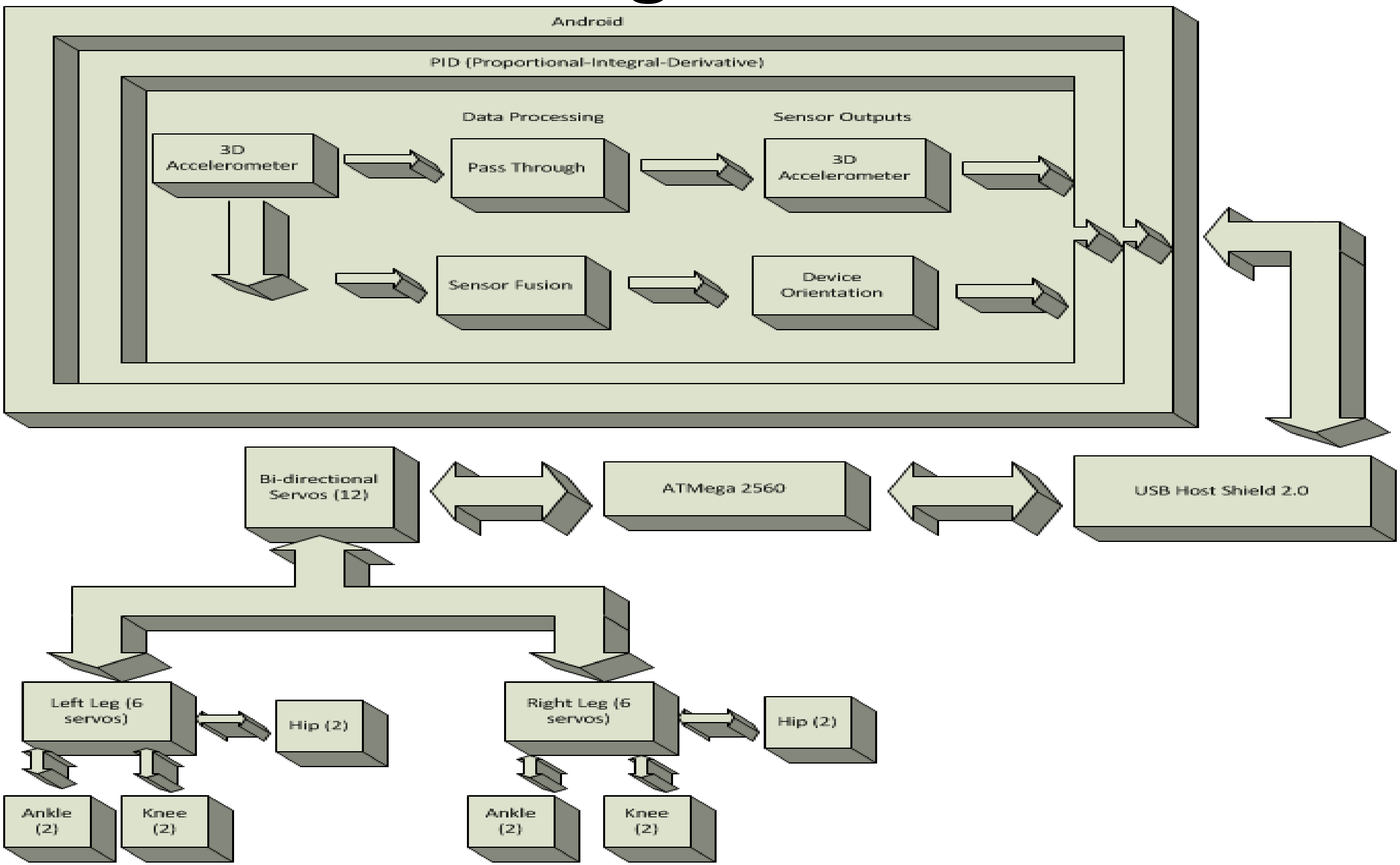
DareL-Next Generation Biped Robot

- **D**ynamic **A**ndroid **R**obot, **E**ngineered in **L**ong beach
- Take elements from RoFi and improve upon them to build dynamic balanced walking robot.

Requirements

- Complete and implement Rofi according to Jonathon Dowdall’s specifications.
- Design and Implement DareL, creating a fully dynamic biped robot

Block Diagram Level 2



Interface Capabilities of our Integrated System

Analog

Arduino	*ATMega2560*		*To Call Pin*		*USB Host Shield*		*Servos*	*IR Sensors*
PIN 0	PIN 97		PF0 (ADC0)					
PIN 1	PIN 96		PF1 (ADC1)					
PIN 2	PIN 95		PF2 (ADC2)					
PIN 3	PIN 94		PF3 (ADC3)					
PIN 4	PIN 93		PF4 (ADC4/TCK)					
PIN 5	PIN 92		PF5 (ADC5/TMS)					Data Signal
PIN 6	PIN 91		PF6 (ADC6/TD0)					
PIN 7	PIN 90		PF7 (ADC7/TDI)					
PIN 8	PIN 89		PK0 (ADC8/PCINT16)					
PIN 9	PIN 88		PK1 (ADC9/PCINT17)		INT			
PIN 10	PIN 87		PK2 (ADC10/PCINT18)		SS			
PIN 11	PIN 86		PK3 (ADC11/PCINT19)					
PIN 12	PIN 85		PK4 (ADC12/PCINT20)					
PIN 13	PIN 84		PK5 (ADC13/PCINT21)					
PIN 14	PIN 83		PK6 (ADC14/PCINT22)					
PIN 15	PIN 82		PK7 (ADC15/PCINT23)					

Interface Capabilities of our Integrated System (Cont.)

PWM (Pulse With Modulation)

Arduino	*ATMega2560*		*To Call Pin*		*USB Host Shield*		*Servos*	*IR Sensors*
PIN 13	PIN 26		PB7 (OC0A/OC1C/PCINT7)					
PIN 12	PIN 25		PB6 (OC1B/PCINT6)					
PIN 11	PIN 24		PB5 (OC1A/PCINT5)					
PIN 10	PIN 23		PB4 (OC2A/PCINT4)					
PIN 9	PIN 18		PH6 (OC2B)					
PIN 8	PIN 17		PH5 (OC4C)					
PIN 7	PIN 16		PH4 (OC4B)					
PIN 6	PIN 15		PH3 (OC4A)					
PIN 5	PIN 5		PE3 (OC3A/AIN1)					
PIN 4	PIN 1		PG5 (OC0B)					
PIN 3	PIN 7		PE5 (OC3C/INT5)					
PIN 2	PIN 6		PE4 (OC3B/INT4)					

Interface Capabilities of our Integrated System (Cont.)

