IPRO 497 – 324

Spring 2010

Power Measurement for Performance Bicycles

Project Plan

Advisors:

Professor Dietmar Rempfer

Professor Sheldon Mostovoy

Team Members:

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Yoshio Piediscalzi

Mark Rhodes

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Table of Contents

Section **Page**

1 Team Charter

1.1 Team Information

Roster

Name	Major	Email	Phone
Jeffrey Aigner	Computer Engineering	jaigner@iit.edu	[redacted]
Brian Albee	Chemistry	balbee@iit.edu	[redacted]
Nick Gaulin	Aerospace Engineering	ngaulin@iit.edu	[redacted]
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Jonathan Swanson	Mechanical Engineering	jswanso5@iit.edu	[redacted]

Team Member Strengths, Needs, and Expectations

Jeff is a fourth-year computer engineering major. He has 7 years of industry experience in programming and managing projects, as well as experience gained from research with the WiNCOM laboratory. His strengths are in computer programming, electronics design and implementation, and project management. He is confident that the team will produce meaningful and valuable results, regardless of where testing results take the project.

Brian is a fourth-year chemistry major. His strengths include communication and writing skills. His weaknesses include a lack of hands on experience with engineering tasks. He expects to gain a better understanding of the principles of engineering in working on this project.

Nick is a third-year Aerospace Engineer who also specializes in computer programming and web design. After starting his own software company in 2004, he has developed many applications and websites for a wide variety of businesses in the Northeastern Illinois and Southwestern Missouri areas. His project management skills will be a valuable asset to the team, and he hopes to gain engineering experience from this program.

Jeonghun is a fourth-year physics major. He has worked in an experimental physics lab and has experience in programming as well as instrumentation and data analysis. His strengths include computer programming, instrumentation, and analytical skills. His weaknesses include a lack of engineering way of approaching a problem. He expects to gain valuable experience working with people from engineering disciplines.

Seunggeun is a fourth-year electrical engineering major who transferred to IIT last year from Korea. His strengths include electrical designing, and an excellent work ethic. He also has some experience with Photoshop. His weaknesses include lack of communication and writing skills. He expects to gain experience of implementing an engineering device as well as improving communication skills.

Yoshio is a third-year Civil Engineer. He is also majoring in Mathematics. He works well in groups. He is also a determined, hard worker. His weaknesses include lack of experience as well as lack of communication skills with people outside of his field. He expects to contribute his maximum effort in order for the project to be completed. He also expects to improve his communication skills.

Mark is a fifth-year electrical engineering student who is also completing certification for secondary mathematics education at IIT. His background includes several engineering internships and he's eager to bring his electronics industry project experience to the team. He's had little opportunity to practice designing circuits, so he sees this as an excellent opportunity to do just that. He's wanted to be a part of this IPRO since he first saw it at IPRO Day during its first semester in the fall of 2008, and he expects this team will have a useful product with suitable accuracy by the end of the term.

David is a fifth-year Material Science major at IIT also enrolled as a Liberal Arts Engineering major at Wheaton College. His background includes an internship with Aldridge Electric and a focus on engineering graphics classes. He has strong communication skills and an aptitude for visual models. David hopes to apply engineering theory to this practical product and achieve functional, accurate results.

Yuriy is a fifth-year physics major. His strengths include problem solving skills. However, he lacks hands-on experience. This experience of applying knowledge to solving a real problem is what he expects to gain from this project.

Jonathan is a third-year Materials Science and Mechanical Engineering Major. His strengths are dedication, organization, and 6 years of industry experience. He expects that the project will be successful in building better professional relationship skills for himself and the other participants.

<u>Team Identity</u>

The team name will contain a slight revision from previous semesters; we have inserted the word “performance” in place of “road” so that IPRO 324 is now named “Power Measurement of Performance Bicycles”. The motto of “No Strain, No Gain” will remain. The logo can be seen on the title page of this report.

1.2 Team Purpose and Objectives

The overall goal of this IPRO is to develop an inexpensive, accurate tool for measuring the power output of a bicycle rider. The current devices on the market have at least one of the following problems: they are expensive ($500+), they may require the replacement of expensive bicycle parts, and/or they are inaccurate.

Our team has divided into three subgroups in order to find a solution: mechanical, electrical and visual. We identified one primary objective for the team as a whole, that our system will report data to a Garmin Edge 705 cycling computer with accuracy within 2%. To measure the accuracy we will perform a road test of our prototype using a bicycle with an installed commercial power measurement system to collect data for comparison.

