# Electric Vehicle Optimization Team 2

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**Sponsor: Cummins - Dr. Michael Hays**
**Advisor: Dr. Juan Ordonez**

# Presentation Outline



- Project Scope
- Preliminary Design
- Final Design
  - Electrical Design
  - Mechanical Design
- Project Management

# Background



- Cabin electronics drain semi-truck batteries.
- Cold weather conditions reduce battery output.
- Hotel System of Charging

- Sponsor presented the design team with two major problems:
  - ✦Current range is unsatisfactory
  - ✦Cannot operate in -29°C (-20°F)

# Overview



**Goal Statement:**

- "To increase the current range and operable conditions of the electric vehicle by utilizing a secondary power source in efforts to apply this to semi-trucks."

**Objectives**

- Increase the lower temperature limit to -29°C.
- Document the current system performance.
- Incorporate a generator.
- Integrate a battery monitoring system.
- Ensure the vehicle can charge while running.

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# Golf Cart Features



## Existing Features

- Powered by six 8V lead-acid batteries.
  - The batteries do not work
- On-Board Charger
  - The charger does not work
- 5,000 Watt DC Motor

## Added Components

- QG2500 Cummins Generator
  - Battery Monitoring System
- New Batteries
- New Charger

Figure 1. Picture of golf cart

# Design Concepts



Table 1. Morphological Chart

| Parameter | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| **Generator Location** | Under back seat | On a Carriage | In place of the back seat |
| **How to warm the batteries** | Use generator exhaust | Use heating pad | Insulate the batteries |
| **Ensure generator operation** | Synthetic oil | Oil pan heater | Oil dipstick heater |
| **Charging system** | Use onboard charger system | Develop new charger system | Modify present charger system |