Communication

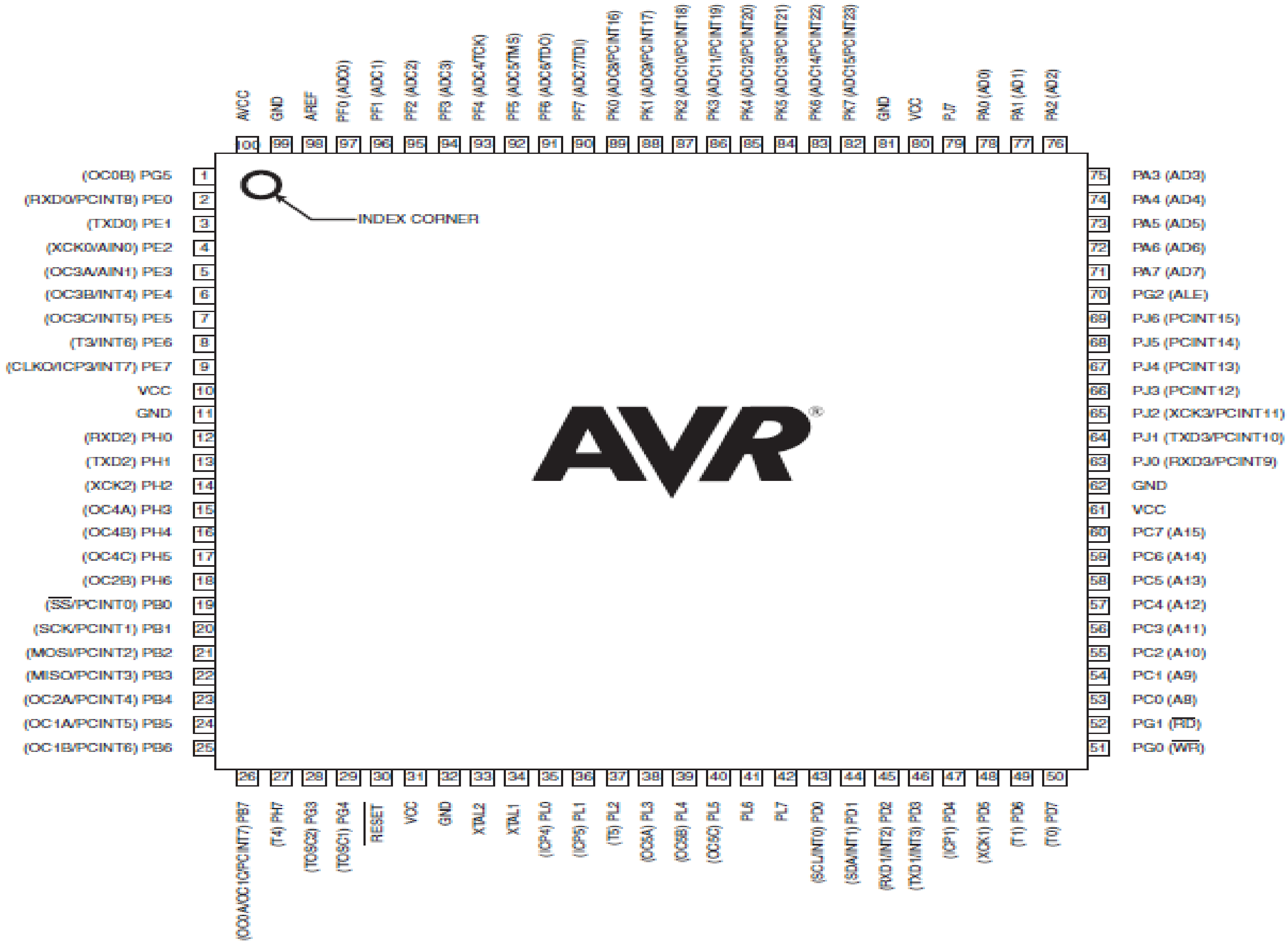
Arduino	*ATMega2560*		*To Call Pin*		*USB Host Shield*		*Servos*	*IR Sensors*
PIN 1	PIN 3		PE1 (TXD0)					
PIN 0	PIN 2		PE0 (RXD0/PCINT8)					
PIN 14	PIN 64		PJ1 (TXD3/PCINT10)					
PIN 15	PIN 63		PJ0 (RXD3/PCINT9)					
PIN 16	PIN 13		PH1 (TXD2)					
PIN 17	PIN 12		PH0 (RXD2)					
PIN 18	PIN 46		PDE (TXD1/INT3)					
PIN 19	PIN 45		PD2 (RXD1/INT2)					
PIN 20	PIN 44		PD1 (SDA/INT1)					
PIN 21	PIN 43		PD0 (SCL/INT0)					

Interface Capabilities of our Integrated System (Cont.)