The team has also identified two secondary objectives:

- Improvement of the circuit and mechanical design
- Adapt the product to work with a carbon-fiber crank set in addition to aluminum

1.3 Background

As mentioned above, the 2010 spring semester of IPRO 324's task is to continue the development of a power measurement device for bicycles. Since the late 1980s, companies have produced devices to address the need among professional cyclists and serious riders to track their variations in performance throughout a training session or a training period. However these devices are unlike heart rate monitors used by marathoners. This is because at varying heart rates, a cyclist's power output to the bike can remain constant, as the opposite can be true as well.

Power measurement systems initially came in two general forms, a handlebar-mounted model and a strain gauge based model, with the latter becoming more popular.

- Bottom bracket power meters rely on the torsional deflection of the bottom bracket shaft. Even though this technique was said to be the most accurate, it wasn't popular among cyclists because of the need for different bottom bracket units for each bike. Meters of this style were produced exclusively by a company named Ergomo, which declared bankruptcy in 2008.
- Free-hub-based devices came about as a solution to the problems posed by the need for unique bottom bracket units. Being mounted on the rear wheel, they were easily interchangeable. However, on a bicycle there is a power loss in the drivetrain between

the crank set and the rear wheel. Therefore a rear wheel based system sees the power output of the cyclist minus the losses in the drivetrain, not his/her full power output. This leads to inaccurate readings with error typically around 1-2%.

- The chain-based technique relied on technology similar to guitar pickups that converted the vibrations in the chain and mathematically converted the signal to the corresponding power. One problem with this model was that there was sometimes interference caused by possible and plausible external noises. Another issue was that the eigenfrequency of the chain is affected by friction, and thus by how well-oiled the chain is. External excitation (riding over a rough road) also had affects on the results.
- The technique with the potential of being least expensive was the opposite force based (handheld mounted) technique. One disadvantage of this model was the complexity of the calculations needed to be performed by the system. There was also the issue of the accuracy of wind-speed and inclination of the road, and, most of all, the variation of the drag coefficient of the rider with posture (e.g. sitting upright versus riding in the drops). Results varied significantly and were easily influenced by irrelevant factors.
- Finally, the most popular technique today is using a system based in the bike's crank set. Power output is measured here using the deflection of strain gauges and the cadence of the pedals. There remains a disadvantage in the need of specific crank sets. However, though the total cost of a crank set/device is lower with higher accuracy compared to the other systems, changing the sets for each bike is considered a problem.

For this project, the goal is to increase accuracy while decreasing price. So far the IPRO has developed a working electronic circuit that supports wireless data transmission using a Garmin protocol called ANT+. It has been documented that the algorithm used by the code controlling the microprocessor needs some readjustment due to a change in mechanical setup.

The ethical concerns in this project are chiefly safety concerns for the end user. We need to keep in mind at all times that our product will be mounted on bicycles that could be traveling at speeds near 40 miles per hour. Our prototype needs to be tested satisfactorily before we send someone on the road with it strapped to the crank.

1.4 Team Values Statement

Team members are expected to come to regularly scheduled meetings and meetings outside of class on time. If a team member disagrees with the decisions made by the team he is expected to bring in his view in an appropriate and polite manner. The opinion of each team member is to be taken with respect.

Problems are to be addressed using ASME and IEEE codes of ethics. Any issues that concern the team as a whole are to be brought up for discussion by the team at the next class meeting. Team members are expected to act professionally and politely.

2 Project Methodology

2.1 Work Breakdown Structure

Our team identified our primary and secondary goals in our first few meetings. Each time we get together, we plan to review our progress and indentify the highest priority tasks that are obstacles for completing our targets. As stated previously, the team's primary objective is to perform a road test to gather data for determination of the accuracy of the prototype.

The following is a list of the major tasks necessary to complete our overall team objectives.

Mechanical Team tasks:

- Lab testing to get strain gauge coefficients required for calculation of the torque
- Mount the crank set with our strain gauges on the test bike
- Perform a road test of the prototype for data collection
- If progress allows, begin to adapt system to carbon fiber crank set

Electrical Team tasks:

- Update microcontroller software with new coefficients from strain gauges
- Update current circuit to incorporate common design practices
- Devise a method of calibration for the circuit

Visual Team tasks:

