KGCOE MSD Technical Review Agenda

P10203: Motor Controller for LV1 Land Vehicle Platform

Meeting Purpose

1. Present an overview of the project.
2. Confirm understanding of Customer Needs and Engineering Specifications.
3. Review Concept Generation and Refinement process.
4. Proposal for a design solution and analysis of benefits vs. disadvantages.
5. Discuss Feasibility and possible alteration of plan.

Materials to be Reviewed

1. Project Description (R#2)
2. Work Breakdown Structure (R#2)
3. Customer Needs (R#4)
4. Engineering Specifications (R#5)
5. Interface Document (R#3)
6. Concept Selection Matrix (R#2)
7. Proposed Ideas
8. RP1 Gen 2 Design vs. LV 1 Gen 1 Design
   - System Level Block Diagram
   - Interconnect Diagram
9. Project Plan Moving Forward
10. Risk Management

Meeting Date: January 15th, 2009

Meeting Location: KGCOE Design Center, Room 09-4435

Meeting Time: 3:30 – 5:00 pm

Meeting Timeline		
Start Time	**Topic of Review**	**Required Attendees**
3:00	Project Introduction	Guide, TA, Dr. Hensel
3:10	Work Breakdown Structure	Guide, TA, Dr. Hensel
3:15	Customer Needs	Guide, TA, Dr. Hensel
3:20	Engineering Specifications	Guide, TA, Dr. Hensel
3:25	Interface Issues	Guide, TA, Dr. Hensel
3:30	Feedback Period	Guide, TA, Dr. Hensel
3:40	Concept Generation and Selection	Guide, TA, Dr. Hensel, Faculty
3:55	Feedback Period	Guide, TA, Dr. Hensel, Faculty
4:10	LV1 Design vs. RP1 Design	Guide, TA, Dr. Hensel, Faculty
4:20	Feedback Period	Guide, TA, Dr. Hensel, Faculty
4:30	Project Plan	Guide, TA, Dr. Hensel
4:45	Feedback Period	Guide, TA, Dr. Hensel
4:50	Risk Assessment	Guide, TA, Dr. Hensel
4:55	Final Feedback – Are we ready to go on with Design?	Guide, TA, Dr. Hensel

Project #	Project Name	Project Track	Project Family
P10203	LV1 Motor Controller Manufacturability	Vehicle Systems and Technology	LV1 Land Vehicle Platform
Start Term	**Team Guide**	**Project Sponsor**	**Doc. Revision**
2009-2	Phillip Bryan	Dr. Edward Hensel	Rev 2

Project Description

Project Background:

This project is a continuation of the Robotics Platform family of projects. The goal of these projects is to design and produce a scalable, modular, open source, open architecture robotics platform that can be used for a number of tasks. These tasks all require the platform to carry a payload between 1 and 100 kg and include use as a learning tool for new students and as a tool for improving future senior design projects.

Previous projects include:

- P07200: RP Family
- P07201: RP10 Gen 1 Motor
- P10202: RP100 Gen 1 Motor
- P07204: RP10 Platform
- P07205: RP100 Platform
- P08201: RP10 Gen 2 Platform
- P08205: RP1 Gen 1 Motor
- P08208: RP1 Gen 1 Motor
- P09204: RP1 Gen 2 Controller
- P09203: RP1 Gen 2 Motor
- P09202: RP10 Software

Problem Statement:

. The primary objective of this project is to design and produce a motor controller that maintains or improves the functionality of the RP1 Gen 2 motor controller while also significantly reducing cost and increasing manufacturability.

Objectives/Scope:

1. Reduce cost of motor controller boards
2. Improve manufacturability
3. Improve aesthetics
4. Provide sufficient agility and controllability
5. Use space more effectively
6. Improve durability
7. Maintain reasonable battery life
8. Implement with low risk
9. Easy for a freshman student to use
10. Interface with other LV1 modules
11. Maintain modularity

Deliverables:

- This project must deliver one or more working motor controllers that perform at or above the level of the previous generation while displaying significant cost reduction

Expected Project Benefits:

- Learning tool for first year students
- Available for future MSD projects
- Available for future research projects
- Reinforce the RIT engineering program

Core Team Members:

- Andrew Krall (ME) – Project Manager
- Adam Gillon (EE) – Interface Manager
- Louis Shogry (ME)
- Kory Williams (EE)
- Oladipo Tokunboh (EE)

Strategy & Approach

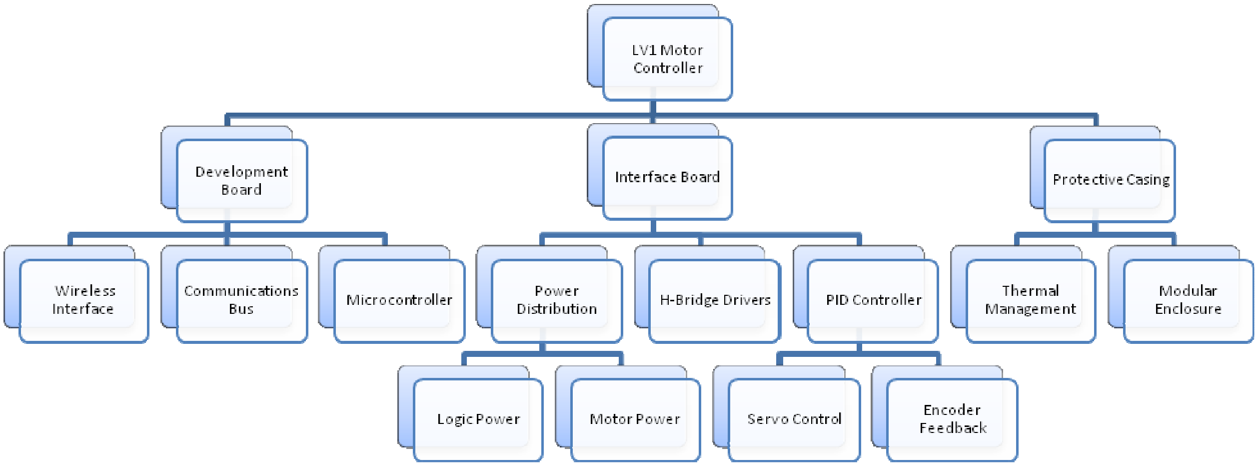
Assumptions & Constraints:

1. The Motor Module that is chosen is a DC Electric Motor with Power Specifications chosen to closely match those of the RP1.
2. The interface between the Motor Controller and the Wireless teams is a wire connected to a wireless transceiver.
3. The team must gain a thorough understanding of the RP1 Motor Controller to develop an idea as to what needs to be changed to increase the performance of the design. Also, the scope of the project must be designed to fit the skill sets of the team members involved.

Issues & Risks:

- Difficulty understanding the high level programming used in the RP1.
- LV1 Project now requires extensive interfacing between other teams. The Motor Controllers requires extensive interfacing with the Wireless Team, Motor Module Team and the Chassis Team.

