IPRO 497 - 324

Fall 2008

Power Measurement for Road Bicycles: Towards a Universal Solution

Project Plan

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Team:

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1.0.Objectives

- Develop a configuration of strain gauges
  - Accurately measure the output of the strain gauges under various load conditions
    - Crank angle
    - Direction of applied force
    - Point of force application
      - Left pedal
      - Right pedal
      - Both left and right pedal
- Develop an electronic processing unit for post-processing the strain gauge signals
  - Implement an algorithm to calculate the applied torque at the bicycle crank set
  - Transmit the data wirelessly to the Garmin Edge 705 using the ANT+ protocol
  - Must be power efficient
- Package the system
  - Must work under realistic conditions
  - Needs to conform to the space requirements associated with a bicycle

2.0. Background

- 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: compatibility so new parts need to be purchased, along with the cost of the product itself, and other systems whose accuracy is not sufficient.
- There are four main ways in which systems measure the power output of a rider. They include crank set, free hub, chain, and opposing force systems. The crank set system uses strain gages to measure the strain in the crank set which can be related to torque from which the power is calculated. The free hub system works in much the same way except the strain gages are attached to the rear wheel of the bicycle. Chain systems detect the vibration and the speed in the chain and convert that to a power reading. Opposing force systems calculate opposing forces to the rider and bicycle including: gravity, drag, acceleration of the bicycle, and wind speed. The system takes all this information and calculates the power using Newton's Third Law.
- The crank set is what the pedals are directly attached to on the bicycle. The crank set includes the spider, which is attached to the crank arm, and the chain rings, which drive the chain. The freehub is used to connect the chain to the rear wheel.
- Each of these methods has downsides. The crank set systems can be very complicated systems and therefore are very expensive. Not only are the systems themselves expensive, but the system requires a new spider, causing the replacement of an expensive part of the bicycle. The Quarq CinQo has an accuracy of ± 2%, but costs $1159.
- The freehub systems have similar problems to the crank set systems plus the accuracy is can be diminished because the power output of the rider is not directly measured. The PowerTap Pro made by Saris has an accuracy of ±1.5%, but costs $899.99 with the computer.
- Inaccuracy is a bigger problem with the chain systems because of power loss from the crank to the chain as in the freehub systems as well as vibration in the chain caused by other factors including terrain. The Polar CS600 cycling computer with Power Output Sensor has an accuracy of ± 5%, but is less expensive than the crank set and freehub systems at $679.95, but this also includes the bicycle computer.
- While cost is not as much a factor in the opposing force systems as in the crank set systems the accuracy can be far less. The inaccuracy can be caused by drag being affected by rider position, weight fluctuation of the rider, as well as surface of riding surface. The iBike Pro claims to have accuracies comparable to those of high end models, like the crankshaft and freehub systems, but says becomes more inaccurate in sharp turns or long stretches of rough terrain. The cost of the iBike system is $399.99.
- The other side of the project is the interaction with the rider. This is done through the bicycle computer. The computer processes the information from the power measurement systems displays it so the rider can see. Problems faced with the computers involve finding a way to relay the information wirelessly. The Garmin Edge 705 bicycle computer will be used to communicate the information to the rider. The ANT+Sport system will be used for communication between the computer and the rest of the system.

3.0. Brainstorm and Work Breakdown Structure

We would like to develop a system that measures the applied torque at a bicycle crank set. In contrast to current solutions, we want to be able to retrofit our system to existing crank sets, obviating the need to abandon parts that the bicyclist already owns. In principle, according to preliminary tests performed at the MMAE department, this can be done using sets of quite inexpensive strain gauges. However, being able to get accurate torque measurements will require some advanced processing of signals from the strain gauges. These signals can then be transmitted wirelessly to a bicycle computer like the Edge 705 that the global positioning system corporation Garmin released this spring. There is a defined wireless protocol, called ANT+Sport, which has been developed specifically for the purpose of transmitting exercise data, such as power output or heart rate, to small computers. Chipsets and development kits for this protocol are also available commercially. Therefore, our task will be to find an optimal configuration of strain gauges that will be attached to the crank set, and to develop an algorithm to process the strain gauge data in order to isolate a signal that is proportional to the applied torque. This signal will then be transmitted to the bicycle computer for display and storage.