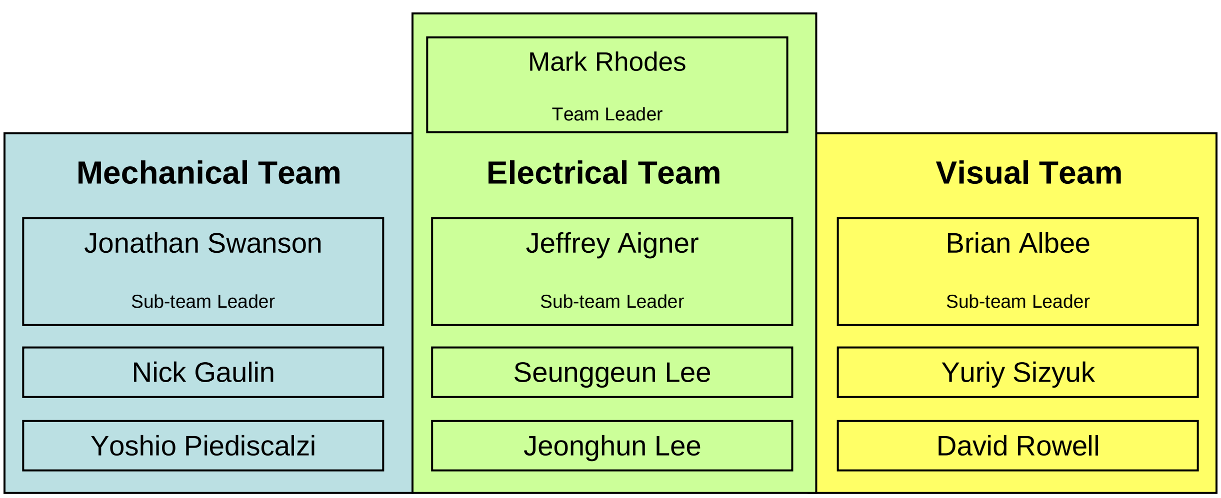
- Research carbon fiber crank sets as a possible extension for this project
- Find and purchase all the parts and equipment for mechanical and electrical teams
- Assist mechanical and electrical teams with documentation and deliverables, as well as anything else that arises during the course of the project

Data from strain gauges will be recorded to a spreadsheet using a strain indicator and recorder manufactured by Vishay that belongs to IIT. This data will be analyzed by the Mechanical team and the subsequent torque calculations will be documented and implemented in the microcontroller code. This process should take less than four weeks(see section 2.1.2 Gantt Chart), at which point the team will start testing with the prototype on a bicycle, which is crucial to our primary objective.

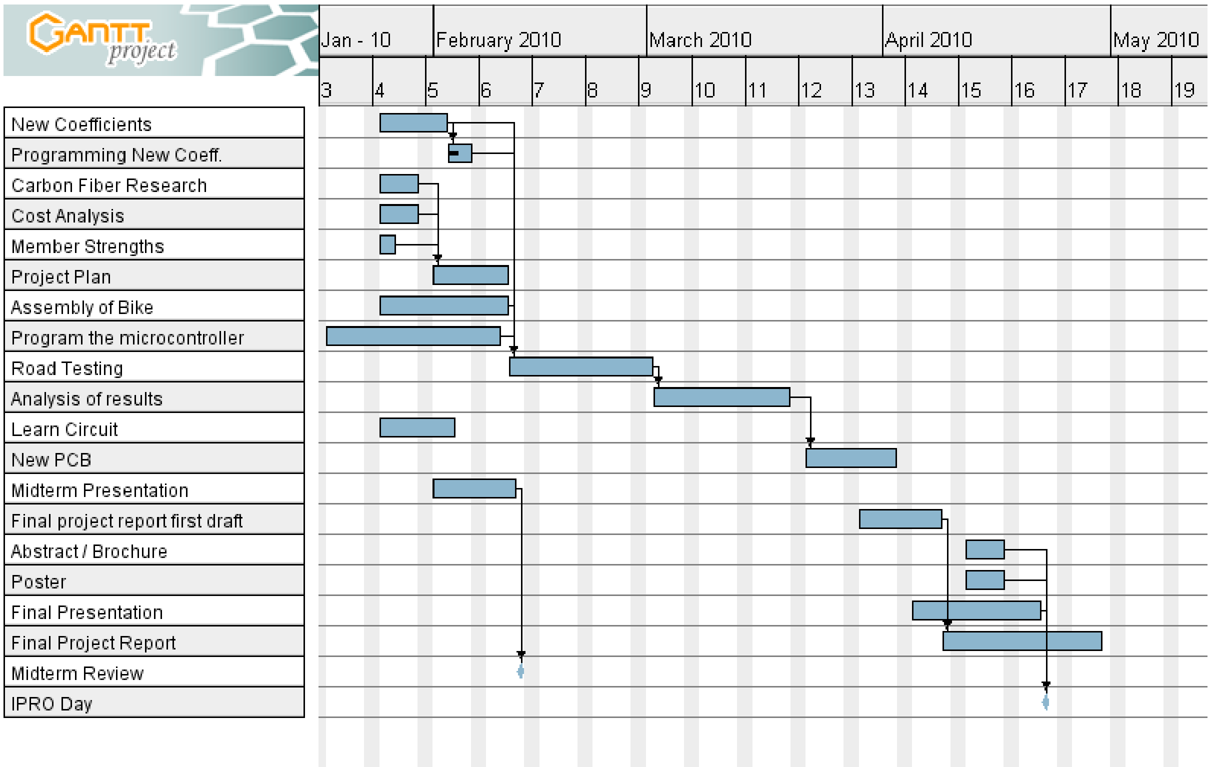
We made the carbon fiber adaptation a secondary objective in order to leave slack time for accomplishing the primary. The Mechanical team is planning not to move on until either they are satisfied with the test results or the only work left to be done is in the circuit.

