IPRO 315
Fall 2003

Hybrid Electric Bicycle

Illinois Institute of Technology

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Previous Semesters:

Focused on researching the various systems of a bicycle and components, also assembled an E-bike (regardless of weight or cost)

This Semester:

We focused on improving the current design of the E-bike by reducing the weight and optimizing the power and control of the various electrical components.

Goals for the semester

- Primary- Compose a complete Design of a hybrid electric bicycle
- Secondary- Build an actual physical prototype of a Hybrid Electric Bicycle (HEB)

Where to start?

The marketing department of company "X" requested that our Hybrid bike met the following specifications.

- Rider : 150lbs
- Bike velocity with out pedaling: 20mph
- Bike velocity with pedaling at 90 rpm: 30 mph

With out pedaling the motor should propell the bicycle at 20 mph for a rider with average weight of 150lbs. With the motor at full throttle, and the rider pedaling at 90 rpm, the bike should travel at 30 mph. If a person pedals at 20mph, the bike should move at 30mph

The Design

Our Design will include:

- A standard bicycle design with lightweight components along with an auxilary Hybrid add-on.
- A complete bill of materials including each part needed, its model#, style, company, and cost

How to Reduce the Weight

Component #1: Battery

Common Batteries are Nickel-Cadmium (very heavy)

Solution: Lithium Ion Battery

This is being made by Grad students in the Chemistry department

(much lighter)

Component #2: Bike Parts

The frame, wheels, seat, pedals, gears, etc are set to be under 10 lbs total.

Solution:

Have one gear as opposed to multiple gears.

Also- Low weight bike parts that won't reduce durability

Component #3: Motor

Ideally we need a motor that is around 5 lbs, However, for our purpose we need a strong motor (High horse power means high weight)

Solution:

¼ hp motor is enough for 2000rpm.

Our motor to wheel ratio is about 10:1 so our wheel will turn 250 rpm.

Motor

Type: Permanent Magnet Brushless DC Motor
Company: MOOG Components Group

Specifications

Rated Voltage: 24 Volts

- Rated Current: 23 Amps
- Rated Speed: 3300 RPM
- Rated Torque: 188 oz-in
- Rated Power: 459 watts
- Power Efficiency: 83%
- Weight: 88 ounces (5.5 lbs)

Why we chose this motor:

- Brushless DC Motor
- Weight of 5.5 lbs is within desired specifications
- High speed capability
- High energy neodymium magnets
- Compact size: 4.5 x 3.4 inches
- Can be functioned as a generator
- Provides adequate power for our application (0.61 HP)

Why Brushless?

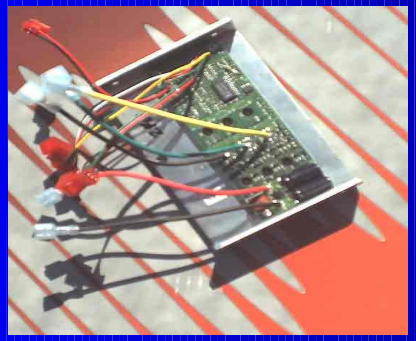
Advantages:

Efficient, quiet, long-life operation, runs at high RPM, and requires less maintenance.

Disadvantages:

Cost was very high.

