IPRO 497-324

Fall 2009

# Power Measurement for Road Bicycles: Toward a Universal Solution

# Project Plan


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**Team Members:**
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Ross Allen
Chris Antonio
Mark Callan
Sara Claxton
Patrick Diesse
Matthew Gaylord
Greg Herbert
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## 1.0 TEAM CHARTER

### 1.1 Team Information

| NAME | MAJOR | EMAIL | PHONE |
|---|---|---|---|
| Luis Adrianzen | Electrical Engineering | ladrianz@iit.edu | [redacted] |
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Luis is an Electrical Engineer. His strengths include Java, circuit theory, and good communication skills. He is also bilingual. His main weakness is that he tends to have a slow start on projects. He expects to learn more about circuits, as well as learning how to be able to apply theory to practice.

Ross is a fifth-year Aerospace Engineer. He left school his 4$^{th}$ year to pursue an internship with NASA and then study in New Zealand. His weak point is his lack of experience with hands-on, engineering problems. He expects the project to produce a fully functioning power meter.

Chris is an Electrical Engineer. His strengths are Java and circuit analysis and his weakness is circuit optimization. He expects that the team will successfully complete the project.

Mark Callan works well in a team, and enjoys doing group work as well as discussing different ways to complete a common goal. His weakness is punctuality. He expects that all team members will learn a lot in this project.

Sara is a fourth-year Mechanical Engineer. She is proficient in Pro-E, and is able to easily learn programming languages (Java, C++, FORTRAN); she also has one year of industry related work experience. Her weakness lies in being able to communicate her ideas clearly. Her expectation about the project is that the team will reach its goal of creating a working system and installing it on a bike.

Patrick is a Computer Scientist. His strengths lie in his independence, logical thought, and maturity. During this project, he would like to work on his ability to work efficiently in a group, as well as to communicate easier.

Matthew is a 4th year Electrical Engineer. He is strong in circuit analysis and digital circuits, he has good organizational skills, and he also works well in a team. His weakness is in circuit design. For this project, he expects that the team will make significant progress, and also learn from the experience.

Greg is a 4th year Mechanical and Aerospace Engineer. He is able to work well with mechanical parts, and he works well in a group; however, his weakness is that he occasionally misses things. He thinks outside the box and is able to visualize problems before they arise. He expects that the team will be able to test the system using a purchased bike.

Dan's skills include soldering, circuit analysis, and programming in Java. His weakness is circuitry. His expectation for the project is to meet the goal of building a functional smaller circuit.

Celeste is a 5th year Mechanical Engineer. Her strengths include leadership, and always seeing a project through start to finish. She is proficient in AutoCAD and Pro-E. Her weakness is in staying calm and rational during stressful times. Her expectation is that the team will work through its weaknesses and difficulties and end up with a successful project.

As a team, all members have decided that the most important elements this semester (i.e. what the team members need from each other) are cooperation, respect, support, and for every team member to put forth an effort.

The team name will remain from previous semesters: Power Measurement of Road Bicycles. The motto of "No Strain, No Gain" will also remain. The logo can be seen on the title page.

## 1.2 Team Purpose and Objectives

The goal of the IPRO is to try to find an inexpensive, but accurate way of measuring the power output of a rider on a bicycle. Problems with systems currently available are: some products are not compatible with all bike systems causing the need to purchase new parts, the cost of the available products is expensive, and some of the available measuring systems are not very accurate. In order to achieve our goals and to improve the current technology, our IPRO is divided into two groups: the mechanical and the electrical team.