1. Electrical Team
    a. Design Power Supply Circuit
    b. Build Circuit to Interface with Strain Gauges
    c. Design Circuit to Obtain RPM
    d. Develop Algorithm
    e. Implement ANT+ Communication
    f. Design Circuit Board

2. Mechanical Team
    a. Research/Organize
    b. Strain Gauge Testing
        i. Apply Strain Gauges
        ii. Acquire Strain Data
        iii. Preliminary Analysis of Strain Data
    c. Reverse Engineer Commercial Product
    d. RPM Measurement Design
    e. Final Analysis of Strain Data

3. Entire Team
    a. Program Hardware
    b. Test Product

4. IPRO Deliverables
    a. Project Plan
    b. Code of Ethics
    c. Midterm Presentations
    d. Final Report
    e. Exhibit/Poster
    f. Abstract/Brochure
    g. Presentation
    h. IPRO Day

4.0 Expected Results

We anticipate being able to assemble a power measurement system, based on the ideas outlined above, that should cost a small fraction of the price at which currently available systems retail. In addition, we expect that our system can easily be used with any existing bicycle, without the need to replace parts. Ultimately, if this development is successful, we may be able to explore the market potential of a commercial product in a follow-up ENPRO project.

5.0 Project Budget

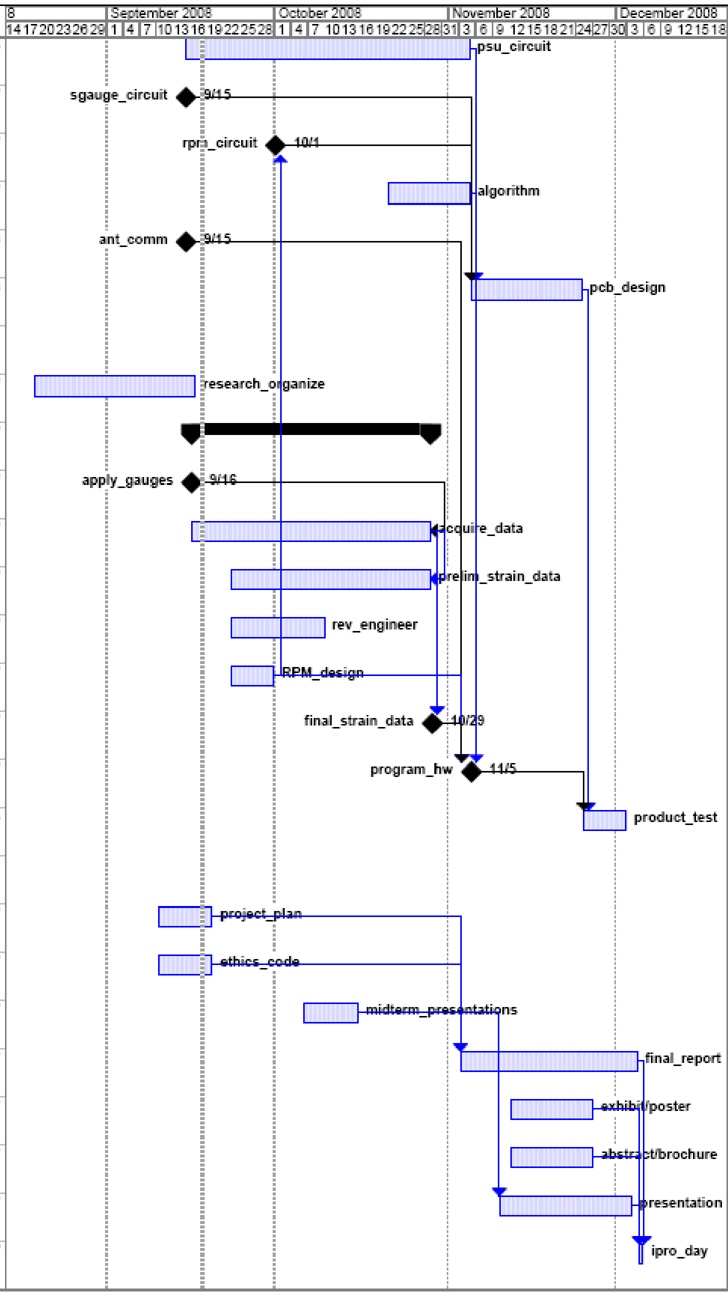
ITEM	UNIT PRICE	QTY	PRICE	PURPOSE	Vendor
Electrical					
NRF24AP1-EVKIT	$699.00	1	$699.00	ANT Developers KIT	semiconductorstore.com
NRF24AP1	$6.00	2	$12.00	ANT Chipset, used for communication with GARMIN Edge 705 using ANT+ protocol	semiconductorstore.com
ANT Alliance membership (5yr)	$500.00	1	$500.00	Needed for Profiles and Network Key	Dynastream/ANT
Garmin Edge 705 bike computer	$470.29	1	$470.29	Displays power data	Garmin
Microcontroller (MCU)	$20.00	1	$20.00	Calculate power, send to transceiver	
Other electronic components	$100.00	1	$100.00	resistors, capacitors circuit boards, clocks, batteries, etc	
Mechanical					
Strain Gauges CEA-13-062UW-350	$442.50	1	$442.50	Sensor to determine torque	Vishay
Strain Gauge Adhesive	$30.00	1	$30.00	Attaching strain gauges	
Quarq Crankshaft	$1,525.00	1	$1,525.00	Reverse Engineering	Quarq
Accelerometer +- 1.2gp 2 axis	$20.00	1	$20.00	Measure cadence (rpm)	
Final Presentation, Materials					
Printer Paper	$15.00	1	$15.00	Reports and Display	
Poster board, paper glue, tape, Binders. etc	$50.00	1	$50.00	Project Displays	
Standard BW copies	$0.11	100	$11.00	Reports and Display	Kinkos
Standard Color Copies per page	$0.59	50	$29.50	Reports and Display	Kinkos
*Brochure Paper + Print fees (100 ct)	$128.00	1	$128.00	Print brochures, flyers, cards, reports	Kinkos
Total			**$4,052.29**		