P10203 Work Breakdown Structure



Assigned Tasks

- Design of Case Structure – Lou
- Design of Thermal Regulator – Andy
- Selection and Order of Hardware Components – Kory and Adam
- Design of Custom Functions
  - Power Distribution – Adam
  - Motor Drivers - Kory
  - PID Controller Integration – Kory
- Assembly of Custom Board – Kory and Adam
- Program of Microcontroller – Dipo
  - Set up Input/Outputs
  - Establish Command Set Input Commands
  - Set up modes of operation on MCU
  - Translate Controller Input into Signals for PID Controller
- Program of PID Controller – Dipo, Kory and Adam
  - Establish/Program Correction Algorithm
  - Assign Servo Control Signals
  - Assign Motor Control Signals

P10203 Customer Needs

Customer Need #	Importance	Description	Comments/Status
CN1	3	The controller is easy to manufacture and assemble.	
CN2	4	The controller is modular, (can be configured in several different options to support varied functionality).	
CN3	5	The controller has a low risk implementation and is stand-alone.	Controller operates as intended even if other groups fail to finish.
CN4	5	The controller is able to properly interface with the other modules of the Land Vehicle Platform.	
CN5	4	The controller is able to be used by first year mechanical/electrical engineering students.	
CN6	3	The controller is able to make the platform move with sufficient agility and controllability.	Sufficient is described as at the same level or better than the RP1.
CN7	3	The new design shall improve upon the aesthetics of the RP1.	
CN8	2	The controller makes effective use of the space provided by the Chassis.	Space effectiveness refers to minimizing overall space requirement without sacrificing cost or performance.
CN9	5	The new design is cost effective, (cheaper than the RP1 with the same, or improved performance characteristics).	
CN10	4	The controller is durable and can withstand repeated use with minimal maintenance.	
CN11	2	The controller has a reasonable battery life.	Reasonable refers to a level at or above the RP1.
CN12	2	The controller is able to be upgraded by future Senior Design teams with little redesign or component replacement needed.	Upgrade is used to refer to the fact that a CE team could be given the controller to add software functions to the system.
CN13	3	The Controller makes use of Prior Generations Designs and Research.	

P10203 Engineering Specifications

Specification ID	Customer Need	Description	Unit of Measure	Ideal Value	Comments
General Design					
3	CN3, CN9	Improve upon designs of RP1.	Boolean	1	
5	CN7, CN8, CN9	Number of PCB Needed.	Count	< 3	
6	CN9, CN13	Total cost of Controller.	% cut from RP1	25%	
7	CN5, CN10	Mounted Controller drop test surviveability.	Feet	5	
9	CN1, CN9	Number of Designed Boards Manufactured.	Count	> 4	
10	CN3, CN10	All sensitive components are separated from Noise Generating Components.	Centimeters	> 10 cm	"Sensitive Components" refers to any device that is affected by EMI or High IV environments.
15	CN4, CN7, CN8	Distance between controller outputs and interfaces.	Centimeters	< 10cm	
16	CN10	Operating Temperature of Controller.	Degrees Celcius	50C Max	
18	CN2, CN4, CN7, CN8	Controller LxWxH Dimensionality.	cm Cubed	LxWxH	
Processing Subsystem					
1	CN4, CN12	Amount of memory on controller.	KB	TBD	
2	CN4, CN12	Number of I/O to be controlled.	Count	TBD	
11	CN4, CN6, CN9	Number of driven motor(s) to control.	Count	< 3	
12	CN4, CN6, CN9	Number of steering motor(s) to control.	Count	< 3	
13	CN4, CN6, CN12	Bandwidth required at input to controller.	Data Rate	kb/sec	
14	CN4	Data Format at Input to Controller.	Format	TBD	Bits, ASCII, etc.
21	CN4, CN12, CN13	Programming Language used to program Controller.	Language	C, C++, VHDL, Assembly	
Correction Subsystem					
17	CN6	Degrees of Freedom maintained by Controller.	X, Y, Speed	FWD&REV, LFT&RGT, SPD	
20	CN4, CN6	Controller Speed Tracking.	% Deviation	1%	
Motor Driver(s)					
4	CN4, CN6	Controller interfaces with motor modules independently.	Boolean	1	
22	CN4, CN11	Drive Motor Power for individual motor modules.	Watts	TBD (Max)	Depends on Selection of Motor Modules
23	CN4, CN11	Voltage level required to drive individual motor modules.	Volts	TBD (Max)	
24	CN4, CN11	Current level required to drive individual motor modules.	Amps	TBD (Max)	
Power Distribution Subsystem					
8	CN11	Power Consumption of the Processing Sub-system.	Watts	< 4.5W	
19	CN5, CN11	Controller's ability to indicate remaining battery life.	Boolean	1	

Power Requirement of Logical Components

- Power Distribution Board for Logic Transfers 9V to PID Controller and MCU Development Board.
- Atmel ATMEGA128 MCU on development board draws 19mA of Current.
- PID Controller I/O pins draw 40mA of current each.
    - Use PWM Outputs of PID Controller, (6 pins).

Rated Power of Distribution Board

9V * 500mA = 4.5W

Development Board Requires

9V * 19mA = 0.171W

PID Controller Requires

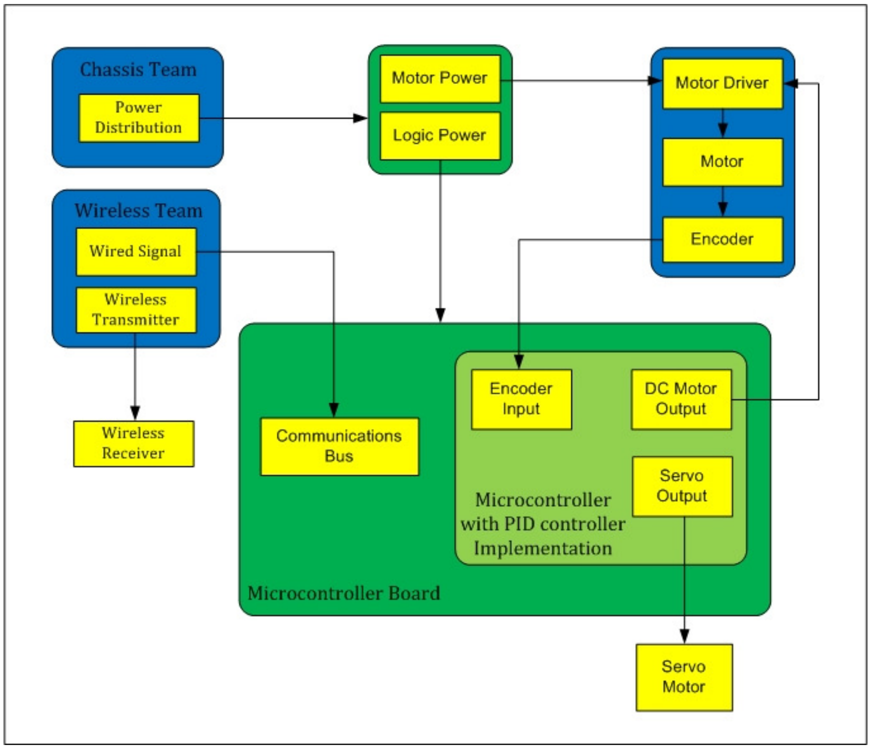
9V * (6*40mA) = 2.16W

Total Power Consumption is 2.331W, well below the 4.5W provided.

