High Level Design
ElecTrek

EE Senior Design
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1 Introduction

As renewable energy technologies continue to develop, new ways to generate electricity have been implemented. The owner of Outpost Sports in Mishawaka would like to generate electricity from his bicycling training facility. The facility allows eight riders to bring in their bikes to train during the winter. The back wheel of the bike is held in a frame in contact with a braking system to provide resistance. During the 30 minute training session, the average power produced by each rider is 250 watts, with peaks of up to 400 watts. Currently, this is all lost to heat. This project is an opportunity to use energy that is already there in a useful way. If all of the energy from the eight riders could be converted to electricity, it would be enough to power ten 100 W bulbs for an hour. ElecTrek's goal is to work with the current system to achieve this conversion by adding components that capture the energy as electricity and store it in a battery or use it during the session to power a device such as a fan or an iPod.

2 Problem Description and Proposed Solution

The customer for ElecTrek is the owner of Outpost Sports, J.V. Peacock. Mr. Peacock identified a way to improve his bicycle training facility and to save him money on electricity. The goal of this project is to route the mechanical energy generated by the riders into electrical energy that he can use elsewhere in the store. Of the eight set ups, only one will be altered for the project, but if successful, Mr. Peacock can implement the design on all eight systems. There is also the option of contacting the company that produces the systems, RacerMate, about adopting the design and improving it to market with their products.

The training facility uses a system called CompuTrainer. CompuTrainer controls the resistance seen by the rider. It allows individuals to program their own rides, via a controller on the handlebars, or to use a preprogrammed course that is controlled from an external computer. The software includes videos of international races that can be projected on a screen to enhance the riding experience. An Outpost store employee enters various parameters for the rider (weight, age, gender, etc) as well as the desired training course into the computer so the only control the rider will have is how fast he pedals during the 30-minute session.

The main goal of indoor cycling at Outpost Sports is for the rider to experience a realistic racecourse, and the CompuTrainer system provides this simulation. ElecTrek's design works with the system to keep the same training conditions. The solution is one that allows for variable resistance and one that does not make any modifications to the mechanics of the braking system or to the coding of the software.

The design uses a generator to convert the mechanical energy of the braking system to electrical energy. This electrical energy will then either be used to power a device such as a fan during the training session through an inverter, or can be stored in a battery as chemical energy for later use. A major goal is to make the system as non-invasive as possible to prevent voiding the warranty on the CompuTrainer system and altering any of the commercial software. The generator will be connected to the rotating shaft on the brakes. We will use a permanent magnet DC generator because it operates at a speed compatible with the bike and outputs 12 VDC. There will be no additional gears between the generator and the bike wheels. The generator will output a DC voltage.

The DC voltage will be fed into a battery or be converted to AC with an inverter, so that devices can be powered during the training session. Current flow into the battery will be regulated with a charging circuit to avoid damaging the battery. Sensors will monitor the power out of the generator and the voltage of the battery. This power and battery information will be displayed for the user with an LCD screen. The screen will also display the instantaneous power, peak power, average power, and total energy generated.

A microcontroller will control the LCD. It will also interpret the information from the sensors to compute power production and battery charge level. The microcontroller will dynamically control the resistance the brakes apply based on how much power is being drawn from the generator. This is important because depending on the load, the generator's internal resistance will change, affecting the overall resistance on the rider.

3 System Description and Block Diagram

The new addition of ElecTrek's system will interface with the existing software and resistance system. We will not alter how the bike is anchored down. The direct contact between the wheel and the brakes will stay the same. The generator will be attached to the braking system on the rotating shaft on the CompuTrainer system. All other interfaces in the system are wired. Figure 1 shows the contacts between the bike, CompuTrainer, and generator.