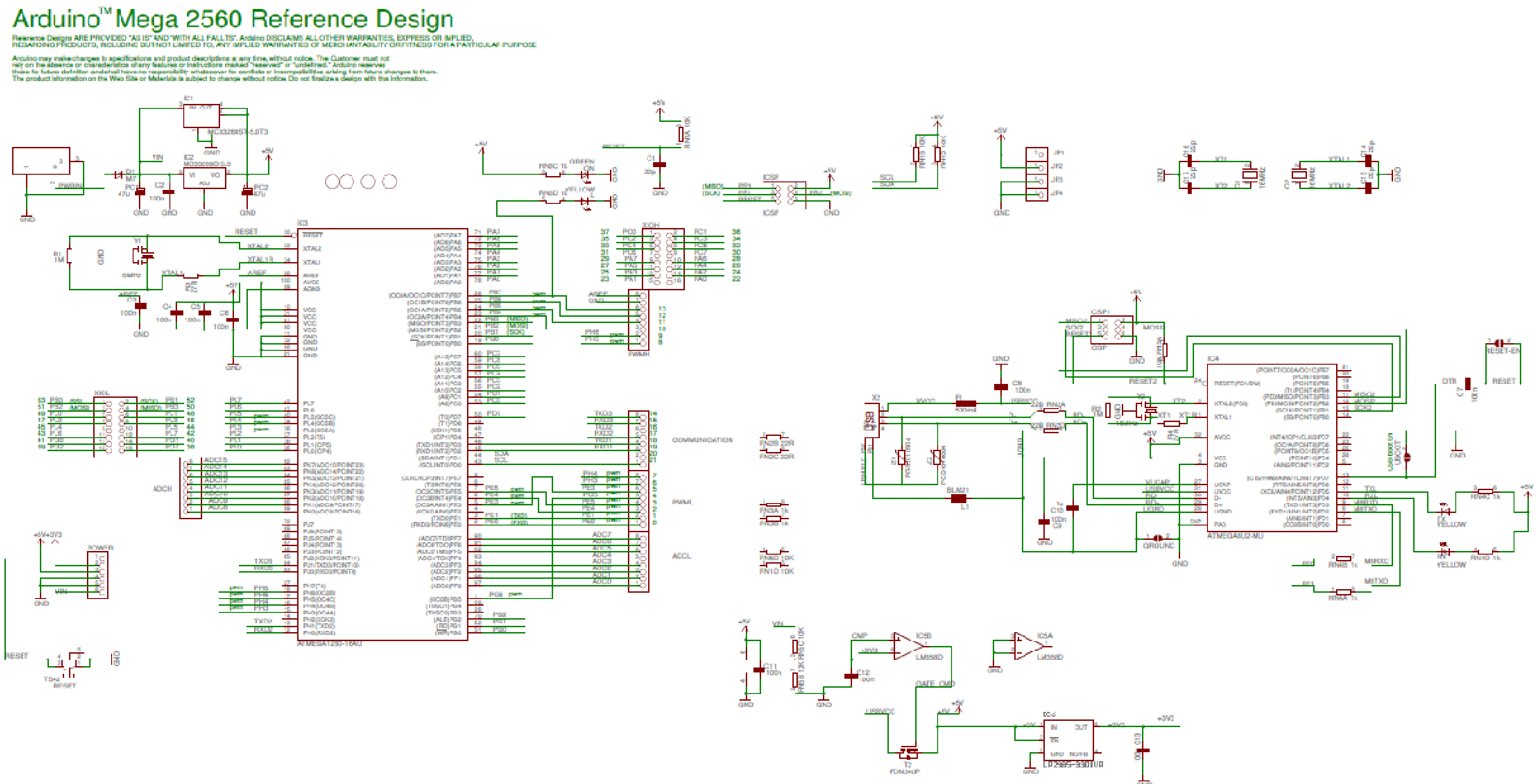
Digital

Arduino	*ATMega2560*	*To Call Pin*	*USB Host Shield*	*Servos*	*IR sensors*
PIN 22	PIN 78	PA0 (AD0)		Control Signal (Ankle)	
PIN 23	PIN 77	PA1 (AD1)			
PIN 24	PIN 76	PA2 (AD2)		Control Signal (Lower Leg)	
PIN 25	PIN 75	PA3 (AD3)			
PIN 26	PIN 74	PA4 (AD4)		Control Signal (Knee)	
PIN 27	PIN 73	PA5 (AD5)			
PIN 28	PIN 72	PA6 (AD6)		Control Signal (Middle Leg)	
PIN 29	PIN 71	PA7 (AD7)			
PIN 30	PIN 60	PC7 (A15)		Control Signal (Upper Leg)	
PIN 31	PIN 59	PC6 (A14)			
PIN 32	PIN 58	PC5 (A13)		Control Signal (Hip)	
PIN 33	PIN 57	PC4 (A12)			
PIN 34	PIN 56	PC3 (A11)			
PIN 35	PIN 55	PC2 (A10)			
PIN 36	PIN 54	PC1 (A9)			
PIN 37	PIN 53	PC0 (A8)			
PIN 38	PIN 50	PD7 (T0)			
PIN 39	PIN 70	PG2 (ALE)			
PIN 40	PIN 52	PG1 (/RD)		Control Signal (Ankle)	
PIN 41	PIN 51	PG0 (/WR)			
PIN 42	PIN 42	PL7		Control Signal (Lower Leg)	
PIN 43	PIN 41	PL6			
PIN 44	PIN 40	PL5 (OC5C)		Control Signal (Knee)	
PIN 45	PIN 39	PL4 (OC5B)			
PIN 46	PIN 38	PL3 (OC5A)		Control Signal (Middle Leg)	
PIN 47	PIN 37	PL2 (T5)			
PIN 48	PIN 36	PL1 (ICP5)		Control Signal (Upper Leg)	
PIN 49	PIN 35	PL0 (ICP4)			
PIN 50	PIN 22	PB3 (MISO/PCINT3)	Connected via ICSP (MISO)	Control Signal (Hip)	
PIN 51	PIN 21	PB2 (MOSI/PCINT2)	Connected via ICSP (MOSI)		
PIN 52	PIN 20	PB1 (SCK/PCINT1)	Connected via ICSP (SCK)		
PIN 53	PIN 19	PB0 (/SS/PCINT0)			
GND			GND	GND	GND
AREF					
5V PIN			PWR	PWR	PWR

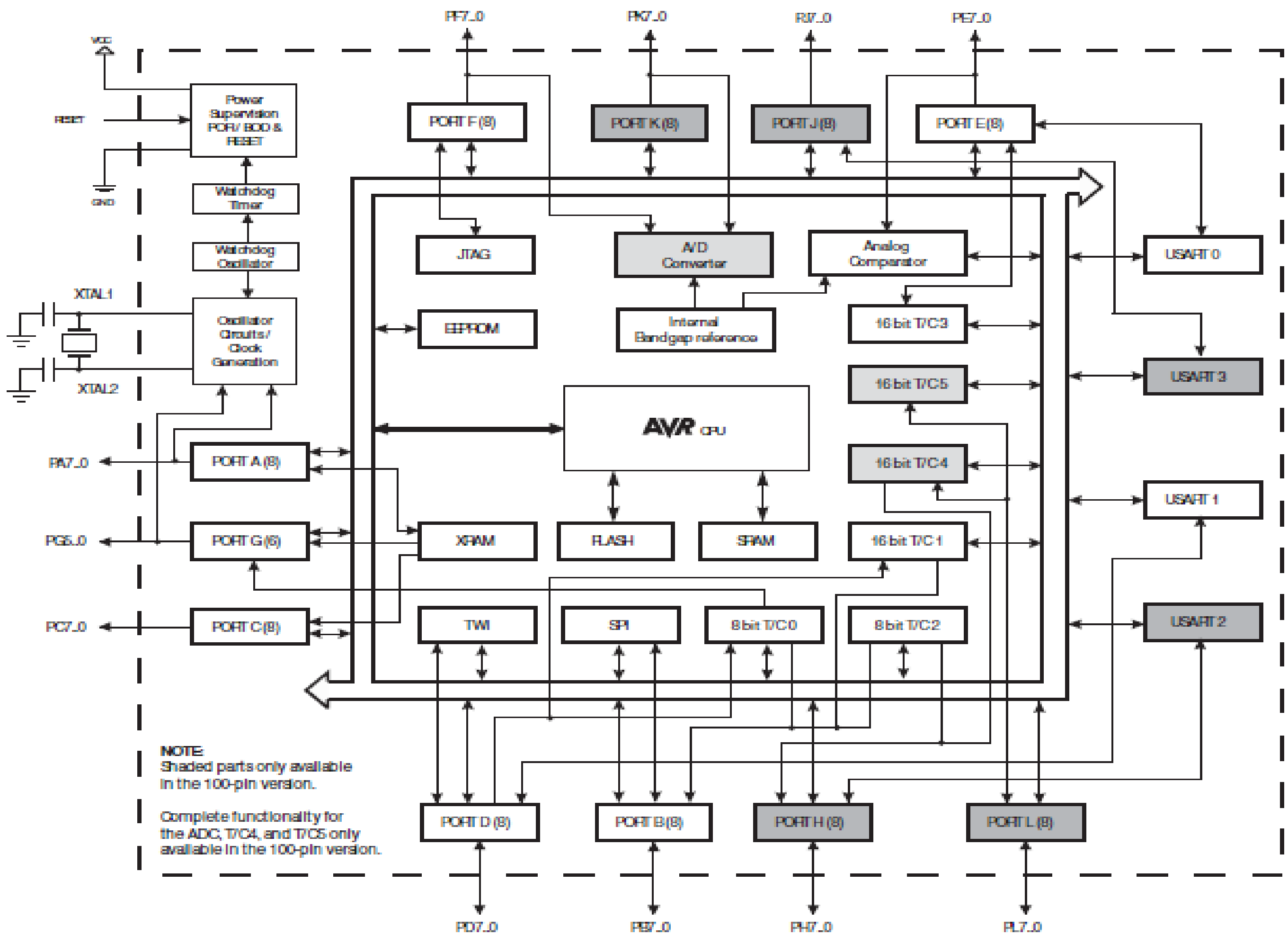
ATmega2560 Pin Configuration(TQFP –pinout)



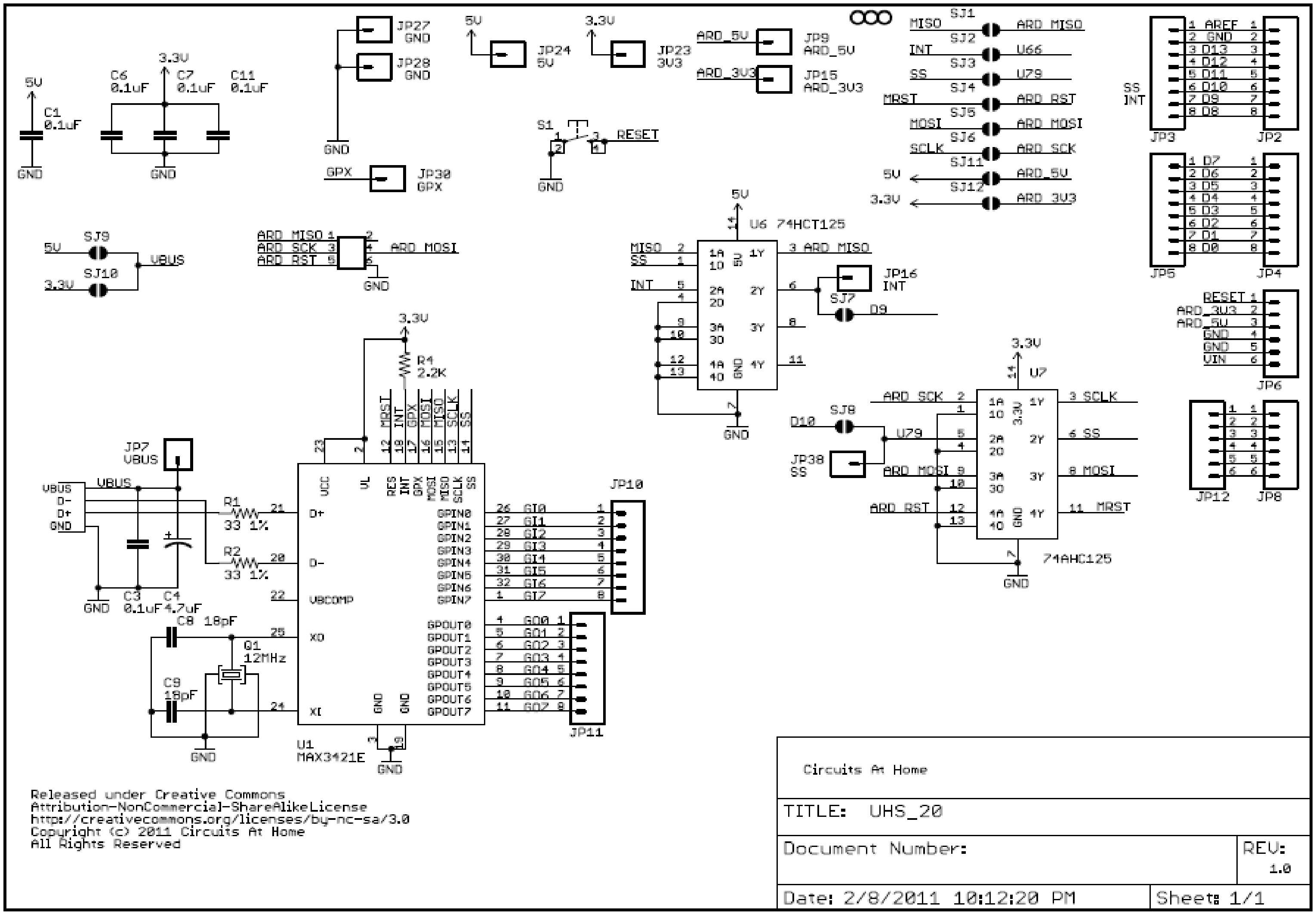
ATmega2560 Schematic



Block Diagram for the ATmega2560



USB Host Shield 2.0 Pin Configuration



Software Requirements-Rofi and DareL

<u>Top-Top Level</u>

- Establish bi-directional connection between Arduino and Android
- Program Android application that sends commands to move servos with Accelerometer and Gyro feedback.