Selected Option

# Proposed System



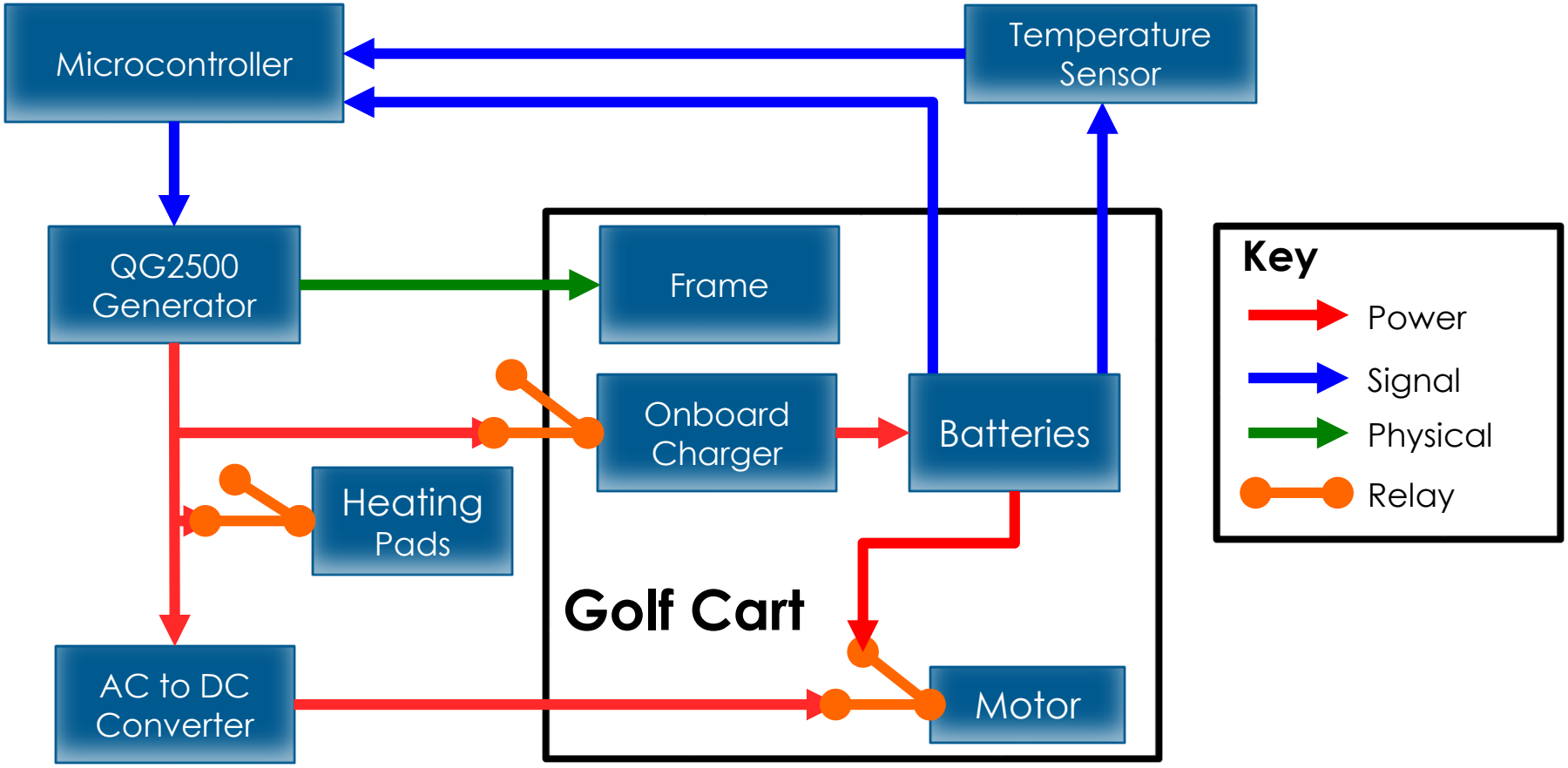


Figure 2. Simplified system diagram of initial design.