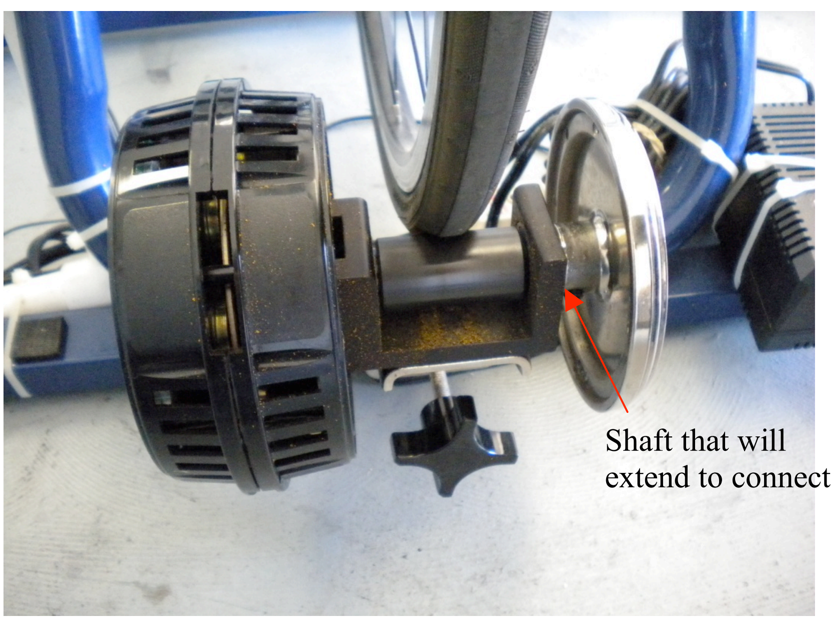

Figure 1. The interface between bike tire and the CompuTrainer system.

The microcontroller is the heart of our design. The microcontroller will intercept the signals from the CompuTrainer software that indicate how much resistance to apply to the wheel. This connection will use the existing cable to the brakes, and the existing cable from the computer, with a DIN-8 connector on each that is wired to the microcontroller. The microcontroller is also wired to the sensors on either side of the charging circuit. All of this information will be displayed on an LCD that is connected to the microcontroller with an I^2C interface.

The charging circuit is the interface between the generator and the battery. It will be between the power sensor on the generator and the voltage sensor on the battery. The information from the sensors will be communicated to the microcontroller via a wired connection. The charging circuit will regulate the voltage and current into the battery and disconnect the battery from the generator when the battery is full. The complete system, with interfaces, is illustrated in Figure 2.

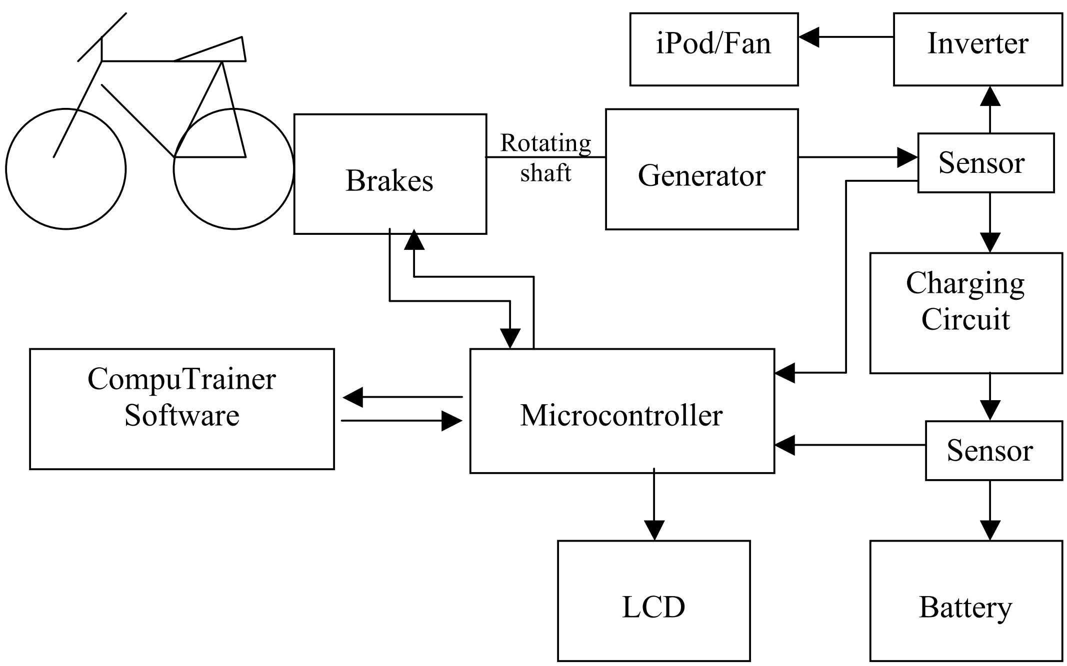

Figure 2. Block system diagram

4 System Requirements

4.1 Overall System

Component	Requirements
Overall System	- Take mechanical energy of stationary bike and turn it into usable electrical energy - Added components should not interfere with rider's experience
User Interface	- Should not change from existing user-handheld device or user-personal computer interfacing (i.e. non-invasive)
Size	- Additional components should not interfere with rider's experience
Weight	- Additional components must be able to be supported by extensions to existing frame that supports CompuTrainer
Safety	- Tripping hazards may exist – extra wires will be taped down, other potential hazards will be flagged so users are aware - No exposed wires or connections - Battery voltage will be regulated
Power	- 120 VAC connection to wall outlet for CompuTrainer - The rest of the system will run off the power going to the CompuTrainer by using DIN-8 cables between components
Cost	- Must fit within $500 budget