- Mechanical Team Objectives
  - Obtain more data from previous crank set
  - Create a 3D model of the crank set using CAD tools
  - Use CAD drawing to create a new support beam
  - Change the chain set up of the previous crank set from a vertical to a horizontal one
  - Design a model that will be easily installed on a real bicycle for testing

- Electrical Team Objectives
  - Improve power efficiency
  - Debug and improve the algorithm used to calculate the applied torque at the bicycle crank set
  - Design a proper packaging System
    - Must work under realistic conditions
    - Needs to conform to the space requirements associated with a bicycle

### 1.3 Background

For the 2009 fall semester, IPRO 324's objective will be to develop a power measurement device for bikes. Since the late 1980s, a few companies came up with various devices to address a requirement that became popular day after day among either professional bikers or just very passionate riders; the need to track down their performances' variations throughout a training session or a training period. *"But isn't this what heart rate monitors are for?"* One might ask. Not quite exactly. If a heart rate monitor is sufficient for a marathoner working his cardio-vascular performance, it can be hardly used in biking. The simplest explanation can be the fact that at varying heart rates, bikers' power output to the bike can plateau, just like with the same heart rate, those measurements might vary (Now let's remember a biker's performance is based on the amount of power he can pass to his bike, so it would probably make sense to focus on that).

The solution initially came in two general forms, each one having its own pros and cons: the handlebar-mounted version and the strain gauge based ones, the latter being more popular.

- Bottom bracket power meters rely on the tensional 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 of a different bottom bracket unit for each bike. Ergomo, the only company making those back then, went bankrupt in 2008.
- The free-hub-based devices came up as a decent solution to the previous problem caused by BB based ones. As they were mounted in the rear wheel, they were easily interchangeable. However, the power being first transmitted through the chain there was loss of intensity, which led to quite inaccurate readings.
- The chain-based technique relied on something similar to guitar pickups that converted the vibrations in the chain and mathematically converted the signal to the corresponding power. The problem caused here was the interferences caused by possible and plausible external noises.
- The technique that might have ended up cheaper for users was the opposite force based ones (handheld mounted). The only disadvantages of these were due to the extreme complexity of the calculations; results varied a lot and were easily influenced by non-acting factors.
- This leads us to the most popular technique used, which is the crank set based. Power output is derived here from the deflection of strain gauges and pedals' cadence. The disadvantage here is the need of specific crank sets. However, since the total net value crank set/device added to accuracy offered, compared to the other systems is low enough changing the sets for each bike is considering minor problem.

For this project, the goal is to increase accuracy while decreasing price. The team inherited a working electronic circuit with wireless data processing ready to use in an ANT+ device from previous sessions of this IPRO (2 of them. The algorithm controlling the microprocessor needs some readjustment due to a change in mechanical setup.

Due to the nature of this IPRO, it is unlikely that ethical issues will arise during the testing and problem solving portions of the project. Most problems currently being faced will be dealt with in a laboratory using machinery and testing equipment. The lack of human interaction and participation at this stage of testing prevents ethical issues from developing.

The issue of miniaturization of electronics for installation on the bicycle might require that we utilize an outside company. This will increase costs and make the IPRO semi-dependant on a separate group to deliver a product.

The team intends on investigating the possibility of performing our own miniaturization of electronics with help from Electrical Engineering faculty. This is intended to keep costs down and create a more in-depth problem solving experience. In the event that this is not successful, the task will be outsourced to company involved in electronics manufacturing.

The power measurement system needs to be installed on a bicycle for road testing.. The expense of the bicycle may prove to be a substantial barrier to the project if sufficient funds cannot be obtained.

To minimize costs and increase flexibility of design of the on-bicycle testing, the team intends to build a bicycle from parts. As an extension of this, the team also plans on approaching bicycle stores for sponsorship.

### 1.4 Team Values Statement

Team members are to come to meetings on time for regularly scheduled meetings and meeting outside class time. If a team member does not agree with a decision, he or she should give their input in an appropriate manner. No team member shall criticize or judge another teammate for his or her opinion.

Problems will be addressed via the ASME and IEEE code of ethics. Problems are preferred to be discussed in person rather than the Internet due to the fact that tone cannot be conveyed through typing and points may be misconstrued. At the beginning of each class meeting, any issues are to be brought up for discussion before the entire team. Team members shall use their best judgment if he or she thinks the issue is a more private matter. If that is the case, then the team member shall discuss the problem at hand with the team leader who will then decide the next course of action.