Hardware + Software

- Arduino (C++)
  - Servo library
  - Microbridge library
- Eclipse (Java)
  - Microbridge library
  - Android SDK

- Arduino Mega 2560
- USB Host Shield
- Archos Android Tablet
- USB Micro B to USB A cable

How It Works

- Create a server that listens to a port on the Android device via TCP (Programmed in Java)
- Arduino client connects to the port via TCP (Programmed in C++)
- Android Debug Bridge forwards TCP request connecting Arduino & Android

Current Status of Android/Arduino Interface

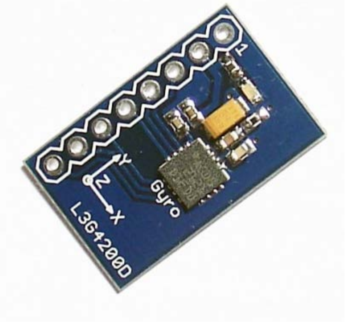
- Android Application
  - Communication with Arduino via microbridge success
  - Accelerometer values successfully accessed in Android

To Do

- Send Arduino gyro values to Android
- Program sensor filter with Accelerometer & Gyro in Java
- Program PID controller with sensor feedback in Java
- Correlate servo movement with PID output and send commands to Arduino

Sensors-Gyroscope

- A gyroscope measures angular velocity, through integration we can get angle.
- The Gyroscope is accurate from the start but over time suffers from the drift effect

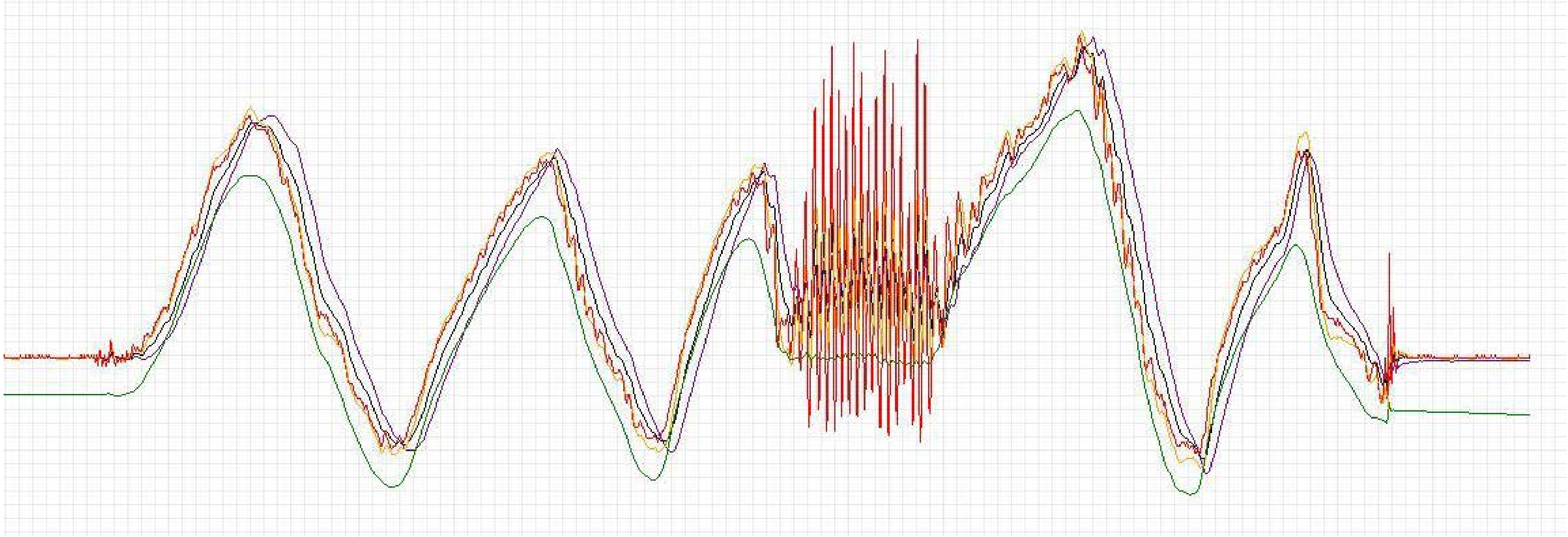


Complementary Filter

- Through using the complementary filter, we plan on mixing, combining, and then estimating the data received from the Gyroscope and Accelerometer
- A complementary filter will compensate for the gyroscope drift effect and the accelerometer vibration error giving an accurate reading.
- It is a simplified version of the Kalman filter

Example

- Red - accelerometer
- Green - Gyro
- Blue - Kalman filter
- Black - complementary filter
- Yellow - the second order complementary filter



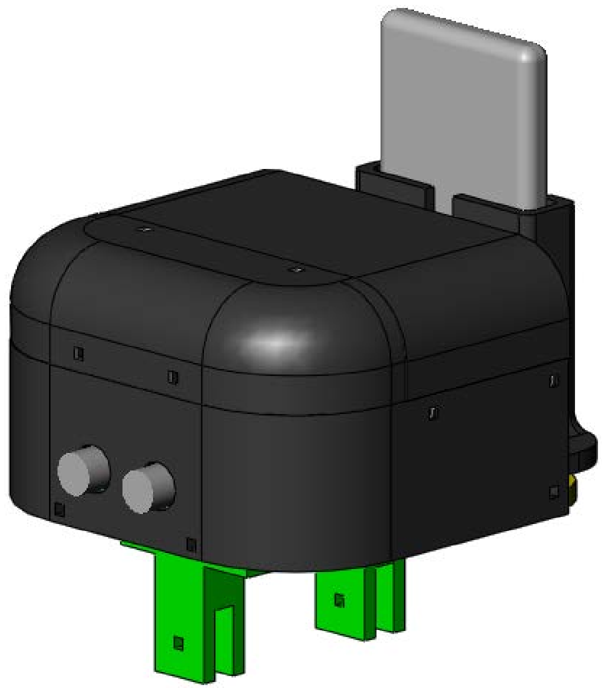
Sensors-IR Ranger

- We plan to replace the ultrasonic sensor with an IR ranger for DareL, possibly Rofi
- Will improve accuracy over ultrasonic sensor by reducing the “field of view”

References

- “ A Comparison of Complementary and Kalman Filtering” by WALTER T. HIGGINS, JR.
- http://www.ocf.berkeley.edu/~tmtong/kalman.php
- http://web.mit.edu/scolton/www/filter.pdf
- http://robottini.altervista.org/kalman-filter-vs-complementary-filter
- Sensors Powerpoint found in EE 444 reference page by Professor Hill

DareL
Next Generation 3d Modeling



Objectives For New Design:

- Main objective: move toward Dynamic Balance
  - Raise center of gravity by moving the batteries out of the feet
  - Re-design the foot
    - To address lack of battery
    - Narrower foot-print (instability)
    - "Organic Curves“