**Note: Kinkos quoted $128.00 for 2 sided, 4 color Matte finish 8.5" x 11" 28lb paper + printer service*
To upgrade paper to a glossy finish, the quote is $228.00
price break for 250+ copies with 1 week lead time

Bold items already purchased

6.0. Schedule of Tasks and Milestone Events

ID		Task Name	Duration
1		Design Power Supply Circuit	37 days
2		Build Circuit to Interface Strain Gauges	37 days?
3		Design Circuit to Obtain RPM	25 days?
4		Develop Algorithm	11 days?
5		Implement ANT+ Communication	37 days
6		Design Circuit Board	14 days
7			
8		Research/Organize	21 days?
9		**Strain Gauge Testing**	**31 days?**
10		Apply Strain Gauges	26 days?
11		Acquire Strain Data	31 days?
12		Preliminary Analysis of Strain Data	26 days?
13		Reverse Engineer Commercial Product	13 days?
14		RPM Measurement Design	6 days?
15		Final Analysis of Strain Data	4 days?
16		Program Hardware	13 days?
17		Test Product	6 days
18			
19		Project Plan	8 days?
20		Code of Ethics	8 days?
21		Midterm Presentations	8 days?
22		Final Report	24 days?
23		Exhibit/Poster	11 days?
24		Abstract/Brochure	11 days?
25		Presentation	18 days?
26		IPRO Day	1 day?



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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