Controller



Type: Transmagnetic Brushless DC Controller

Company: ThunderStruck Motors

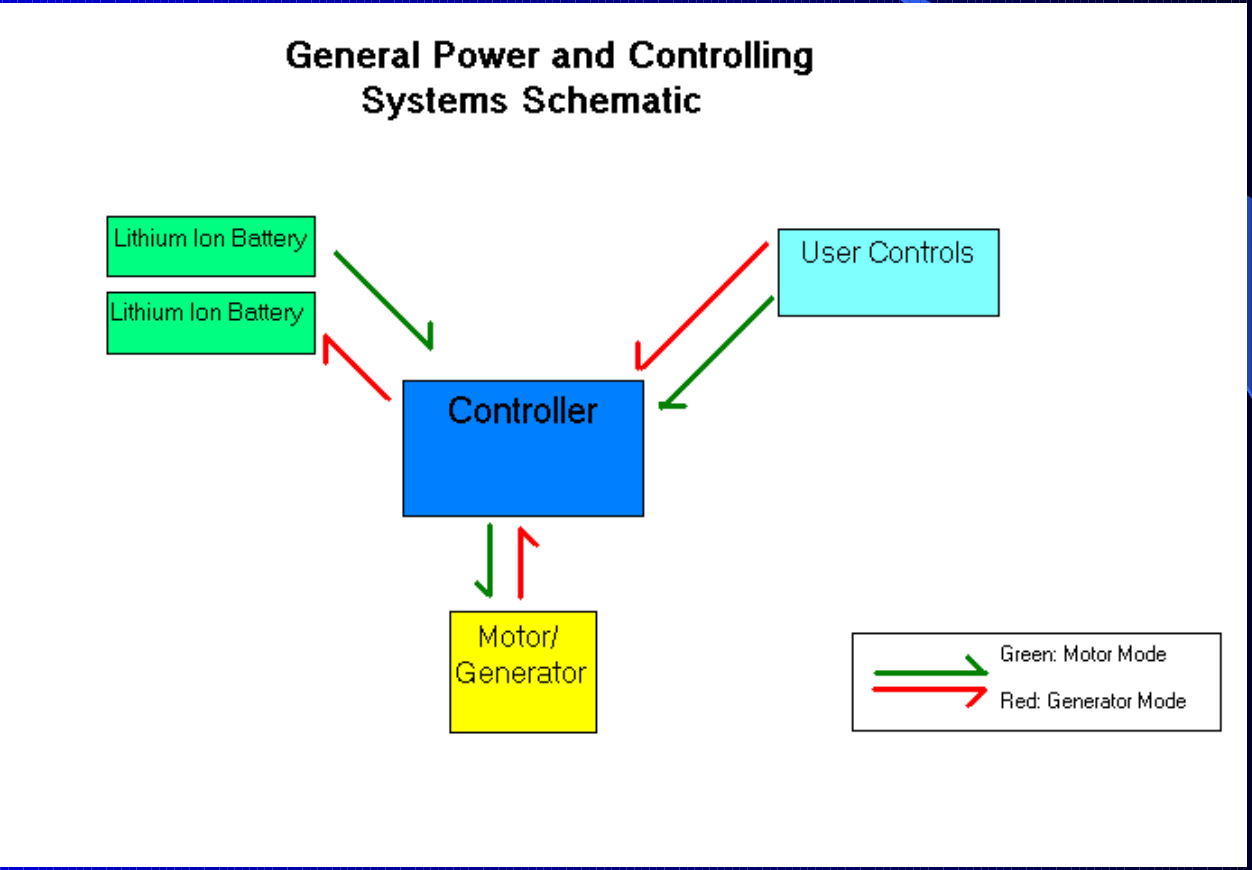
Specifications

- Voltage Rating: 24 Volts
- Current Rating: 35 Amp

Why we chose this controller:

- Voltage is consistent with Motor voltage
- Current is safely above the motor current rating of 23 Amps
- Regenerative Braking
- Ability of bike to reclaim energy lost to braking
- Allows the option to start, stop and reverse
- Speed control using potentiometer
- Current-limit control
- Thermal protection
- Discount