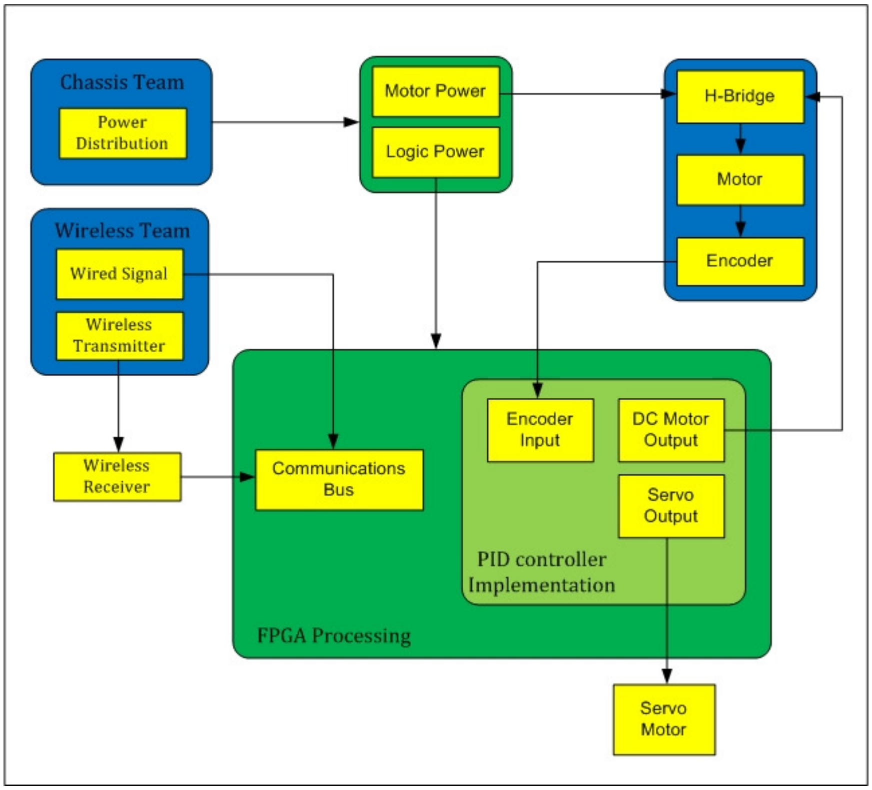
P10203 Interface Issues

Interface Name	System A	System B	Interface Item	Value
RF Tranceiver	Receiver	Controller	Connector	Type of Connector, (RS-232, USB, etc)
			Connector Location	Location on Board
			Data Rate	Rate in kb/s
			Data Structure	Number of Bits to be sent over
Environment	Environment	Controller	Temperature	Max Temp in Celcius
			Humidity	Max Relative Humidity in %
			Pressure	Max Pressure in N/m2
			Acceleration	Max Speed, reference to shock and vibration
Contoller Mounting	Chassis	Controller	Connection Pattern	Pattern of connection
			Connection Type	Device for mounting
			Connection Torque	Torque of connections
			Space Allocation	Dimensions in LxWxH
Power System	Controller	Chassis	Voltage	Voltage in Volts
			Current	Current in Amps
			Connector	Type of Power Connector
			Connector Location	Location on Board
Thermal Control	Chassis	Controller	Heatsink	Heat Dissipation in Joules
Motor Connectors	Controller	Motor Module	Connector Type(s)	Type of Motor Connectors, (electrical)
			Connector Position	Location on Board
			Signal Type	PWM or Voltage/Current Control
			Power	Power Requirement of Module
Motor Encoders	Controller	Motor Module	Data Rate	Rate in kb/s
			Data Format	Specified Format based on type of encoder.
Wiring Integration	Chassis	Controller	Wire Positioning	Organization of wires on board
			Wire Routing	Route of wires on board

		On-Board Calculations								
			A			**B**			**C**	
			Microcontroller			**FPGA**			**Dev Board**	
			Atmel AT Mega128			**Spartan-3A**			**BD Micro**	
Selection Criteria	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Speed	10%	2	16 MHz	0.20	3	Fast by Comparison	0.30	2	16 MHz	0.20
Memory	5%	2	4KB	0.10	3	Large By Comparison	0.15	2	4KB	0.10
Package Size	15%	3	TQFP-64	0.45	2	TQFP-144	0.30	2	2.2 x 3.6 in	0.30
Power Consumption	10%	2	Low, with Sleep	0.20	2	Low	0.20	2	Low	0.20
Price	15%	2	Low, but requires PCB	0.30	2	Moderate	0.30	2	High, but could be reused	0.30
Existing Code Base	15%	3	Yes	0.45	1	No	0.15	3	Yes	0.45
Expandable Memory	10%	3	Yes	0.30	1	No	0.10	3	Yes	0.30
Experience	20%	2	Used in P09204	0.40	1	None	0.20	3	Replica of P09204	0.60
	100%									
	Total Score		2.40			1.70			2.45	
	Rank		2			3			1	



PID Implemented on MCU



PID Implemented on FPGA

		Case Concepts								
			A			B			C	
			Sliding Case(s)			**No Case**			**Coating**	
						Mount on Chassis				
Selection Criteria	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Size	15%	2	Components would be placed on a smaller layout	0.30	2	Components would be more spread out	0.30	3	Negligible	0.45
Price	15%	1	Slightly more expensive	0.15	3	No Cost except for minor fastening materials	0.45	2	Less expensive by comparison	0.30
Modularity	20%	3	Very modular depending on chassis	0.60	1	No modularity can be expressed	0.20	2	Very Modular Depending on Chassis	0.40
Flexibility (Material)	10%	3	Very Flexible, any number of materials could be chosen	0.30	1	Not Flexible, chosen by Chassis Team	0.10	2	Limited to epoxy and rubber materials	0.20
Heat Dissipation	15%	2	Integrated Cooling System needed	0.30	2	Components more spaced out, less cooling required.	0.30	1	Extensive Cooling required	0.15
Complexity	5%	2	Not very complex	0.10	2	Not Complex	0.10	3	Easy to implement	0.15
Durability	20%	3	Much improved shock absorption	0.60	1	Non-existent protection from environment	0.20	3	Environmentally and operationally stable.	0.60
	100%			0.00			0.00			0.00
	Total Score		2.35			1.65			2.25	
	Rank		1			3			2	