7.0. Individual Team Member Assignments

Name	Major / Year	Skills and Strengths	Experience and Academic Interest	Subteam	IPRO Assignments
Sergio Aguilar	Computer Engineering 4th Year	Experience in hardware and software design for microprocessors, fluent with multiple programming languages	Intern at Rush Oak Park Hospital - IT Dept.	Electrical	Familiarize with Garmin computer / Interface with ANT or Design power supply circuit (using a coin cell like CR2032)
Patrick Becker	Electrical Engineering 4th Year	C++, Assembler, Ladder Logic programming	Associate Process Control Engineer at the Metropolitan Water Reclamation District of Greater Chicago. Maintain a Remerson and Rockwell Distributed Control Systems.	Electrical	MCU Programming, circuit design and testing
Daniel Gonzalez	Electrical Engineering 4th Year	Experience in MATLAB, C++, Java, Assembly Language, building and debugging circuits, good writing skills, bilingual (Spanish-English)	Electrical engineering and MATLAB code writing. Work in IPRO 302 last semester	Electrical	Member of the electrical team. Design power supply for the circuit. Implement Algorithm for Gauge processing / Misc Coding
Bryan Kaminski	Electrical Engineering 3rd Year	Various computer languages, EagleCAD, MPLAB	Familiarity with programming microcontrollers, soldering	Electrical	Sub team lead Implement ANT+ Communication
Nathan Knopp	Aerospace Engineering and Mechanical Engineering 4th Year	Experience in Pro/E, MATLAB, multiple computer programming languages. Practical experience with instrumentation.	Mechanical engineering work in IPRO 310 in Spring 06. Propulsion systems engineering co-op with NASA Kennedy Space Center.	Mechanical	Mechanical sub team lead. Apply/test strain gauges on bike spider and analyze results.
Crystal Jankhot	Aerospace Engineering 4th Year	MATLAB, LABVIEW, Pro/Engineer, interested in project management.	Laboratory experience (setting up experiments, data acquisition, processing, fluid dynamics [esp. flow visualization])	Mechanical	Team Facilitator, Apply/test strain gauges and process/isolate signals, possibly help design the product packaging
Brandon Marcellis	Aerospace Engineering 3rd Year	MATLAB, AUTOCAD, Some electronic instrumentation experience	Interest in using equipment and solving problems.	Mechanical	Apply/test strain gauges on bike spider and analyze results.
David Poli	Electrical Engineering and Engineering Physics 4th Year	MATLAB, circuit simulation, Printed Circuit Board (PCB) design, instrumentation interfacing, practical instrumentation	Optics and Detectors Internship at Ball Aerospace & Technologies, Technical Co-op at Argonne National Laboratory Electrochemical Analysis and Diagnostics Laboratory	Electrical	Electrical sub team scribe, Final presentation compiler
Ryan Ruidera	Mechanical Engineering 4th Year	Experience in Pro/E, Solid Works, MATLAB, multiple computer programming languages. Practical experience with instrumentation.	Mechanical engineering work in IPRO 349 in Spring 08. SAE build team for last year's 3rd place Formula Hybrid Competition	Mechanical	Mechanical sub team lead. Apply/test strain gauges on bike spider and analyze results.
Henrietta Tsosie	Mechanical Engineering 4th Year	Experience in SolidWorks, MATLAB, Maple, C++, and Adobe Illustrator. Microsoft Office (WORD, Excel, etc). Instrumentation in Lab--soldering, recording data, etc.	Internship at Argonne National Lab (research in enhanced heat transfer). Academic interest in hybrid vehicles, heat transfer applications, engine efficiency, and alternative energy.	Mechanical	Apply/test strain gauges on spider crank set and data analysis. Scriber. Ethics and team charter deliverables.
Jaewon Yoo	Electrical Engineering 4th Year	MATLAB, Dreamweaver, Orcad for electrical design automation.	Rockwell Automation Korea during summer 08. Interested in designing power circuits.	Electrical	Abstract/Brochure, tasks for sub-team.
Arkadiusz Ziomek	ECE 3rd Year	SolidWorks, AutoCAD, MATLAB, Simulink, C, Assembler of AVRAtmega16/32	Experience in design and construction of four legged walking machine. Interested in mechatronics, robotics, electronics, and control systems.	Electrical	Testing of an interface between strain gauges and microcontroller.

8.0 Designation of Roles

Team Leader

- Crystal Lybolt

Mechanical Sub-team

- Nathan Knopp (Sub-team Lead)
- Crystal Jankhot
- Brandon Marcellis
- Ryan Ruidera
- Henrietta Tsosie

Electrical Sub-team

- Bryan Kaminski (Sub-team Lead)
- Sergio Aguilar
- Patrick Becker
- Daniel Gonzalez
- David Poli
- Jaewon Yoo
- Arkadiusz Ziomek

Scribe

- Henrietta Tsosie

Igroups Moderator

- Ryan Ruidera

Sub-team Responsibilities

Mechanical

- Apply and test strain gauges on various areas of the bike's spider
- Analyze results of strain gauge testing
- Reverse engineer commercial device
- Design device to measure bike RPM

Electrical

- Develop microcontroller and circuitry for strain gauges and RPM measurements
- Interface standard bike computer with measurement circuitry

9.0 Sources

Quarq CinQo: www.quarq.us
iBike: http://www.ibike.com.ar/faq.html, http://www.bikyle.com/PowerMeters.asp Polar
Polar CS600: http://www.bikeradar.com/gear/category/accessories/gadgets/cyclecomputers/product/cs600-cycling-computer-with-power-output-sensor-17033?_brc=1,
Saris PowerTap: http://www.saris.com/p-328-powertap-pro.aspx
Garmin: www.garmin.com
ANT+: www.thisisant.com