4.2 Subsystem and Interface Requirements

Component	Requirements
CompuTrainer	- Pre-existing component - Operates essentially as a "black box" - Uses electromagnetic brakes to provide resistance to the rider based on signals received from the software package on the personal computer - Includes PC software package
Permanent Magnet DC Generator	- Generates a 12 VDC output - Increases the mechanical resistance presented to the rider by producing electrical power - Must run at RPM in the low thousands
CompuTrainer-Generator Interface (Flywheel)	- Smooth connection joint between CompuTrainer and generator shafts–needs to compensate for two different diameters - Generator should rotate freely with CompuTrainer
Charging Circuit	- Uses the DC current from the generator to charge the battery - Needs to regulate the current flowing into the battery

Generator-Sensors Interface	- Monitor the power coming from the generator by measuring the voltage and current at the generator output - Report these statistics to microcontroller
Charging Circuit-Voltage Sensors - Battery Interface	- Need to monitor the voltage across the battery, which comes from the charging circuit, to ensure battery does not overcharge - Report these statistics to the microcontroller
Sensors-Battery-Disconnect	- Once the sensors determine the battery is full, an automatic disconnect needs to prevent current from flowing into the battery
Battery (Lead-Acid)	- Operates at 12 VDC - Two functions: charging or powering a load - Must be able to handle several amps of direct current - Must withstand deep cycling and intermittent charging
Inverter	- Converts DC into AC to power a load - Convert from 12 VDC to 120 VAC
Load	- Variable, e.g. fan, lamp, cell phone charger - Connects via standard wall socket
LCD screen	- Runs off 5 VDC power supply - Compatible with I^2C interface - Needs enough display space to show the total energy generated; the instantaneous, average, and maximum power generated during the training session; the battery charging level; and whether or not the battery is connected to the system
Microcontroller (μC)Software	- Runs multiple functions and interfaces, e.g. intercepting signals from the CompuTrainer software; sending signals to the LCD, CompuTrainer, and generator; and polling the various voltage and current sensors in the system (see interface descriptions below) - Must have at least 3 analog-to-digital converters
μC-Software Interface	- Intercept signals determining required resistance and distribute to CompuTrainer and generator - Acquire statistics (e.g. power readings) from software so it can be displayed on the LCD screen
μC-LCD Interface	- μC sends signal to LCD telling it what statistics to display
μC- CompuTrainer Interface	- After μC intercepts signals from software which indicate the required resistance, μC apportions part of that resistance to the CompuTrainer by sending a signal to it
μC-Generator Interface	- Use voltage and current readings from sensors to determine power being produced by generator and then the resistance the generator is providing to the rider

4.3 Future Enhancement Requirements

Component	Requirements
CompuTrainer/Generator Interface	- Will be one system instead of two integrated components. The system will use purely electrical resistance from an applied load to make the generator harder to spin, thereby generating mechanical resistance. This would make for a more efficient combined training and energy capture system.
Energy Capture Subsystem (Generator-Battery-Load)	- Will include a resistive element that dissipates heat generated by the system to the outside rather than in the building - Must be used with the single CompuTrainer/generator system mentioned above - Charge multiple batteries in parallel

5 High Level Decisions

5.1 Generator Unit

A generator will be connected to the shaft of the CompuTrainer system in place of the standard flywheel. A coupler will be used to provide a direct connection and compensate for any differences in diameter between the generator's shaft and the CompuTrainer system's existing axle. The turning resistance of the axle will be a combination of both the generator and the braking system's combined mechanical resistance. The generator will run with an upper limit of about 4000 RPM, and output a power of a few hundred watts. The output will be 12 VDC.

A power sensor will be connected to the generator's electrical output. This sensor will send its readings back to the microcontroller in order to monitor power production.