The Electrical team will verify and improve the circuit function in a laboratory environment. They will use simulated inputs to document internal circuit function as well as output where appropriate. This data will be analyzed for both design and troubleshooting purposes. Depending on the current performance of the circuit as it was handed down from previous groups, this could be either a simple process or an arduous one. They cannot be sure until they get the circuit on a lab bench, so they plan on starting as early as possible to leave a lot of slack time in case many improvements are necessary to satisfy the objectives. Their first priority is to ensure that the circuit is functioning so that the Mechanical team can perform tests on a bicycle.

2.1.1 Team Structure



2.1.2 Gantt Chart



The milestones are defined in the Gantt chart above as the Midterm Review on February 22 and IPRO Day. The team chose the Midterm Review as a target date for completing a test of the prototype on a bicycle. The second milestone will then be IPRO Day, where we hope to have accomplished both our primary and secondary objectives.

2.2 Expected Results

The first task of this team will be to verify the results of the previous groups. We will first test the system on a lab bench with simulated inputs. Once we obtain accurate information regarding its operation, the next step will be to test it using a bicycle set up on a trainer. This is a piece of equipment that securely suspends the bicycle above the ground so that it effectually becomes a stationary bike. The final stage of testing will be to test the system on the bicycle trails of Chicago.

In order to determine the accuracy of the data that our prototype produces, we will need to employ another system with reliable output that is already on the market to serve as a benchmark. We have chosen to use the PowerTap system manufactured by Saris Cycling

Group. Using a bicycle with both the PowerTap and our prototype installed, we will be able to calculate our magnitude of error.

The team intends to further develop the current working model where we deem it necessary. Product design is a process, and it is rare for a final product to match the first prototype, as no rough draft is ever ideal. Recognizing this, the team will be constantly looking for ways to improve the design that has been passed to us from previous teams. We intend to use the knowledge and skills that each of us possess, as well as that which we will gain through research, to enhance reliability and functionality.

There are several improvements we initially identified to make to the current prototype. On the electrical side, we plan to update the circuit with filter capacitors on the integrated circuits to filter out noise in the circuit. Also, the ground plane of the printed circuit board layout needs to be reworked to isolate the AC and DC ground signals from each other on the board, which is considered good design practice.

For the mechanical design, the placement and measurement process of the strain gauges need to be evaluated and possibly improved. The coefficients from the strain gauge readings need to be recalculated per a recommendation by the previous semester's team. We also hope to devise a way to turn the device on and off.

We are working with a prototype designed by students. It can sometimes be difficult to infer why certain design decisions were made. Because the prototype was reportedly functioning at the conclusion of last semester, we don't want to change too much at one time and become overwhelmed. It will be a delicate balance throughout the project to improve the prototype while maintaining its functional integrity.

Our progress this semester will hopefully put the IPRO in a position to begin an investigation of the marketability of this product. The time that we invest this semester will continue to build the foundation for a useful product that can help save bicyclists money while keeping them on the competitive edge.

2.3 Project Budget

Item	Explanation	Cost
Carbon fiber crank set	One of the secondary objectives is to adapt the product for a carbon fiber crank set	$350
Strain gauges	Integral part of the system, and they are fragile so we need plenty	$50
Electronics (PCBs, components, etc.)	Electrical team is most likely going to do a board redesign	$100
Accessories for Garmin	Team doesn't currently have a handlebar mount for the Garmin device	$50
Rechargeable batteries	To power the device	$30
Bike lock	To secure the test bicycle while in storage	$50
Air pump	For tires of test bicycle	$40
	Total	**$670**

2.4 Designation of Roles

- Minute Takers: Brian Albee & Nick Gaulin
- Agenda Maker: Mark Rhodes
- Time Keeper: Mark Rhodes
- iGroups Moderator: Jeff Aigner