## 2.0 PROJECT METHODOLOGY

### 2.1 Work Breakdown Structure

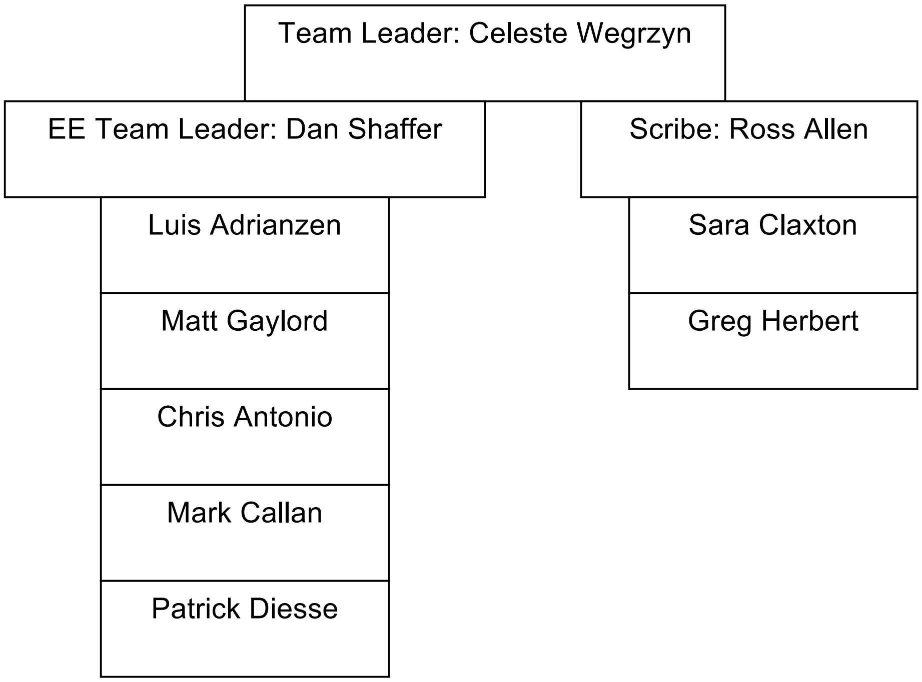
The team's major tasks are to reduce the size and power consumption of the circuit and to modify the test apparatus to obtain more accurate measurements.

To reduce both size and power consumption of the circuit, the team will replace components with smaller, more efficient ones and restructure the current implementation to remove redundant components. The team will consult the data sheets for each potential component and identify specifications necessary to its corresponding function, such as power supply range and input/output impedance. Final testing through actual construction of circuit will determine feasibility of design. The team will also transfer the circuit schematic into a PCB layout to further reduce circuit size and implement switches for certain components to reduce power consumption. The team will consider surface-mount devices for their compact size while taking note of its costs and will record the power saved due to the switches against the overhead introduced to the system.

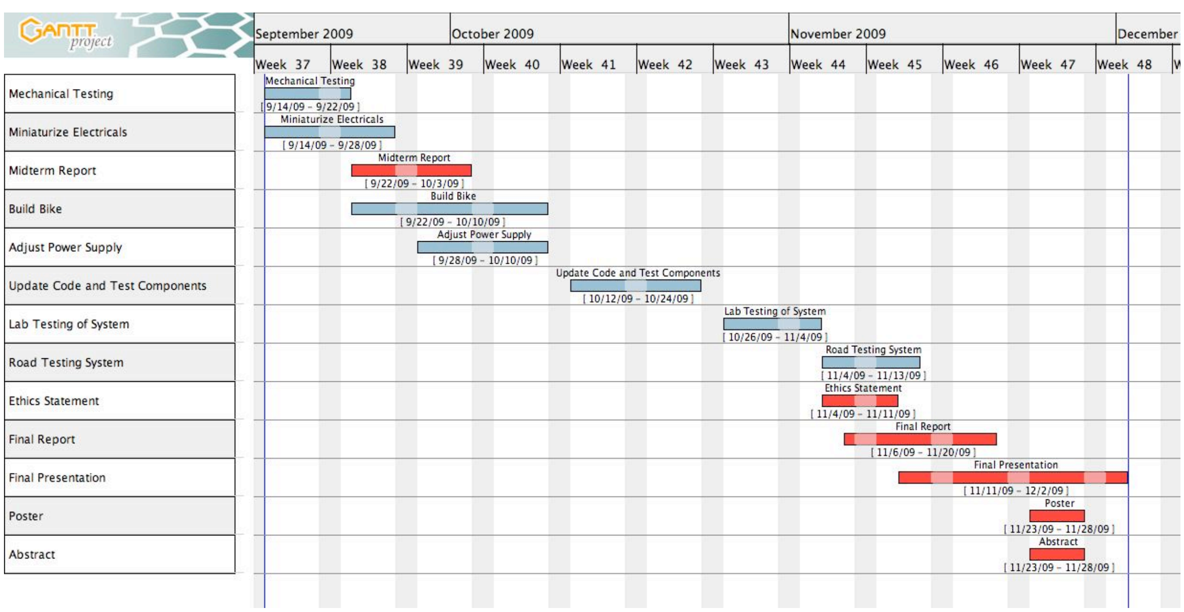
Modifying the test fixture containing the crank set will require the chain length to be perpendicular to the applied force, as opposed to the previous semester where the force was parallel to the chain. This new experimental setup requires new measurements and consequently recalculation of the coefficients. The team will also introduce a self-calibrating function to the algorithm to gain more accurate torque calculations. By sampling the strain gage bridge configuration at no load on startup, the torque formula will automatically adjust for each session. We will test the algorithm by comparing the power output as displayed by the bicycle computer to a controlled power output.