- Secondary Objective: Incorporate internal phone sensors
  - Re-design "Head"
    - Re-orient phone to take advantage of back camera (if available)
    - Devise mount system to adapt to size of available phone (upgrade capable)
    - Make room for Batteries, Ultrasonic/IR sensor, Gyro (if available)
    - "Organic Curves"

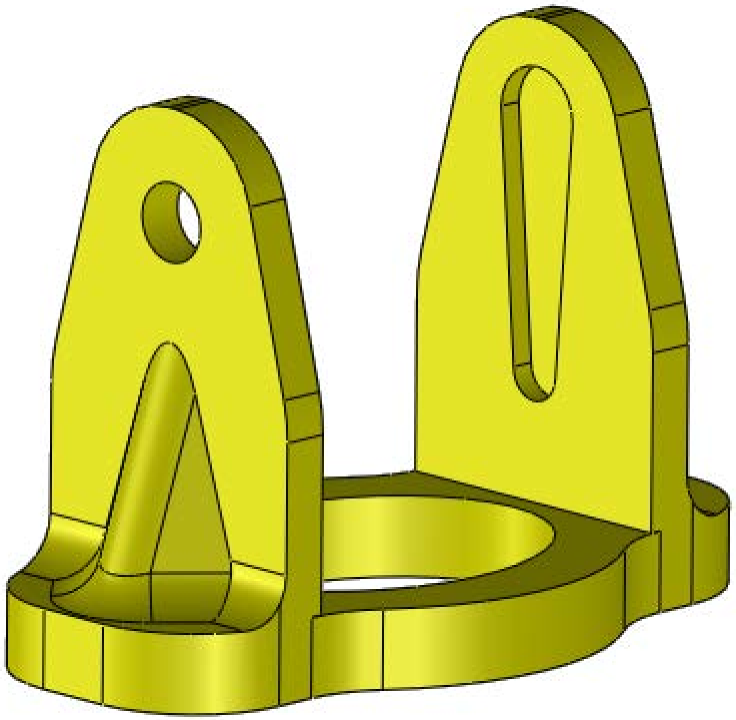
Execution of Objectives

- Parts List:
  - Uniform Foot
  - Head Bottom
  - Phone Bracket Left
  - Phone Bracket Right
  - Head Sides
  - Head Top
  - Head Dome

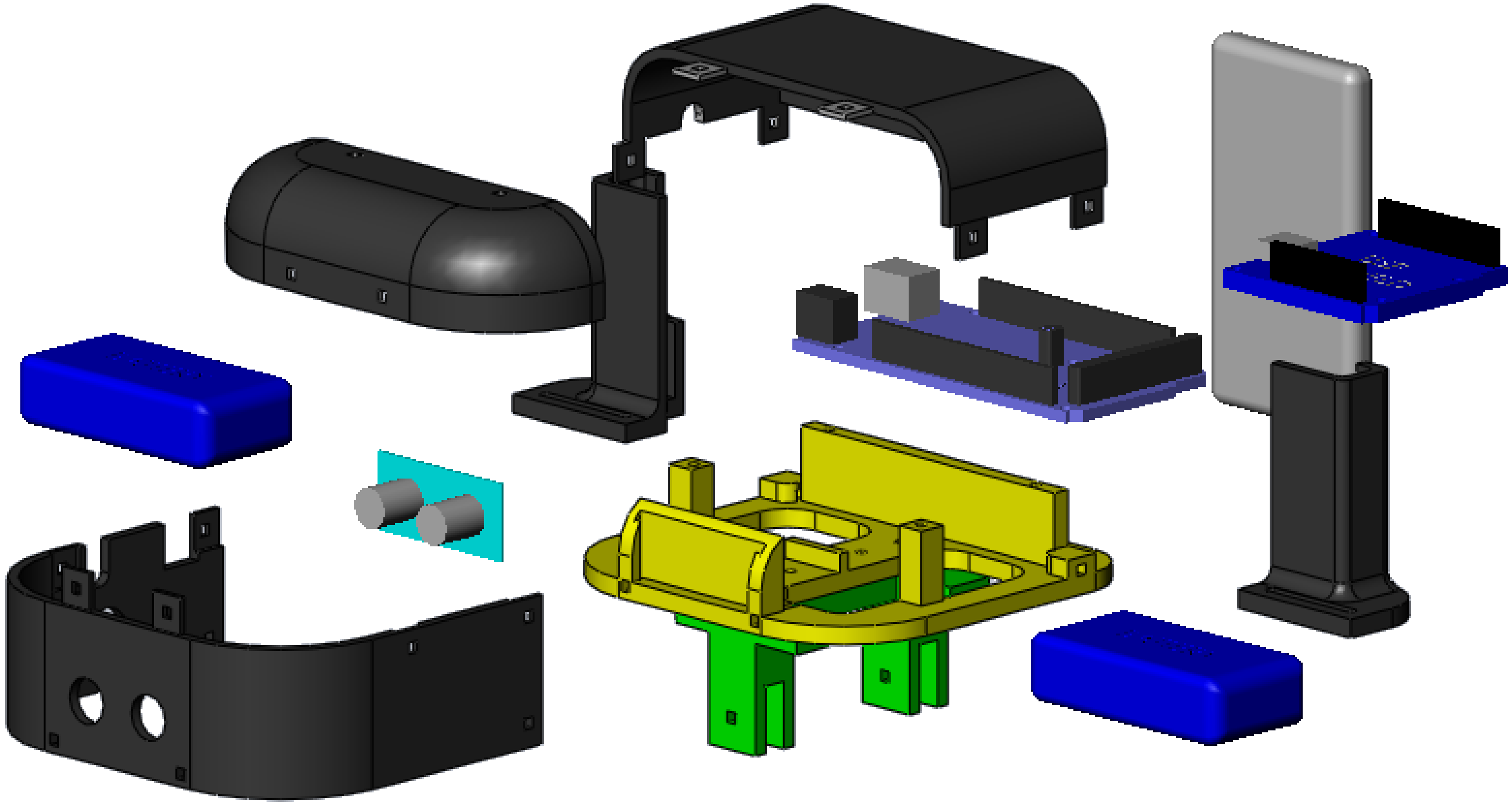
    \+ Body Riser from Original ROFI

Uniform Foot

- Same model for both left and right
- Thicker walls around bearing holes
- Narrower Footprint
- “Organic Curves”

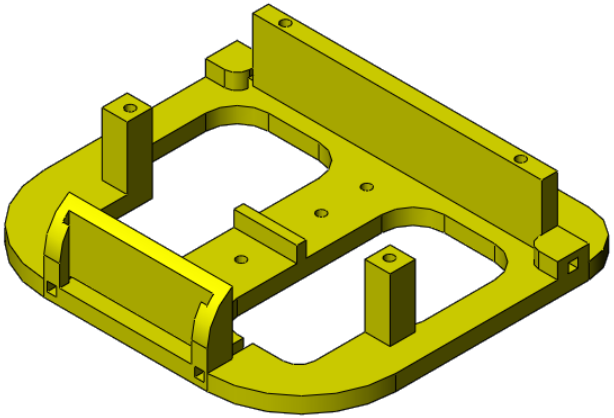


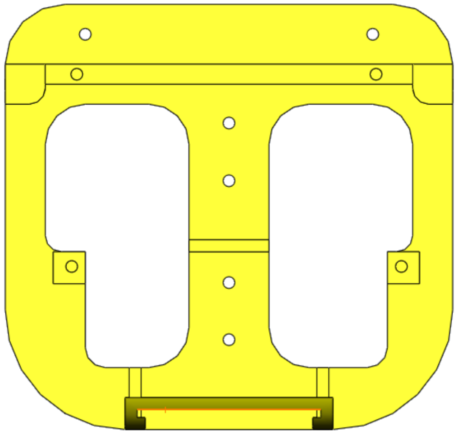
New Head

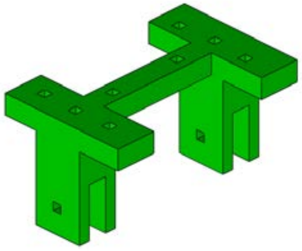


Head Bottom

- Attaches to Original ROFI "Body Riser"
- Arduino Mega Mounts
- Battery body stops
- Slot mount for Ultra Sonic Range Finder
- Sliding Phone Bracket Mounts

