Bicycle-Powered Charger

Design Team:
Alex Howell
Daylon Roitsch
Taylor Wollert

Advisor:
Dr. Kevin Kilty
Overview

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5. System Design
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Project Description

• Bicycle-powered charging system
• Charge typical 5 V electronics
• Accommodate any adult bicycle
• Quick transition
Background

• Rationale:
  • Sustainability movement
  • Reliance on small electronic devices
    • 2% of all home electrical consumption
  • Cycling popular form of exercise/transportation
    • 50% of fuel consumption used for trips less than 10 miles

• History:
  • Bottle-cap generator
  • Atom
  • Wheel-belt system

Figure 1: (a) bottle cap generator (Chicargobike, 2010), (b) Atom charger (Siva, 2015), (c) wheel-belt system (DIY Bike Generator, 2015)
Background: Small Household Electronics

Figure 2: Electronic device peak power consumption. Values were self-obtained from personal electronics.
### Design Considerations

Table 1. Design constraints for each sub-system of the Bicycle-Powered Charger system.

<table>
<thead>
<tr>
<th>Item</th>
<th>Considerations</th>
<th>Other Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support Frame</td>
<td>Must support standard retail bicycles (focusing on wheel sizes) and riders weighing a maximum of 95% of male weight to a minimum of 5% female weight</td>
<td>Weight, Size, Strength, Safety, Cost, Aesthetics, Ease of Use</td>
</tr>
<tr>
<td>ATV Magneto</td>
<td>Must generate power required for 12V charging system</td>
<td>Size, Level of Resistance, Cost</td>
</tr>
<tr>
<td>Battery Pack</td>
<td>Must store 12V DC and have multiple removable charge outlets</td>
<td>Longevity of Charge Cycles, Safety, Cost</td>
</tr>
<tr>
<td>Unified Electronics</td>
<td>Must increase/decrease input voltage to meet battery voltage requirements</td>
<td>Compatibility, Safety, Cost</td>
</tr>
<tr>
<td>Display</td>
<td>Must show calories burned, distance covered, current speed, and charge accumulated</td>
<td>Weight, Durability, Safety, Readability, Ease of Use, Cost</td>
</tr>
</tbody>
</table>
Objectives

- User Desirability
- System Integrity
- Overall Cost
- Charge Capabilities
Objectives: User Desirability

• Aesthetics
  • Reduce bulkiness
  • Appearance

• Ease of Use
  • Light weight
  • Fast transition
  • Universal compatibility

• Cost
  • Between $200-$400

• Safety
  • Consumer Product Safety Commission
  • American Society for Testing and Materials
Objectives: System Integrity

• Support frame
  • Durable

• Charging system
  • Robust
    • Lead-acid battery
  • Effectiveness

• Display
  • Accurate
  • Rugged
  • Relevant
Objectives: Overall Cost

- **Budget:** $700 provided by Dr. Kevin Kilty
  - Bicycle trainer
  - Generator
    - Shaft manufacture
  - Battery pack
  - Aesthetic components
  - Display

<table>
<thead>
<tr>
<th>Support Frame</th>
<th>ATV Magneto</th>
<th>Electrical Components</th>
<th>Shaft System</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>$59</td>
<td>$0</td>
<td>$4.50</td>
<td>$72.23</td>
</tr>
<tr>
<td>Manufacture</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>24 hrs.</td>
</tr>
<tr>
<td>Time</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Objectives: Charge Capabilities

• Convert variable AC voltage into consistent DC voltage
• Directly charge small electronic devices
• Charge 12 V battery pack
  • Lead-acid battery
  • Removable storage
  • Multiple USB 5 V charge outlets
System Integration

Figure 3: Integration of various sub-systems of bicycle-powered charger design.
<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>PART</th>
<th>DESCRIPTION</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>frame front</td>
<td>3/16” Walling Aluminium Hollow Tubing, Pipe Diameter: 1/4”, Tube Length: 1/16”</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>support upright</td>
<td>3/16” Walling Aluminium Rectangular Tubing, Outer Dimensions: 1/2” x 1/2”, Inner Dimensions: 1/4” x 1/4”</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>support cover</td>
<td>1/4” Aluminium Plate, Outer Wedge Triangle Dimensions: 3/4” x 3/4” x 1/4”, Inner Rectangular Dimensions: 1/2” x 1/2”</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>foot</td>
<td>3/4” Rubber Feet, 3/16” Stud</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>backbone</td>
<td>See Back Assembly, Attachment</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>top offset side</td>
<td>See Top Support Attachment</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>top</td>
<td>See Top Attachment</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>M8 x 1.25 x 25</td>
<td>1/4” Hex Nut</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>socket head cap screw, oil</td>
<td>Socket Head Cap Screw, Head Diameter: 3/8”, Thread Diameter: 1/4”, Length: 2.75”</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>socket head cap screw, oil</td>
<td>Socket Head Cap Screw, Head Diameter: 3/8”, Thread Diameter: 1/4”, Length: 2.75”</td>
<td>4</td>
</tr>
</tbody>
</table>

**Figure 4(a): Complete frame**

**Figure 4(b): Support top**

**Figure 4(c): Normal Top**
## Shaft System

Table 3: Output of the new design plan for various bicycle tire diameters.