Concept Generation – Enclosure

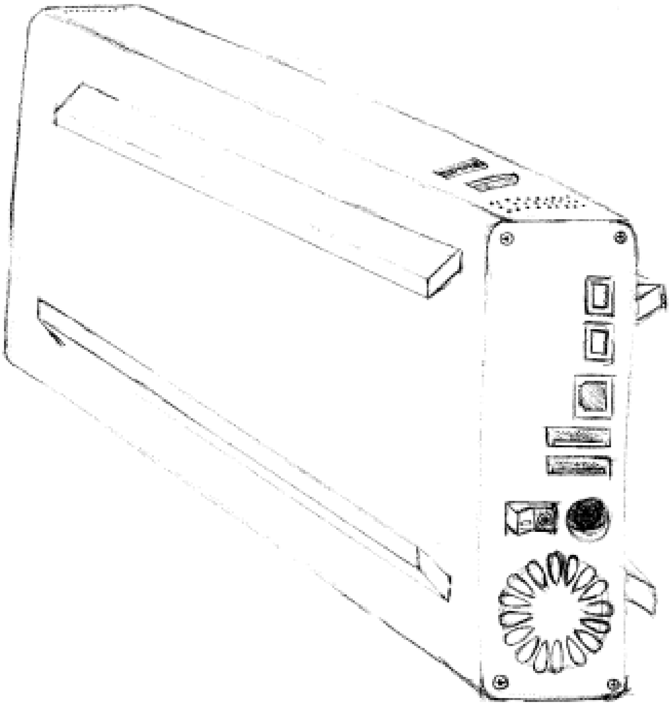
Concept I: Case

Materials:

- Plastic
    - Plexi-glass
    - Polyurethane
    - Polypropylene
- Metal
    - Aluminum
    - Steel
- Composites
    - Fiberglass
    - Kevlar
    - Carbon
- Wood
    - Ply
    - Particle Board
    - Balsa

Advantages:

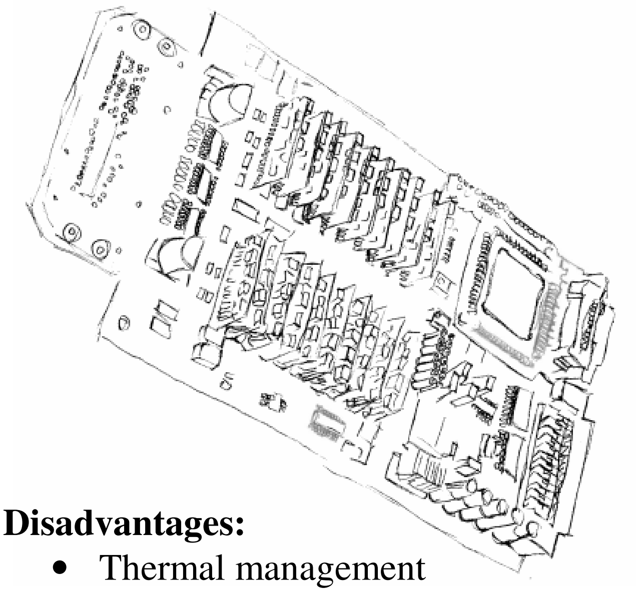
- Potentially inexpensive
- Easily implemented
- Enables board access
- High shock resistance
- High environmental protection
- Easily mountable
- Modular
- Plug and play
- Aesthetically pleasing
- Eliminates tampering



Disadvantages:

- Thermal management
- Size
- Additional cost
- Limited board accessibility

Concept II: Coating



Materials:

- Epoxy
    - Clear
    - Colored
- Silicone
- Acrylic
- Urethane
- Paraxylene

Advantages:

- Potentially inexpensive
- Easy to implement
- Good chemical and moisture resistance
- Reduces mechanical stress
- Coatings are usually transparent
- Plug and play
- Eliminates Tampering

Disadvantages:

- Thermal management
- Additional cost
- Limited to no board accessibility
- Unable to be removed
- Possible damage to components during heated cure

Concept III: No enclosure

Advantages:

- No cost
- Easy thermal management
- Easily manufacturable
- Easy board access

Disadvantages:

- Thermal management
- No shock protection
- No moisture or chemical resistance
- Exposed wiring
- More difficult mounting
- Aesthetically unpleasing
- Reduced modularity
- No resistance to tampering

Concept Generation – Thermal Management

Concept I: Heat Sink (on components)

Advantages:
- Easy to implement
- Inexpensive
- Moderate to good heat dissipation
- Little space required

Disadvantages:
- Cannot be implemented with case
- Difficult to remove from components

Concept II: Heat Sink (on case)

Advantages:
- Good to excellent heat dissipation

Disadvantages:
- Must utilize metal case
- Potentially expensive
- Difficult for manufacturing
- Must use thermal paste to transfer heat
- Complex case design
- Increased space

Concept III: Fan

Advantages:
- Excellent heat dissipation

Disadvantages:
- Added cost
- Power consumption
- Requires case
- Difficult implementation
- Increased space