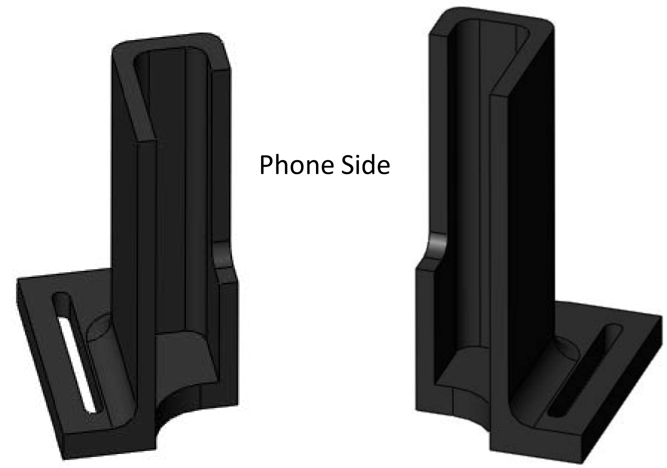


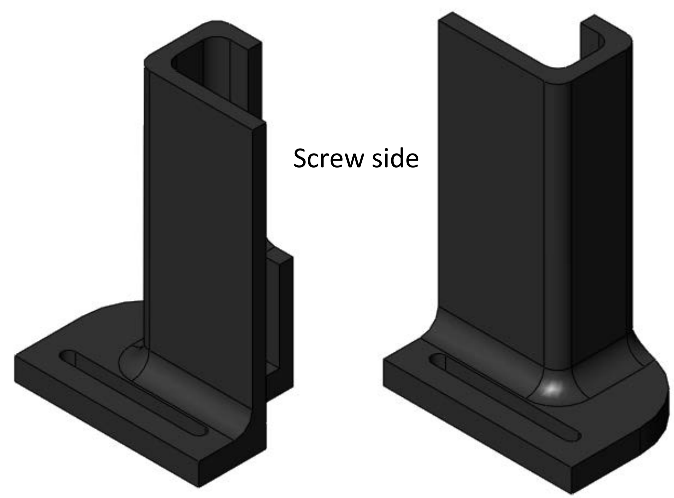




Sliding Phone Bracket

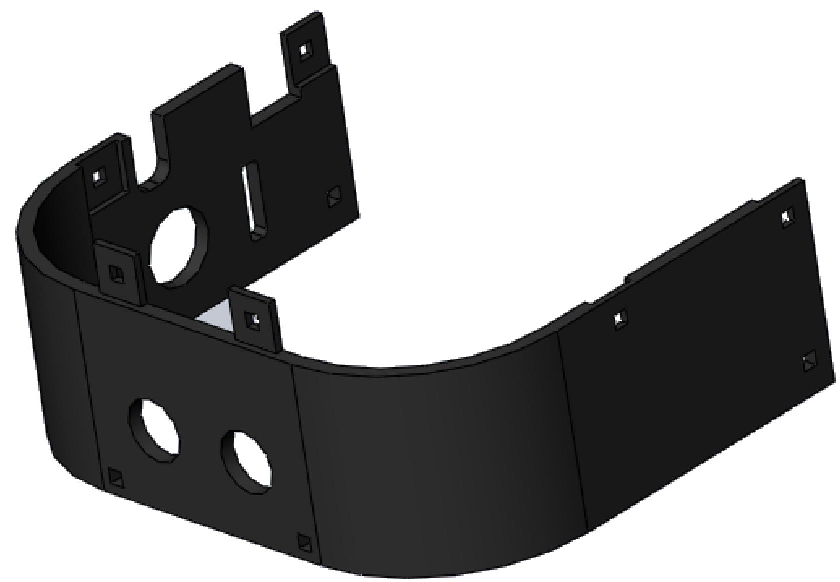
- 2 Piece Bracket
- Adjusts from 48mm-105mm wide
- 60mm side walls support phone in a vertical orientation
- Non-slip inserts
- “Organic Curves”





Head Sides

- Shell pieces attach with 'tongue-and-groove' plus screws
- Holes to accommodate
  - Ultra Sonic RF "eyes"
  - Servo Power Switch
  - Servo Power Fuse
  - Arduino Power
  - Arduino USB

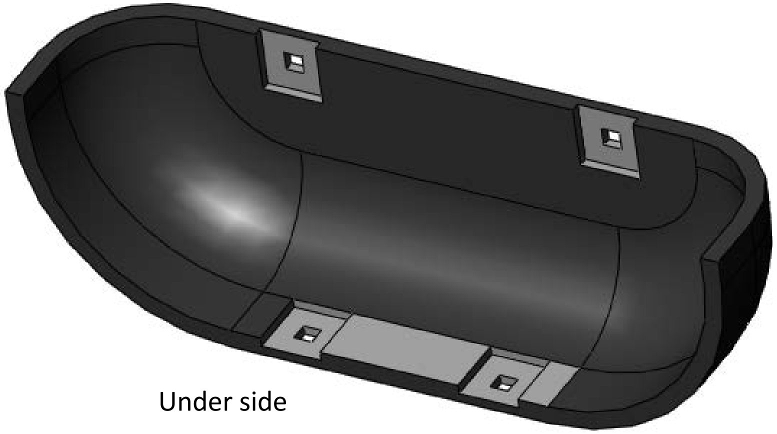


Head Top

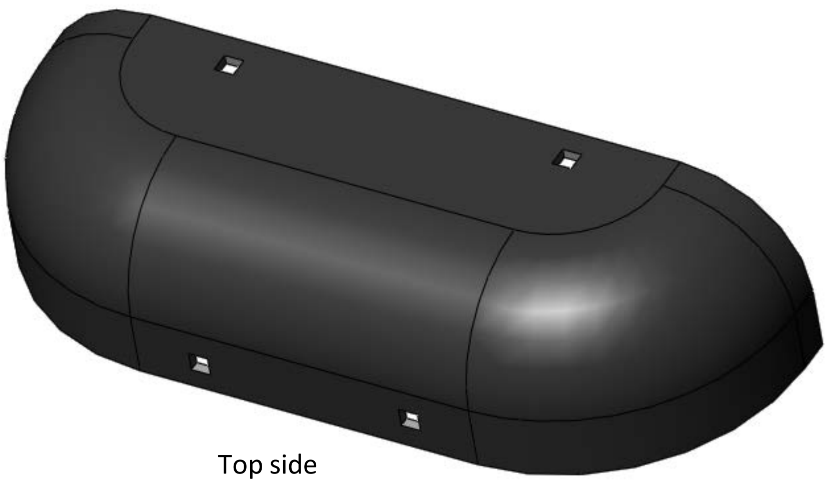
- Attaches to Head Sides and Head Dome via Tabs and screws
- Notch to accommodate USB from USB shield