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# Detailed System Diagram



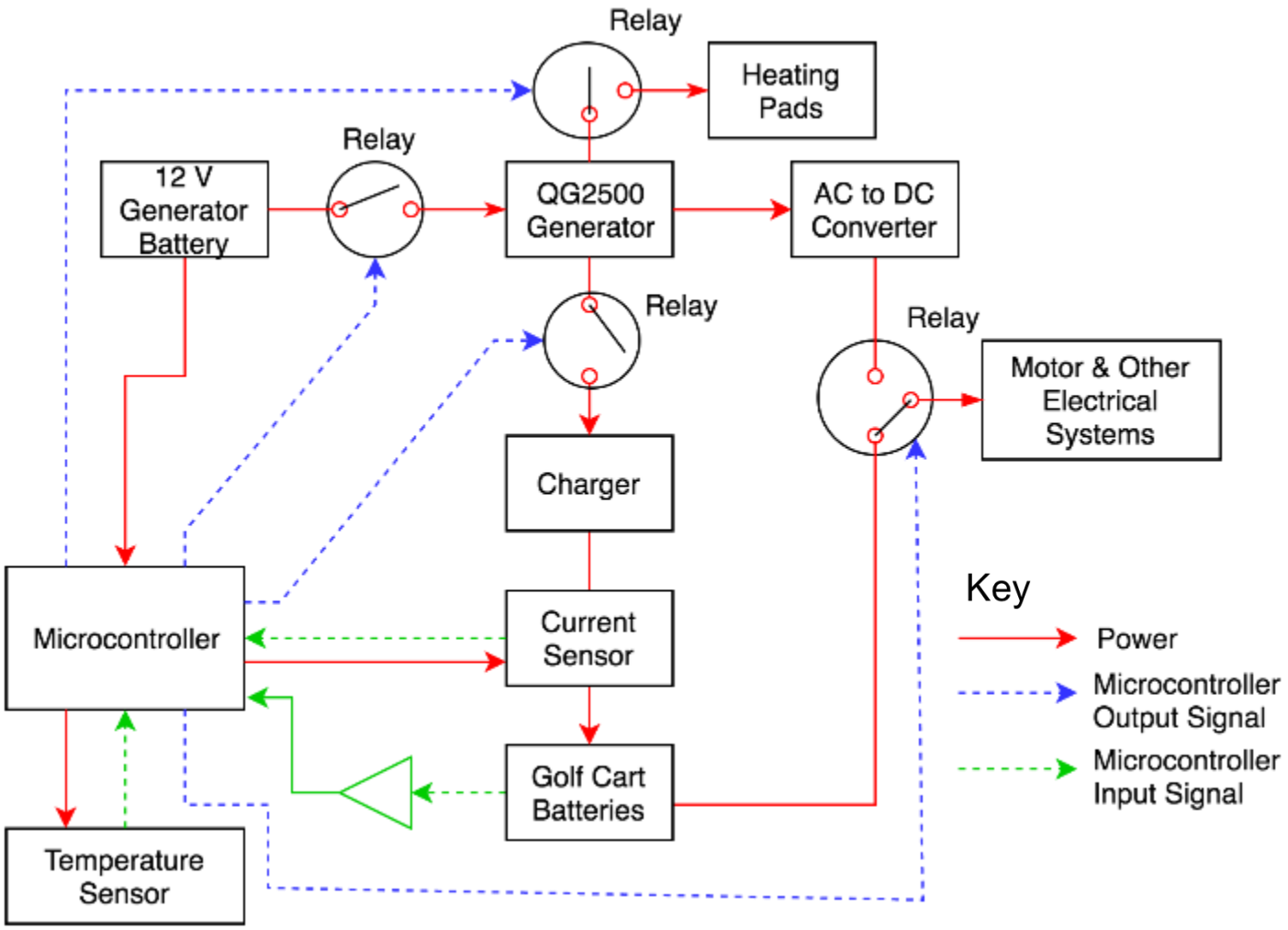



Figure 3. Detailed System Diagram

# Motor Power System




QG2500 Cummins Generator

**MAX. OUTPUT:** 2,500 W

RSP-1500 Power Supply

**MAX. INPUT:** 1,500 W
**Efficiency:** 91%

Ametek DPDT Relay

**RATING:** 150A @ 48$V_{DC}$

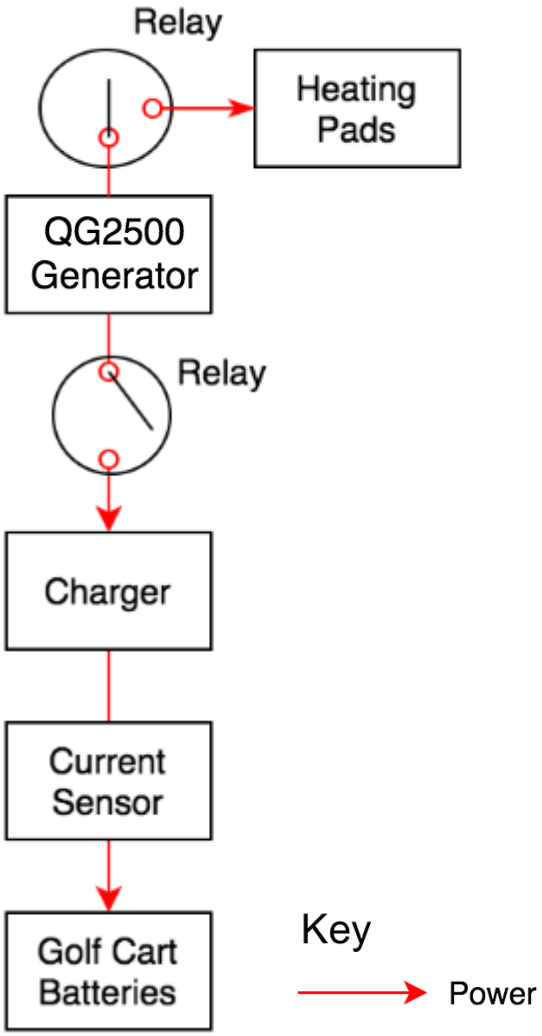



Figure 4. Power System Diagram

# Auxiliary Loads



JM SPST Relay
**Rating:** 20A @ $240V_{AC}$





Zerostart Heating Pad
**INPUT:** 160 W

Delta Q 48V Charger
**INPUT:** 1,200 W
**OUTPUT:** 1,000 W

Figure 5. Auxiliary Load System Diagram

# Sensor Inputs



Ruggeduino-ET
**I/O Pins:** 14
**A/D Pins:** 6
**Op. Range:** -40° to 85°C

DFRobot 50A Sensor
**Range:** -50A to +50A
**Max. Voltage:** $500V_{DC}$
**Op. Range:** -40°C to +150°C