How Controller w/ battery and motor work together



Motor/Generator & Controller

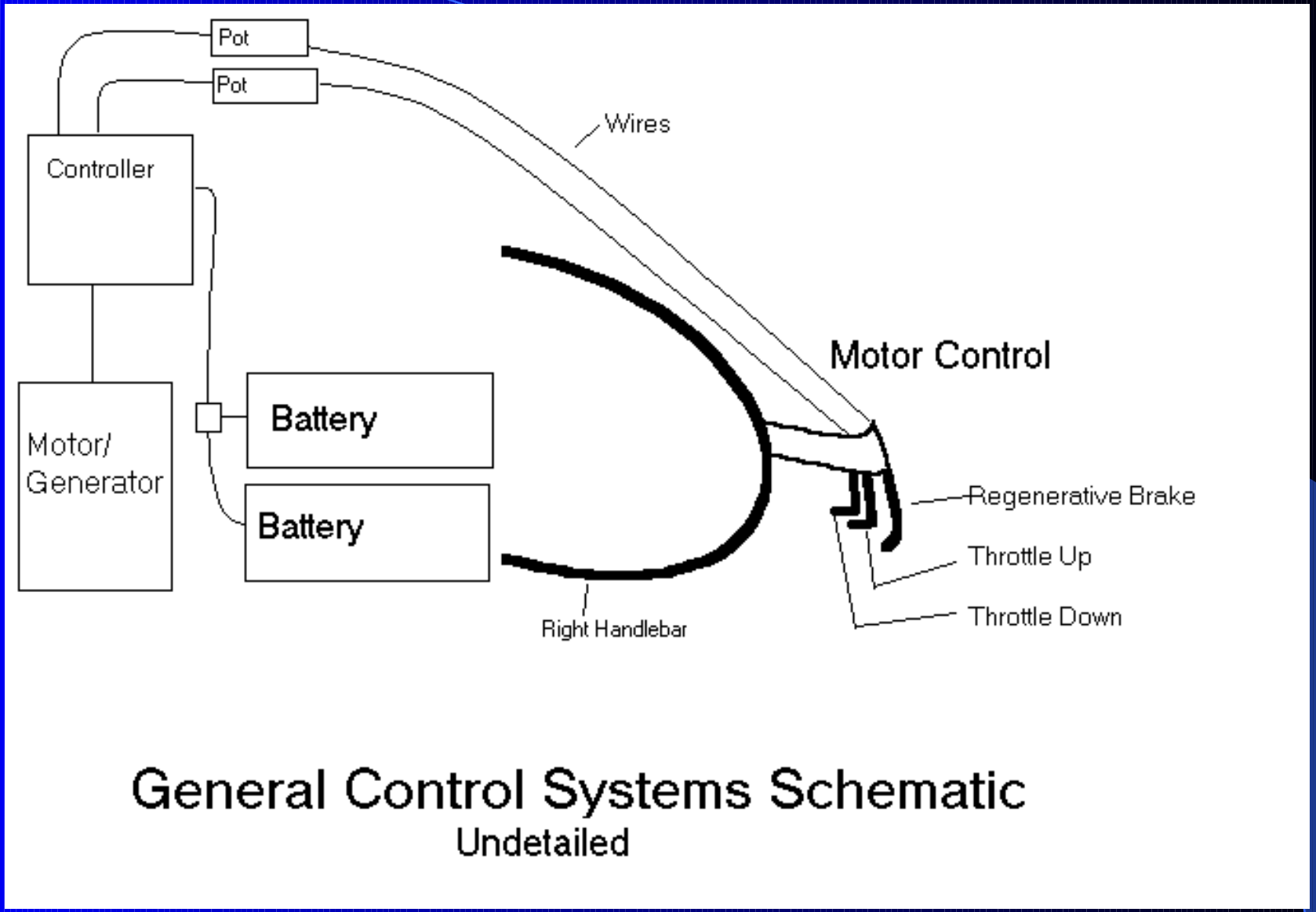
- In Motor mode, the controller powers the motor via the battery
- In Generator mode, the motor sends current to the controller to recharge the battery
- Three phase, four quadrant compatibility, for PMDC brushless motor
- Motor speed controlled by a potentiometer in the controller (0-5kHz)
- Add-on internal potentiometer for load adjustment in generator mode

Battery & Controller

- 36V Battery to 24V Controller
- The current rating of the battery is built to the controller specifications
- A manual current limit adjust on the controller allows for battery protection.
- In non-use mode, the bicycle may be charged by a regular 12 volt house outlet
- Battery has extra circuitry for protection

Controls & Controller

- Linear wire movement from bicycle controls (Handbrake, paddle shift) is transformed by linear potentiometers into an electrical signal and sent to the controller
- Some circuitry may be added for a throttle override
- Controller add-on for user control of regenerative braking



General Control Systems Schematic

Undetailed

Problem #1
Battery protection

Solution: The team consulted with IIT's lithium ion battery research group. The result was custom designed batteries to fit the needs of IPRO-315. Research on how to distribute the battery damaging excess current supplied by the generator was performed. Ideally the use of super-capacitors would be implemented. However, the cheap and feasible solution was the use of resistors.

Problem #2: Device compatibility

Solution: Device compatibility was achieved by consulting with numerous experts. The team worked directly with suppliers, professors, and on-line resources to ensure compatibility.

Problem #3: Interfacing the System Controls with the user

Solution: Decided from a brainstorming session. The result was two controls in one device. The single device is a handbrake with paddle-shifters behind the brake lever. The paddle-shifters control the throttle, and the handbrake administers the variable load for the regenerative brake.

Physical Prototype

- Bike with a motor attached to enhance the speed.
- Field Trip to TREK Bicycle Company (Milwaukee, WI): Donated rear wheel and front fork.