Head Dome

- Attaches to Head Sides and Head Top via grooves and screws



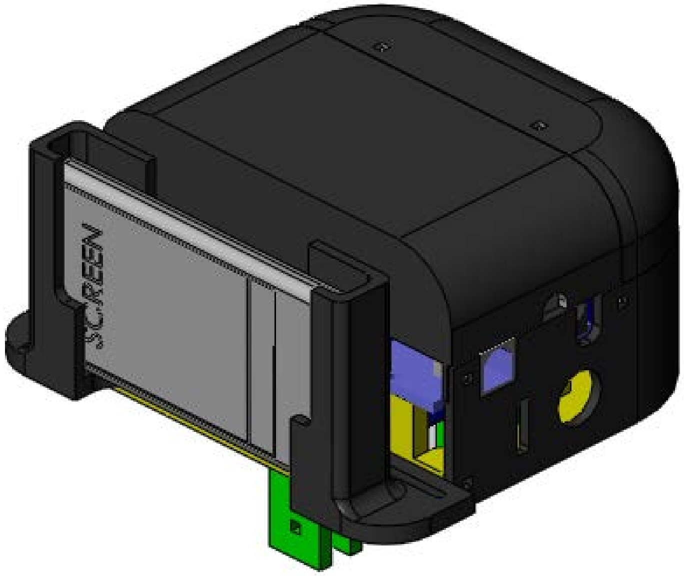
Under side



Top side

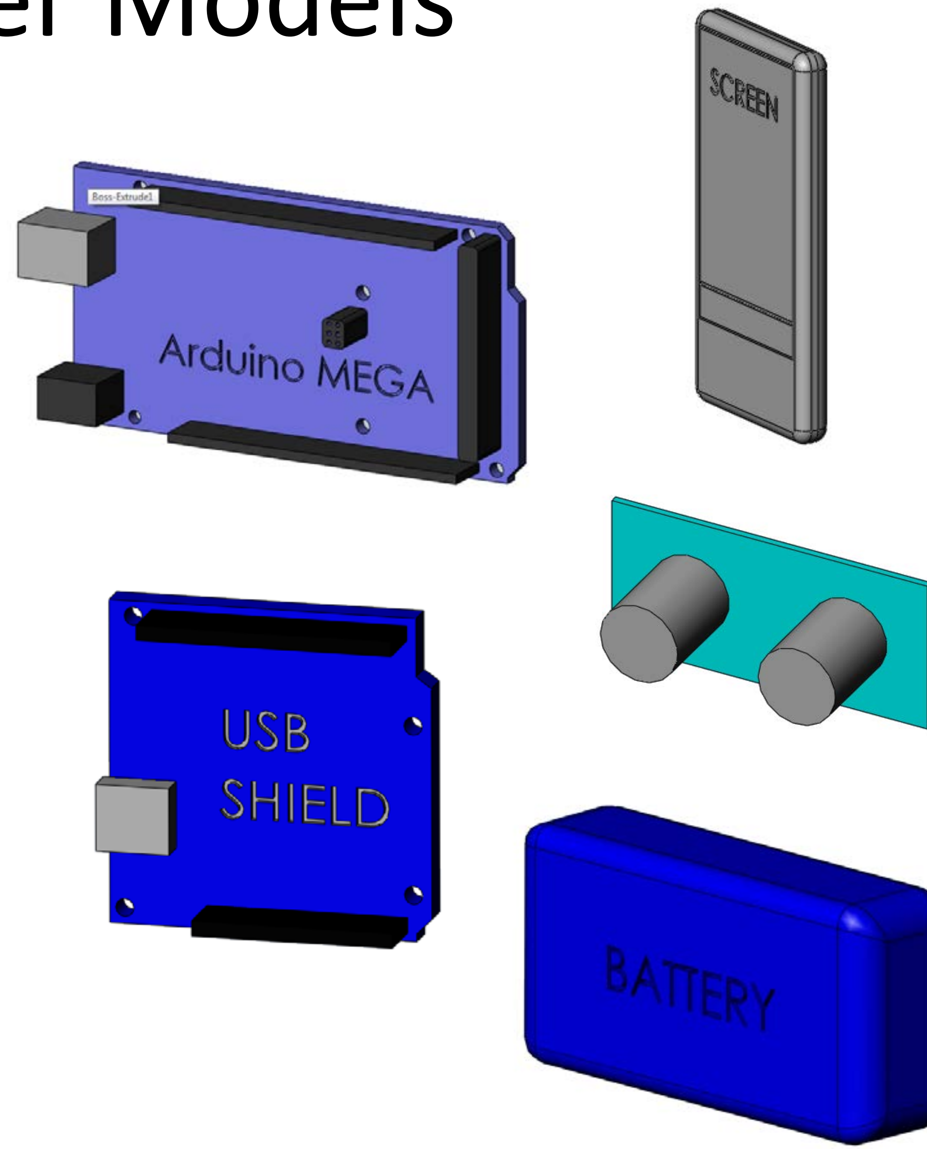
Looking Forward

- Phone with Back or Front Camera
- Phone with internal Gyro
- Use Phone camera for Range Finder
- Entire assembly may be rotated 180° for phone with Front Camera



Other Models

- Archos7 Phone
- Arduino Mega 2560
- Arduino USB Shield
- ROFI Battery
- Ultrasonic RF



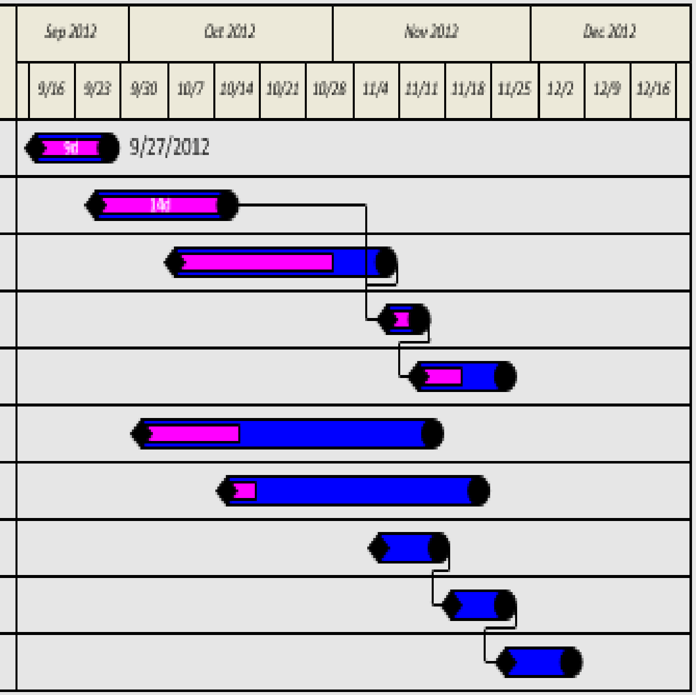
Control Issues

- Implement then improve on PID controller.
- Learn Solidworks to model the robot, bypassing the need for messy mathematical computations.
- Look into feasibility of redesigning knee joint to a more realistic model.
- Model with inverted pendulum approach.

Schedule (Level 1)

Team Biped

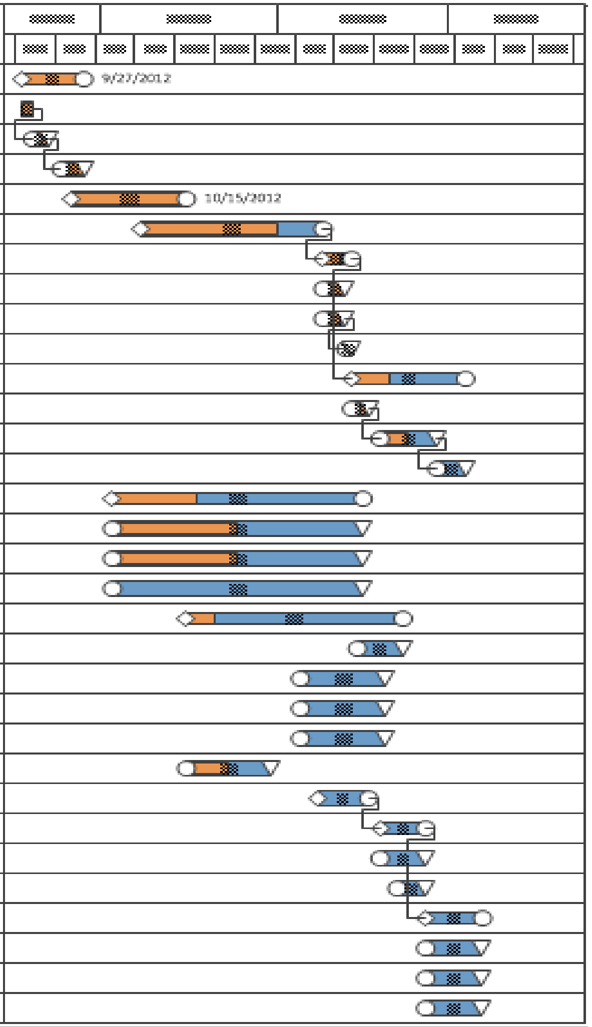
	Task Name	Start	Finish	Duration	% Complete
1	Get FoBa working	9/17/2012	9/27/2012	9d	100%
2	Order/Received Rofi Parts	9/26/2012	10/15/2012	14d	100%
3	Print RoFi Parts	10/8/2012	11/8/2012	24d	75%
4	Build RoFi	11/9/2012	11/13/2012	3d	80%
5	Implement RoFi	11/14/2012	11/26/2012	9d	50%
6	Design Next Generation RoFi Body Modifications	10/3/2012	11/15/2012	32d	33.33%
7	Improve Android "Brain" elements	10/16/2012	11/22/2012	28d	11%
8	Print/Order Parts for Next Generation	11/8/2012	11/16/2012	7d	0%
9	Build Next Generation	11/19/2012	11/26/2012	6d	0%
10	Implement Next Generation*	11/27/2012	12/6/2012	8d	0%