TMP36 Sensor
**Op. Range:** -40°C to +125°C




Figure 6. Sensor Inputs System Diagram

# Detailed System Diagram



R55 DPDT Relay
**Rating:** 25A @ $28V_{DC}$

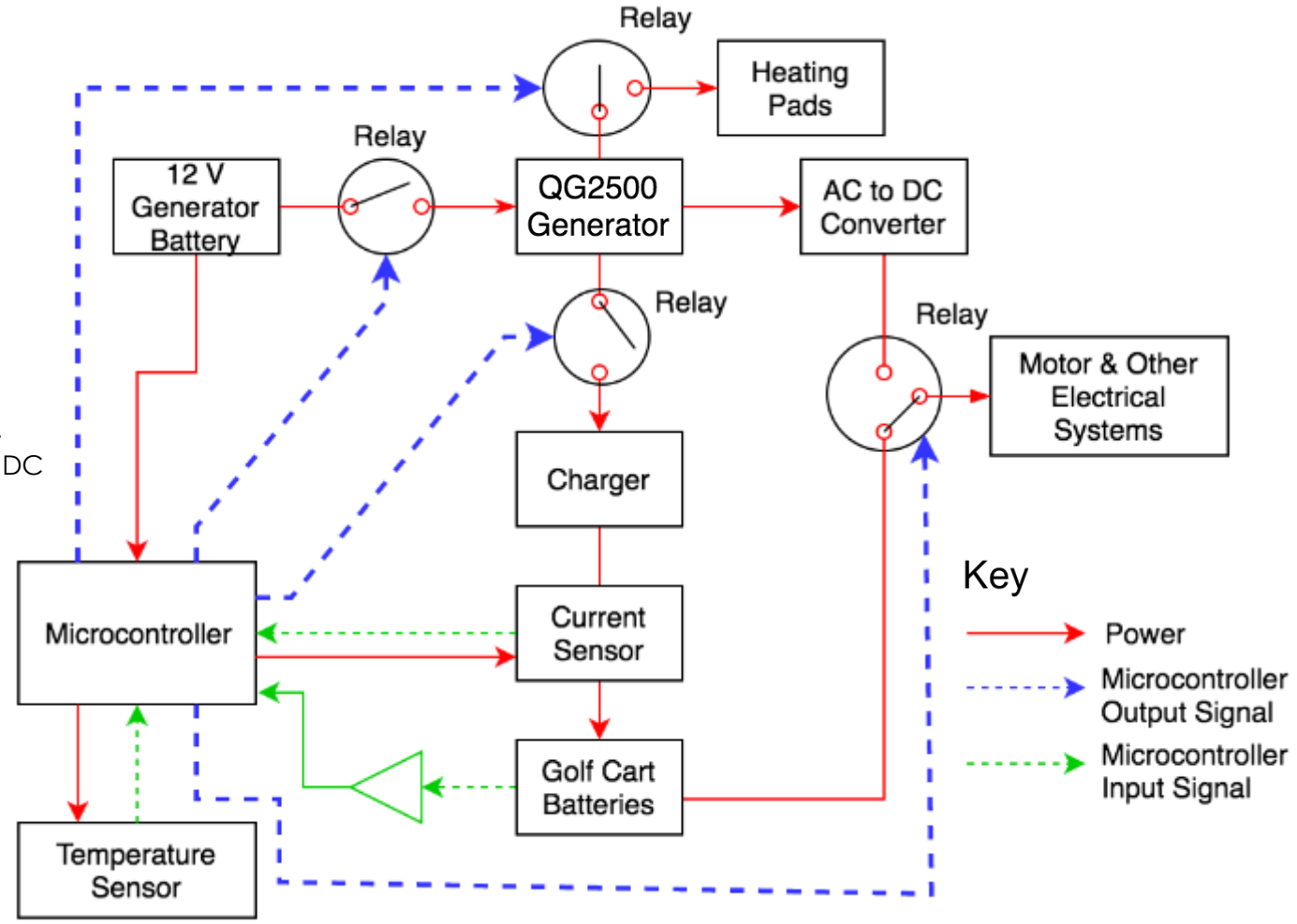



Figure 7. Detailed System Diagram

# Mechatronic System Requirements



- Control when generator turns on and off.
- Control when heating pads are on.
- Monitor the battery temperature.
- Monitor the battery voltage.
- Control the motor power source.
- Control when the batteries are charging.