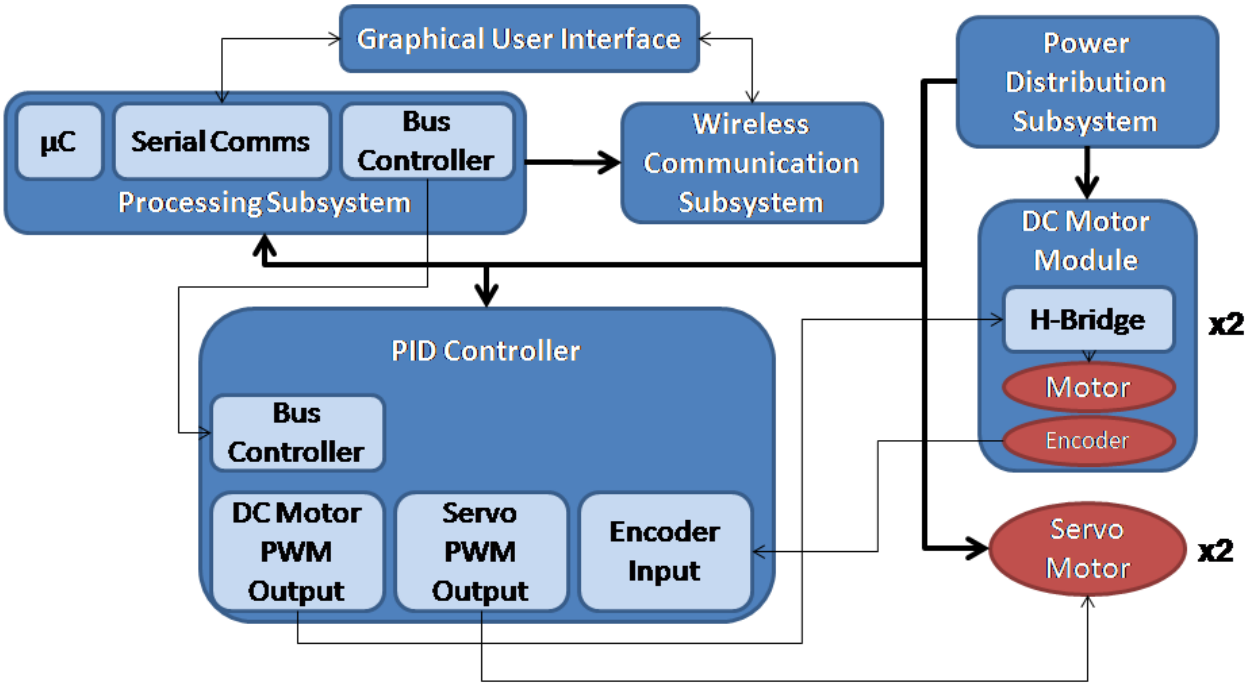
Concept IV: No Thermal Management

Advantages:
- No cost
- Easy implementation

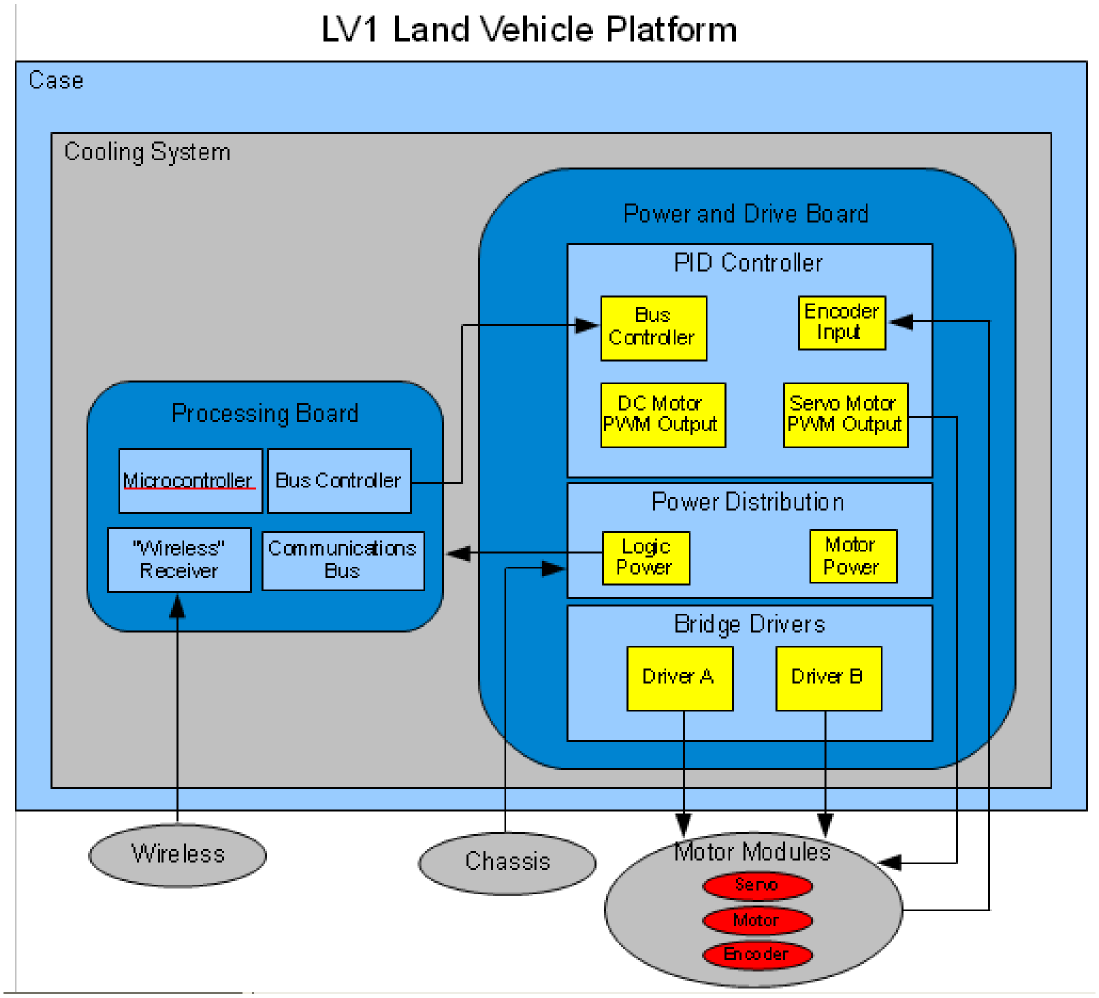
Disadvantages:
- Possible component failure
- Dangerous
- Decrease in component life

		Modularity Concepts												
			A			B			C			D	
		Combine Drivers and Power Separate			Combine Drivers and Power Together			Combine Drivers, Power and PID			Maintain Separate Parts		
Selection Criteria	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Size	15%	2	Would slightly lower size	0.30	3	Greatly reduces overall board size.	0.45	3	Greatly reduces overall board size, (PID negligible).	0.45	1	Overall board size is large due to separate boards	0.15
Wiring Complexity	20%	1	Same complexity, since no wires go between modules	0.20	2	Wiring between Drivers and Power eliminated.	0.40	3	Complexity greatly reduced, PID has many connections.	0.60	1	Very complex wiring between controller components.	0.20
Modularity	20%	2	Overall it is easier to configure less PCB, but there will be less possibilities	0.40	2	Total of 3 boards with reduced wiring restrictions.	0.40	2	Total of 2 boards, almost no wiring restrictions.	0.40	2	Total of 6 boards can be configured, but there are wiring restrictions	0.40
Ease of Integration	10%	3	Fairly easy, little redesign required	0.30	2	More strict redesign is required.	0.20	1	Must account for 40-DIP package of PID controller	0.10	3	No integration needed.	0.30
Grouping by Function	15%	3	About the same function groups as before.	0.45	1	Functions will still be grouped by function, but slight sacrifices may need to be made to reduce board size.	0.15	2	Grouping by functionality is a necessity to separate PID controller from noisy drivers.	0.30	3	Each board has it's own function.	0.45
Cost	20%	2	Slightly lower cost to reduce needed PCB Fabrication	0.40	3	Cost drop, only 1 board needs to be fabricated, not 4.	0.60	3	Cost drop, only 1 board needs to be fabricated, not 4.	0.60	1	Expensive to fabricate 4 separate boards.	0.20
	100%			0.00			0.00			0.00			0.00
	Total Score		2.05			2.20			2.45			1.70	
	Rank		3			2			1			4	

P09204 – Robotic Platform 1kg (RP1)