The Drive train

- Motor speed is 3300 rpm
- Rear wheel must spin at ~250 rpm
- 2-stage gear reduction is needed
- Cons of single stage: noisy chain, flying lubricant

The Drivetrain: Gearing Design

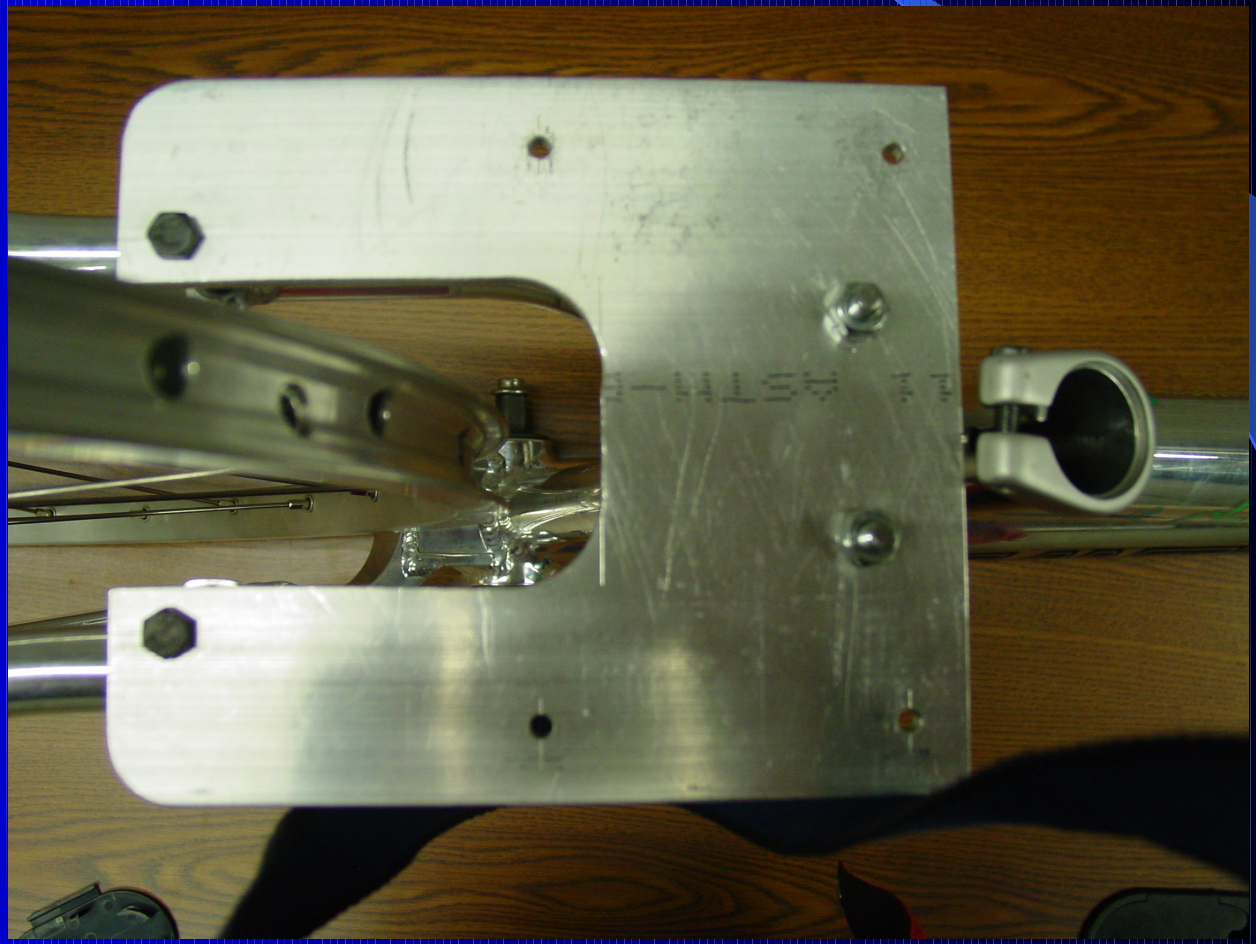
- Used HVAC belt and pulleys for high rpm
- Used a drive shaft to transition to cogs
- Overall gear reduction achieved ~ 10:1

- The Main Problem: How to mount everything?

The Drivetrain: Mounting Design

- Used frame's existing rear brake mounts
- Also mounted onto frame's seat stay
- Designed plates that connect motor, bearings, and driveshaft
- Mounting blocks aligned chain-drive
- Custom pieces made in E1 Machine Shop

Mounting



The Final Product

Future Semesters

- We hope that future semesters will develop regenerative breaking

- The energy from breaking can be transformed into energy to recharge the battery.

THE END

Questions?