5.2 Electricity Storage Unit

A 12 VDC deep-cycle lead acid battery will be used to store unused electrical energy. There will be a charging circuit that connects to the generator at the circuit's input and to the battery at its output. This charging circuit will regulate the voltage and current going to the battery in order to properly charge it. This circuit also ensures that the battery is not overcharged. The voltage at the input to the battery will also be monitored in order to estimate the charge level of the battery. This information will be routed back to the microcontroller.

5.3 Inverter

An inverter will be connected in parallel with the storage unit to the generator's electrical output. The inverter will convert our DC voltage into the 120 VAC voltage found at a typical wall socket and provide the standard three-prong connection. This will allow us to supply power directly to devices. When the generator is producing insufficient power, the battery will be used to power the inverter. The power that is not used by the inverter will be used to charge the battery.

5.4 Display Unit

There will be an LCD which displays instantaneous power, maximum power, average power, total energy generated, the charge level of the battery, and whether the battery is connected. This device will be connected via an I^2C interface to the microcontroller.

5.5 Control Unit

The microcontroller will collect readings from the voltage and power sensors, calculate power generation and battery charge level, and determine the necessary braking needed by the CompuTrainer. The microcontroller will need three ports with analog to digital conversion, one port with an I^2C connection, one port of digital input and one last port for digital output.

The voltage and current sensors will be connected to the A/D ports. The LCD will be connected via the I^2C interface. The digital input will be used to read the resistance requirement sent by the CompuTrainer software. The digital output will then be the adjusted resistance command that will be sent to the variable resistance device that has been altered to account for the resistance of the generator.

The CompuTrainer software connects to the brakes via a DIN-8 connection. This connection carries power, ground, resistance, and RPM information. The load generator sends the RPM back to the software, and the software sends the required resistance to the brakes. Our device will be connected between these two systems. Power, ground, and RPM pins will be wired together; however our microcontroller will intercept the resistance signal. The mechanical resistance of the generator will be calculated based on its instantaneous power output, and that will be subtracted from the required resistance. The microcontroller will then send a new resistance signal to compensate for what our generator cannot provide.

6 Open Questions

There are a few unknowns remaining in this project that will need to be addressed throughout the project timeline. One important problem involves the resistance of the generator. Being able to provide a reliable resistance to the rider is a major deliverable of this project. We must accurately measure the resistance provided by the generator. This measurement will be used to determine how much resistance must be provided by the CompuTrainer system. The sum of the resistance from the generator and from the CompuTrainer system will deliver the total resistance to the rider. Our main problem here is compensating for both the mechanical and the electrical resistance of the generator. We do not know for certain whether measuring the voltage and the current of the generator will provide an accurate representation of the resistance delivered to the rider by the generator. A dynamometer can be used to measure the resistance of the generator. Our setup requires that the resistance measurements must be made constantly to ensure that the variable generator resistance combined with the brake system resistance delivers the correct rider resistance.

A second question is how to interpret the signals sent by the software to the CompuTrainer brake system. Currently, the software sends a signal to the CompuTrainer brakes to provide a certain amount of resistance to the rider. Since we are planning on supplying this resistance with the generator as well as the brake system, we need to alter the signal telling the brake system how much resistance to apply. We do not yet know which data format the software uses to communicate with the brake system. Since communication between the computer and the brake system relies on a standard connector, we can use the Logic Analyzer to look at the signals. This testing will have to occur at Outpost Sports in the bike training facility. We currently do not know which test setup will verify all signals coming from the CompuTrainer software, but we plan to start working on this problem soon.

7 Major Component Costs

Table 1 below gives an estimated cost breakdown of our project. Our most expensive items are the generator, battery, and printed circuit board. Other components will be required to build the charging circuit and to populate the boards, but these costs are minimal.

Table 1. Cost Breakdown

Component	Individual Component Cost
CompuTrainer system with software	$0.00
DC permanent magnet generator	$191.36
Current sensor on generator output	$4.66
Deep cycle lead acid battery	$59.95
Microcontroller	$13.32
LCD	$24.90
Inverter	$45.00
Printed Circuit Board (PCB)	$50.00
Total:	**$389.19**

8 Conclusions

ElecTrek's design for Outpost Sports' bicycle training facility will allow the owner to capture the energy created by the riders into a useful form. The design will generate electricity without altering the training experience and will not alter the braking system or the existing software. The primary components will be a generator, battery, inverter, sensors, and a microcontroller.

The primary issues with the design involve dynamically changing the resistance on the braking system to make up for the resistance added by the generator. These will be resolved throughout the design process. We anticipate that working out each question with the design will be challenging, but that we will be able to complete the project successfully.