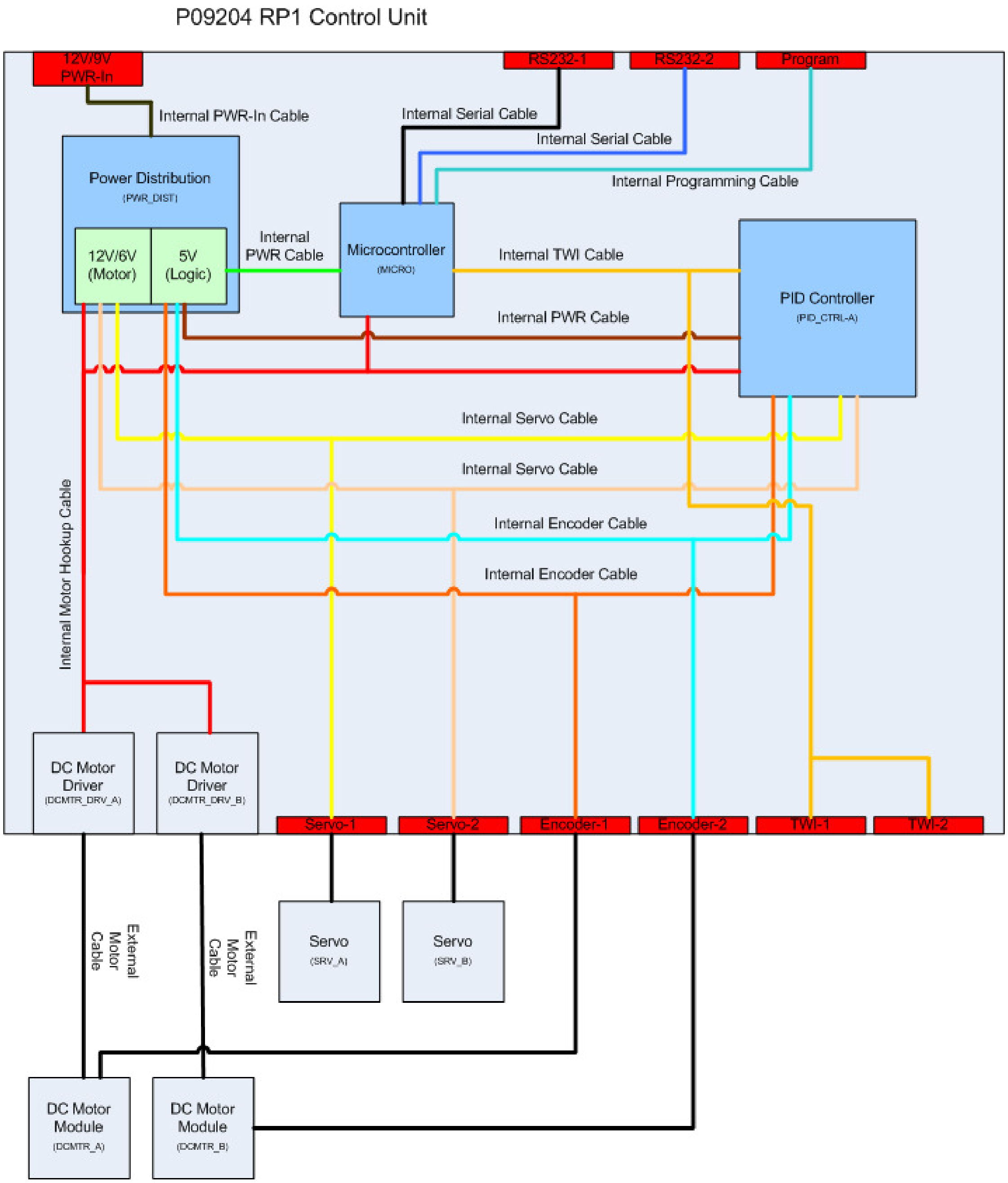


Pros	Cons
• Very High Level Programming of PID Controller and Microcontroller. • Powerful Processing capability. • Successfully demonstrated full control over Robot steering and drive functions.	• Construction of controller design is sloppy. • Not robust enough to be used by primary consumers, (first year KGCOE students). • Design is not yet cost efficient enough to fit into allocated budget to manufacture