Accomplishing both tasks seems reasonable, as the team does not foresee any substantial obstacles to impede progress.

### 2.1.1 Team Structure




### 2.1.2 Gannt Chart



## 2.2 **Expected Results**

The team intends to further develop the current system to the point of producing a working prototype. A smaller system will be installed onto a complete road bike and the resulting power measurements will be compared to those of a commercially available system. This prototype will demonstrate the accuracy and feasibility of the current system and give future teams much information about how to improve it. Once the prototype is accurate and reliable enough, the focus can then shift to producing a marketable product.

To accomplish these results, the current team must purchase a bicycle, miniaturize the electronics, install the system on the new bike, and install a commercial system on the bike. The mechanical team will be in charge of building the bike and strain gauge installation and calibration as well as lab testing to make sure strain measurements can be accurately made. The electronics group will focus on miniaturizing and optimizing the circuitry that will be on the crank. Once every step has been tested in lab conditions, the system will be tested in realistic biking conditions.

This IPRO also will be able to produce a second version of a working prototype. Since there is the preliminary design work done by previous semesters. The team will be looking into making the prototype as close to actual bike conditions while keeping it compact to easily test for accuracy.

Our major concern this semester is to keep the same functionality of the circuitry while reducing the overall size of our product. This is in an attempt to eventually make this product marketable. Some risks that we are going to have to overcome are making sure that this product is not violating any copyrights from other companies in similar fields. Also this product is going to have challenges associated with accuracy. We are testing and coding as students not professionals so we must be very weary of new ideas since we have never been here before. Research on the topic must be thorough before we proceed in making radical changes.

We are currently finding outside resources to help us in the process of completing our expected results. Our group leaders and advisors will drive this overall goal of the team. Our work in this semester might lead the next team to be able to start on the marketability of this product. Our challenges that are overcome this semester will set the foundation for a great product to be produced to help save bike riders money while keeping them on the competitive edge.

## 2.3 Project Budget

### 2.3.1 Proposed Spending

The mechanical team would like to build a bike and test both our power measurement crank set and the QUARK crank set to compare results. In order to eliminate errors from the equipment, the bike will be built from Shimano Ultegra or 105 components on a solid frame. The Estimated cost of the bike, "depending on the level of sponsorship from a cycle shop" is $1200. The items needed for purchase are: front and rear derailleur, brake levers and shifters, shifting/brake cables, stem, handle bars, headset, forks, frame, chain, seat and post, rear cassette, wheels, tubes, and tires.

## 2.4 Designation of Roles

- Team Leader: Celeste Wegrzyn
- EE Subteam Leader: Dan Shaffer
- Minute Taker: Ross Allen
- Time Keeper: Luis Adrianzen
- Agenda Maker: Celeste Wegrzyn
- iGroups Moderator: Luis Adrianzen