<table>
<thead>
<tr>
<th>Diameter of Bicycle Tire (operating at 3 rps)</th>
<th>Output in RPM</th>
<th>Diameter of Bicycle Tire (metric) (operating at 3 rps)</th>
<th>Output in RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>24”</td>
<td>1080</td>
<td>700x18</td>
<td>1165.5</td>
</tr>
<tr>
<td>25”</td>
<td>1125</td>
<td>700x23</td>
<td>1183.5</td>
</tr>
<tr>
<td>26”</td>
<td>1170</td>
<td>*700x25</td>
<td>1192.5</td>
</tr>
<tr>
<td>27”</td>
<td>1215</td>
<td>700x32</td>
<td>1201.5</td>
</tr>
<tr>
<td>28”</td>
<td>1260</td>
<td>700x35</td>
<td>1215</td>
</tr>
<tr>
<td>29”</td>
<td>1305</td>
<td>700x47</td>
<td>1233</td>
</tr>
</tbody>
</table>

*Size of test bicycle

Figure 5: SolidWorks model of the shaft system spun by the rear bicycle wheel used to spin the rotor.
Generator

- ATV magneto stator
  - Bought rotor
  - Manufactured cover
- 13.4V generator
- Two outputs

Figure 6. ATV magneto components.
Sub-System Integration: Unified Electronics & Control

Figure 7: Components of the Unified Electronics and Control sub-system and its outputs.
Unified Electronics & Control

Figure 8: Shunt regulated power supply prototype.
<table>
<thead>
<tr>
<th>Item / Function</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>Sev</th>
<th>Potential Cause(s)/Mechanism(s) of Failure</th>
<th>Prob</th>
<th>Current Design Controls</th>
<th>RPN</th>
<th>Recommended Action(s)</th>
<th>Responsiblity &amp; Target Completion Date</th>
<th>Actions Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Magnet Motorcycle Magneto</td>
<td>Crack/break. Burst. Side wall flex. Lost magnets.</td>
<td>Magnetic field broken. System won't operate. During breakage may be hazardous to the user.</td>
<td>8</td>
<td>System operating at too high rpm. Movement of magnetic field. Child or pet tamper with system.</td>
<td>2</td>
<td>Display, detectable cracks, bends, breakage</td>
<td>5</td>
<td>Construction of lid to shield moving parts, testing system limits</td>
<td>Design Team by May 2016</td>
<td>Construction of lid to shield moving parts, testing system limits</td>
</tr>
<tr>
<td>Bicycle Trainer Frame</td>
<td>Crack/break/bend</td>
<td>Drops the bicycle</td>
<td>8</td>
<td>Overload the yield strength</td>
<td>2</td>
<td>Cracks, bend, breakage</td>
<td>5</td>
<td>Test for yield strength, tensile strength, stress</td>
<td>Design Team by May 2016</td>
<td>Test for yield strength, tensile strength, stress</td>
</tr>
<tr>
<td>Shaft System</td>
<td>Crack/break/bend</td>
<td>Damage and halt of product operation</td>
<td>9</td>
<td>Overload the yield strength of shaft and/or fasteners</td>
<td>2</td>
<td>Cracks, bend, breakage, audibility during operation</td>
<td>2</td>
<td>Test for yield strength, tensile strength, stress</td>
<td>Design Team by May 2016</td>
<td>Test for yield strength, tensile strength, stress</td>
</tr>
<tr>
<td>Electrical Components</td>
<td>Crack/break/bend/frayed wires</td>
<td>Harm to user, harm to system, fire hazard</td>
<td>5</td>
<td>Burn out/cuts from sharp edges/long-term use</td>
<td>3</td>
<td>Visible crack/break/bend/frayed wires</td>
<td>5</td>
<td>Purchase for durability, shield from potential damage</td>
<td>Design Team by May 2016</td>
<td>Purchase for durability, shield from potential damage</td>
</tr>
<tr>
<td>Battery</td>
<td>Explosion, leaks of corrosive/acidic fluids</td>
<td>Fire hazard, acid burns, toxic fumes, shrapnel</td>
<td>10</td>
<td>Failure of electrical components</td>
<td>2</td>
<td>Display, visible corrosion</td>
<td>3</td>
<td>Prevent overcharge of battery, prevent damage to electrical components</td>
<td>Design Team by May 2016</td>
<td>Prevent overcharge of battery, prevent damage to electrical components</td>
</tr>
</tbody>
</table>
FMEA: Bicycle Frame

• Sources of Failure and Effects

• Testing:
  • Yield strength
  • Ultimate strength
  • Stress
  • Stability
  • Strength and fatigue of welds
Testing: Plan

• Strength
• Stability
• Safety
• Electrical Outputs
• Display
Testing: Generator Output

- Voltage & current outputs from ATV magneto

Table 4. ATV magneto output results.

<table>
<thead>
<tr>
<th>Wire type</th>
<th>Voltage</th>
<th>Current</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge</td>
<td>7 V rms</td>
<td>2 A</td>
<td>14 W</td>
</tr>
<tr>
<td>Spark Plug</td>
<td>140 V rms</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 9: (a) Bicycle test setup, (b) charge wire test, (c) spark plug wire test.
Testing: Generator Output
Testing: Shunt regulated power supply

Figure 10. Shunt regulated power supply testing results. A standard 7 V RMS AC source was used.
### Commercial Viability

Table 5. Material & manufacturing costs spreadsheet used to analyze commercial viability of mass producing bicycle-powered charger systems.

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unified Electronics and Control</td>
<td>$16.45</td>
</tr>
<tr>
<td>Display</td>
<td>$15.00</td>
</tr>
<tr>
<td>Charging System</td>
<td>$35.50</td>
</tr>
<tr>
<td>Roller System</td>
<td>$47.12</td>
</tr>
<tr>
<td>Contracted Generator</td>
<td>$20.00</td>
</tr>
<tr>
<td>Contracted Frame</td>
<td>$30.00</td>
</tr>
<tr>
<td><strong>Total Integration Cost</strong></td>
<td><strong>$164.06</strong></td>
</tr>
</tbody>
</table>

Consumer Price Range $300-$400