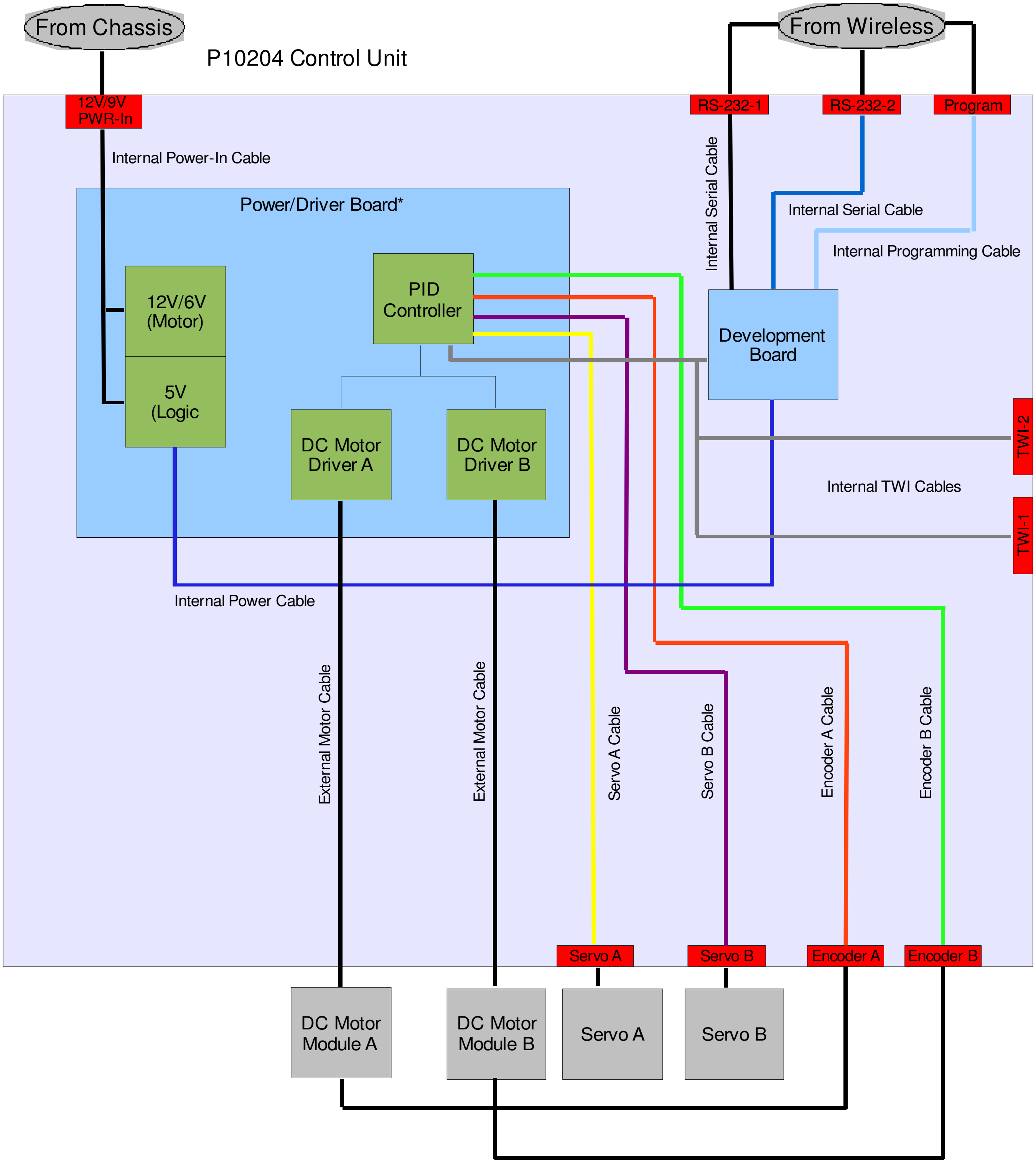


Idea	Proposition	Reasoning
Mod	Combination of Driver Boards, Power Distribution Boards, and PID Controller board.	Fabrication of Multiple boards was the most expensive portion of the Controller in the RP1. Putting all functions on a single board will cut cost and improve aesthetics.
Keep	Reuse OTS Development Board and PID Controller.	The previous RP1 team used these controllers and programmed them at a high level. The members of the LV1 team do not have the expertise needed to debug the code, and it was proven to be fully functional previously.
Mod	Design an enclosure for the controller to neatly package the device and offer a higher degree of modularity.	The RP1 controller was bolted on to the Chassis, making it non-modular and unprotected. An enclosure will increase durability and offer a level of modularity.

P09204 RP1 Interconnect Diagram

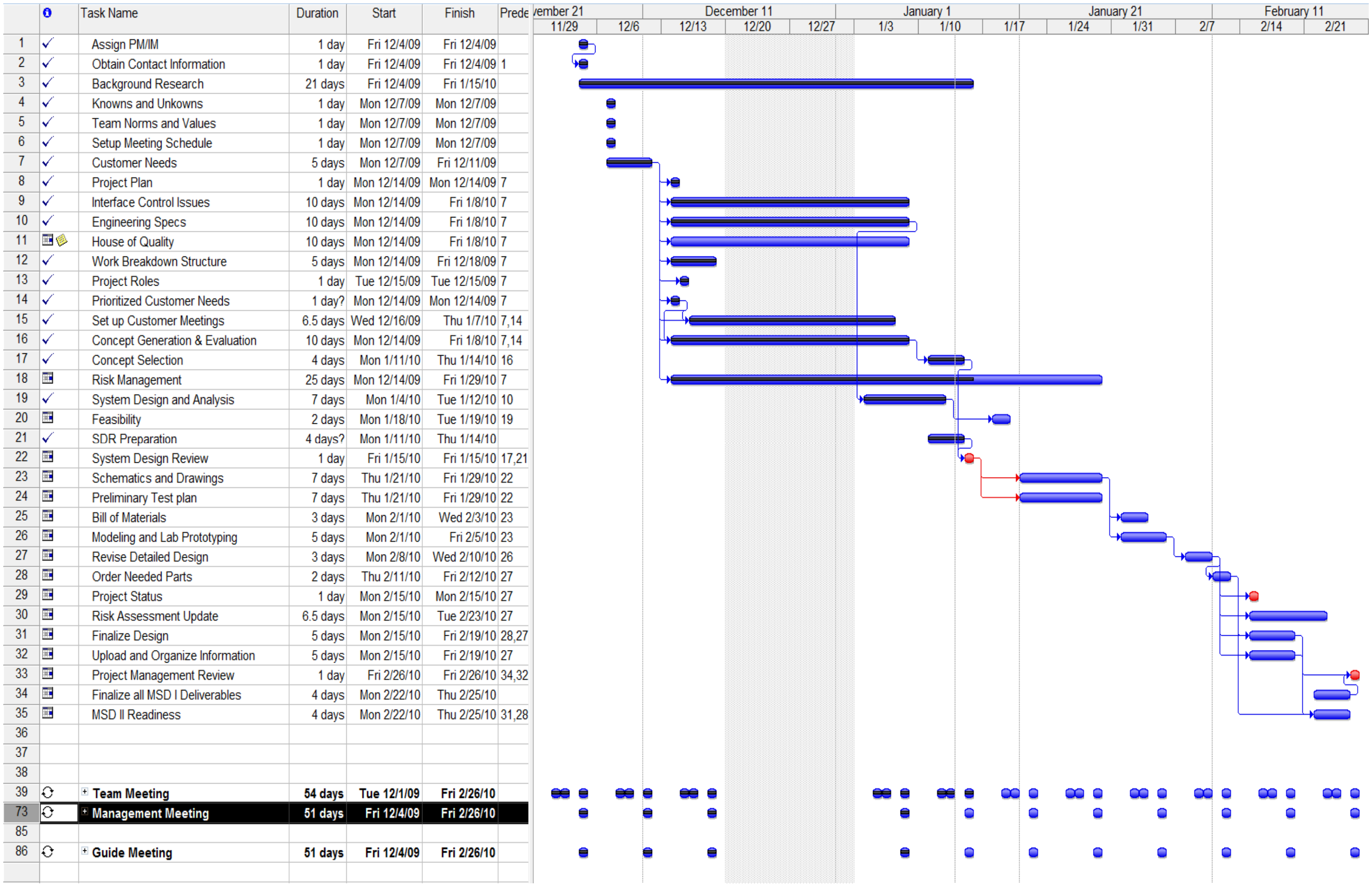


P10203 LV1 Interconnect Diagram



*The Power/Driver board uses on board PCB Routing to connect the Power, PID and Driver Modules