Schedule (Level 2)

Team Biped

	Task Name	*Start*	*Finish*	*Duration*	*% Complete*	*Division*	*Member*
1	**Get FoBs working**	**9/17/2012**	**9/27/2012**	**9d**	**100%**	**NA**	***Sean Capp (PM)***
2	Download fobs poser	9/17/2012	9/18/2012	2d	100%		
3	Mechanical	9/19/2012	9/21/2012	3d	100%		
4	Get it walking	9/24/2012	9/27/2012	4d	100%		
5	**Order/Received RoFi Parts**	**9/26/2012**	**10/15/2012**	**14d**	**100%**	**NA**	***Sean Capp (PM)***
6	**Print RoFi Parts**	**10/8/2012**	**11/8/2012**	**24d**	**75%**	**3D Printing**	
7	**Build RoFi**	**11/9/2012**	**11/13/2012**	**3d**	**80%**		
8	Prepare the Servos	11/9/2012	11/12/2012	2d	100%	Control	*Isaura Ramirez*
9	Make the legs	11/9/2012	11/12/2012	2d	75%	All	*All*
10	Make the Body	11/13/2012	11/13/2012	1d	50%	All	*All*
11	**Implement RoFi**	**11/14/2012**	**11/26/2012**	**9d**	**50%**		
12	Get Software Working	11/14/2012	11/16/2012	3d	100%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
13	Calibration	11/19/2012	11/28/2012	8d	50%	Control	*Isaura Ramirez*
14	Test/Walking	11/29/2012	12/3/2012	3d	0%	All	*All*
15	**Design Next Generation RoFi Body Modifications**	**10/3/2012**	**11/15/2012**	**32d**	**33.33%**		
16	Features (IR Sensors)	10/3/2012	11/15/2012	32d	50%	3D-Modeling/ Sensors	*Bryant Tram/Mike Piuma*
17	Solidworks (Generate Model)	10/3/2012	11/15/2012	32d	50%	3D-Modeling	*Mike Piuma*
18	Refine model w/ what we have learned from RoFi	10/3/2012	11/15/2012	32d	0%	3D-Modeling	*Mike Piuma*
19	**Improve Android "Brain" elements**	**10/16/2012**	**11/22/2012**	**28d**	**11%**		
20	Implement Gyroscope	11/15/2012	11/22/2012	6d	0%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
21	Voice command	11/5/2012	11/19/2012	11d	0%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
22	Phone camara	11/5/2012	11/19/2012	11d	0%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
23	Medium IR sensor	11/5/2012	11/19/2012	11d	0%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
24	Coding	10/16/2012	10/30/2012	11d	50%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
25	**Print/Order Parts for Next Generation**	**11/8/2012**	**11/16/2012**	**7d**	**0%**	**3D Printing**	
26	**Build Next Generation**	**11/19/2012**	**11/26/2012**	**6d**	**0%**		
27	Software	11/19/2012	11/26/2012	6d	0%	MC3/Sensors	*Kevin Nguyen/ Bryant Tram*
28	Mechanical	11/22/2012	11/26/2012	3d	0%	All	*All*
29	**Implement Next Generation***	**11/27/2012**	**12/6/2012**	**8d**	**0%**		
30	Software	11/27/2012	12/6/2012	8d	0%	MC3/Sensors	
31	Calibration	11/27/2012	12/6/2012	8d	0%	Control	*Isaura Ramirez*
32	Testing	11/27/2012	12/6/2012	8d	0%	All	*All*



RoFi Cost-Parts

Item	Description	Provider	Part Number	Price	Qnty	Shipping	Total Cost	Running Cost
Break Away Right Angle 3x40	Used to connect Servos to Arduino	SparkFunk Electronics	COM-10095	$4.95	1	$3.64	$8.59	**$8.59**
55g/10kg/.20 sec	Servos for the leg joints	HobbyKing	MG996R/6221	$50.34	6	$9.99	$60.33	**$68.92**
UBEC-5A-HV (High Voltage Ultimate BEC)	Power supply	Hobby Partz	07E32-ExceedRC_UBEC-5A-V1	$23.75	1			
Gens Ace 4mm Banana Battery Connector	Battery to wire	Hobby Partz	98P-4mmBanana-For-Battery	$1.99	2			
JR TX 2.1mm to banana plug adaptor	Apator for battery and Rofi	Hobby Partz	79P-10043	$1.90	1			
Hitec Servo extention lead 150mm (5 pcs)	Extension wires for the servos	Hobby Partz	79P-10066	$1.80	3	11.98 + tax	$50.08	**$119.00**
623ZZ 10 Bearing Shielded 3x10x4 Miniature Ball Bearings	Bearings for the leg joints	VXB Bearings	623ZZ10	$16.60	1	$6.07	$22.67	**$141.67**
USB Host Shield	USB Host Shield for Arduino	Circuits@Home		$25.00	1	$5.50	$30.50	**$172.17**
2.2lb (1kg) 1.75mm Black PLA Filamen	For3D printing parts	Maker Farm Inc	1kgBlackPLA175	$39.00	2.2lb (1kg)			
2.2lb (1kg) 1.75mm Yellow PLA Filament	For 3D printing parts	Maker Farm Inc	1kgYellowPLA175	$39.00	2.2lb (1kg)	$17.15	$95.15	**$267.32**
Archos 28 4 GB Internet Tablet (Black)	Android "Brain"	Amazon.com	Archos 28 4 GB Internet Tablet (Black)	$56.30	1	$0+tax	$61.23	**$328.55**
Arduino Mega 2560 R3	Microcontroller	Amazon.com	Arduino Mega 2560 R3	$51.95	1	$0	$51.95	**$380.50**
TOTAL COST								**$380.50**
POSSIBLE UNEXPECTED EXPENSES							~$50	**$430.50**
RANGE OF COST								**$430.50**

Main Support Issues

ROFI Parts

Part	Quantity	Color	PLA/ABS	Print Date	Notes (etc)	Needed		Finalized
Foot	2	Black	ABS	sirac and steve	maker	0		2
Servo Band	4	Yellow	PLA	10/9/12 PF	Robot Company	0		4
Servo Wrap Lower Right	1	Yellow	PLA	10/14/12 PF REDONE	Robot Company	0		1
Servo Wrap Lower Left	1	Yellow	PLA	10/14/2012 PF REDONE	Robot Company	0		1
Servo Wrap Upper Right	1	Yellow	PLA	10/14/12 PF		1		0
Servo Wrap Upper Left	1	Yellow	PLA	10/14/12 PF	Robot Company	0		1
Knee Frame	2	Yellow	PLA	10/10/12 PF	Robot Company	0		2
Heel	2	Yellow	PLA	10/15/12 PF	Maker/Robot Company	0		0
Bearing Bar	4	Black	PLA			4		0
Bearing Frame	1	Black	PLA	10/15/12 PF		1		0
Side Knee Bracket	4	Black	PLA		maker	0		4
Center Bracket	1	Black	PLA	10/15/12 PF	maker	0		1
Body Riser	1	Black	PLA	10/17/12 PF	maker	0		1
Body Panel RIGHT	1	Black	ABS			1		0
Body Panel BACK	1	Black	ABS			1		0
Body Panel FRONT	1	Black	ABS			1		0
Body Panel LEFT	1	Black	ABS			1		0
Body Strut	1	Black	ABS			1		0
Servo Bracket - Left	2	Black	ABS		maker	0		2
Servo Bracket - Right	2	Black	ABS		maker	0		2
Body Panel Top	1	black	ABS		maker	0		1

Measures of Success

- Successful Rofi Operation
- Next Generation (DareL)
  - Dynamic walking
  - Walk up an incline
  - Respond to impulse

Conclusion

- Rofi is moving much slower than anticipated, but will be completed by end of semester.
- Unforeseen issues have limited the viability of implementing full functionality of DareL. In the event we are unable to complete DareL's main objectives, our goal will be to provide resources and documentation to enable the success of next semester's biped robot group.