P10203 Project Plan



	ℹ	Task Name	Duration	Start	Finish	Prede
1	✓	Assign PM/IM	1 day	Fri 12/4/09	Fri 12/4/09	
2	✓	Obtain Contact Information	1 day	Fri 12/4/09	Fri 12/4/09	1
3	✓	Background Research	21 days	Fri 12/4/09	Fri 1/15/10	
4	✓	Knowns and Unkowns	1 day	Mon 12/7/09	Mon 12/7/09	
5	✓	Team Norms and Values	1 day	Mon 12/7/09	Mon 12/7/09	
6	✓	Setup Meeting Schedule	1 day	Mon 12/7/09	Mon 12/7/09	
7	✓	Customer Needs	5 days	Mon 12/7/09	Fri 12/11/09	
8	✓	Project Plan	1 day	Mon 12/14/09	Mon 12/14/09	7
9	✓	Interface Control Issues	10 days	Mon 12/14/09	Fri 1/8/10	7
10	✓	Engineering Specs	10 days	Mon 12/14/09	Fri 1/8/10	7
11	▦ ✎	House of Quality	10 days	Mon 12/14/09	Fri 1/8/10	7
12	✓	Work Breakdown Structure	5 days	Mon 12/14/09	Fri 12/18/09	7
13	✓	Project Roles	1 day	Tue 12/15/09	Tue 12/15/09	7
14	✓	Prioritized Customer Needs	1 day?	Mon 12/14/09	Mon 12/14/09	7
15	✓	Set up Customer Meetings	6.5 days	Wed 12/16/09	Thu 1/7/10	7,14
16	✓	Concept Generation & Evaluation	10 days	Mon 12/14/09	Fri 1/8/10	7,14
17	✓	Concept Selection	4 days	Mon 1/11/10	Thu 1/14/10	16
18	▦	Risk Management	25 days	Mon 12/14/09	Fri 1/29/10	7
19	✓	System Design and Analysis	7 days	Mon 1/4/10	Tue 1/12/10	10
20	▦	Feasibility	2 days	Mon 1/18/10	Tue 1/19/10	19
21	✓	SDR Preparation	4 days?	Mon 1/11/10	Thu 1/14/10	
22	▦	System Design Review	1 day	Fri 1/15/10	Fri 1/15/10	17,21
23	▦	Schematics and Drawings	7 days	Thu 1/21/10	Fri 1/29/10	22
24	▦	Preliminary Test plan	7 days	Thu 1/21/10	Fri 1/29/10	22
25	▦	Bill of Materials	3 days	Mon 2/1/10	Wed 2/3/10	23
26	▦	Modeling and Lab Prototyping	5 days	Mon 2/1/10	Fri 2/5/10	23
27	▦	Revise Detailed Design	3 days	Mon 2/8/10	Wed 2/10/10	26
28	▦	Order Needed Parts	2 days	Thu 2/11/10	Fri 2/12/10	27
29	▦	Project Status	1 day	Mon 2/15/10	Mon 2/15/10	27
30	▦	Risk Assessment Update	6.5 days	Mon 2/15/10	Tue 2/23/10	27
31	▦	Finalize Design	5 days	Mon 2/15/10	Fri 2/19/10	28,27
32	▦	Upload and Organize Information	5 days	Mon 2/15/10	Fri 2/19/10	27
33	▦	Project Management Review	1 day	Fri 2/26/10	Fri 2/26/10	34,32
34	▦	Finalize all MSD I Deliverables	4 days	Mon 2/22/10	Thu 2/25/10	
35	▦	MSD II Readiness	4 days	Mon 2/22/10	Thu 2/25/10	31,28
36						
37						
38						
39	⟳	+ **Team Meeting**	**54 days**	**Tue 12/1/09**	**Fri 2/26/10**	
73	⟳	+ **Management Meeting**	**51 days**	**Fri 12/4/09**	**Fri 2/26/10**	
85						
86	⟳	+ **Guide Meeting**	**51 days**	**Fri 12/4/09**	**Fri 2/26/10**	

MSD Project Risk Assessment Template

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
	Describe the risk briefly	*What is the effect on any or all of the project deliverables if the cause actually happens?*	*What are the possible cause(s) of this risk?*			*L*S*	*What action(s) will you take (and by when) to prevent, reduce the impact of, or transfer the risk of this occurring?*	*Who is responsible for following through on mitigation?*
1	Delay of ordered parts being shipped.	Project build gets behind schedule.	Parts get lost, wrong parts ordered. Ordered too late.	3	2	6	Prevent by ordering parts ahead of time, communication with vendor.	Kory
2	Issues with reuse of previous generation's work.	Start over from scratch on that aspect of project.	Insufficient personnel for project. Insufficient documentation from previous group.	3	3	9	Reduce by performing proper background research and consulting faculty guides.	All
3	Interfacing issues with other teams.	Vehicle does not perform as intended.	Non-effective communication between groups.	2	2	4	Prevent by having frequent interface meetings between groups.	Andy and Adam
4	Possible sickness, unavoidable absence, poor weather.	Project schedule gets behind schedule.	Person(s) unavailable	2	1	2	Accept	All
5	Component failure or breakdown.	Vehicle does not perform as intended. Increase budget need.	Damage in shipping, Poor part selection, Operator error.	2	3	6	Reduce by using sufficient background research on parts. Use of reliable vendors. Order parts ahead of time.	Dipo
6	Budget Allocation conflicts.	Insufficient funds for components.	Non-effective communication between groups.	1	3	3	Prevent by having frequent interface meetings between groups and by researching component cost.	Adam and Andy
7	Components don't meet requirements of design.	Vehicle does not perform as intended.	Insufficient component research.	2	2	4	Prevent by using sufficient background research on components.	Kory
8	Insufficient Personnel for Project.	Vehicle does not get completed.	Group members do not have enough expertise in needed areas.	1	3	3	Reduce by getting assistance from faculty guides and conducting thorough research.	All
9	Hardware testing reveals unforeseen problems with component selection.	Parts must be replaced and reordered. Design has to be altered.	Poor Design in MSD I and non-effective communication.	1	2	2	Prevent by using effective planning strategies and conducting thorough feasibility analysis.	Kory, Dipo, Adam
10	Conflicts amongst team members.	Team morale suffers and communication breaks down.	Non-effective communication, poor professional conduct.	2	2	4	Prevent by using Peer Review and by abiding by Team Norms and Values.	All
12	Decision to change an aspect of RP1 snowballs into redesign of entire system.	Customer needs are not met. Project is unable to advance properly.	Improper design choices to improve previous design.	1	3	3	Reduce by only changing design where absolutely necessary or the change will produce a significant cost	All

							reduction or performance increase.	
13	In house designed PCB layouts are incorrect.	Redesign and re-fabrication required.	Poor design and preliminary testing.	1	2	2	Prevent by having the RP1 boards available and by using effective testing.	Kory
14	Electronic components are not properly protected while LV1 is operational.	Controller gets damaged and must be replaced.	Poor interfacing with Chassis, poor enclosure design.	1	3	3	Prevent by designing a shock reducing protective case around controller.	Andy and Lou

Likelihood scale	**Severity scale**
1 - This cause is unlikely to happen	1 - The impact on the project is very minor. We will still meet deliverables on time and within budget, but it will cause extra work
2 - This cause could conceivably happen	2 - The impact on the project is noticeable. We will deliver reduced functionality, go over budget, or fail to meet some of our Engineering Specifications.
3 - This cause is very likely to happen	3 - The impact on the project is severe. We will not be able to deliver, or what we deliver will not meet the customer's needs.

“Importance Score” (Likelihood x Severity) – use this to guide your preference for a risk management strategy	
Prevent	Action will be taken to prevent the cause(s) from occurring in the first place.
Reduce	Action will be taken to reduce the likelihood of the cause and/or the severity of the effect on the project, should the cause occur
Transfer	Action will be taken to transfer the risk to something else. Insurance is an example of this. You purchase an insurance policy that contractually binds an insurance company to pay for your loss in the event of accident. This transfers the financial consequences of the accident to someone else. Your car is still a wreck, of course.
Accept	Low importance risks may not justify any action at all. If they happen, you simply accept the consequences.