# State Diagram



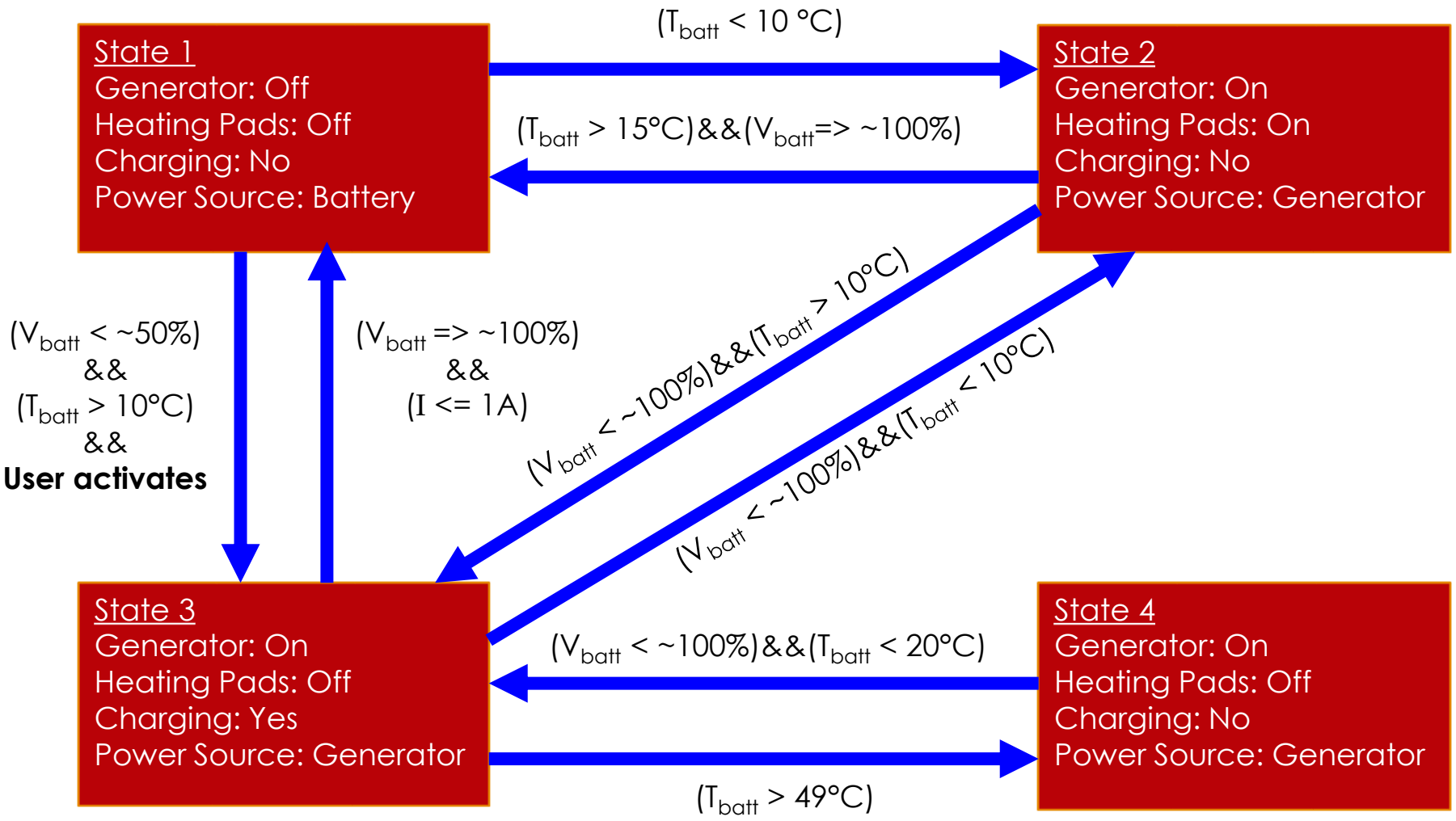



Figure 8. State Diagram of the proposed mechatronic system.

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# Generator Mount Design



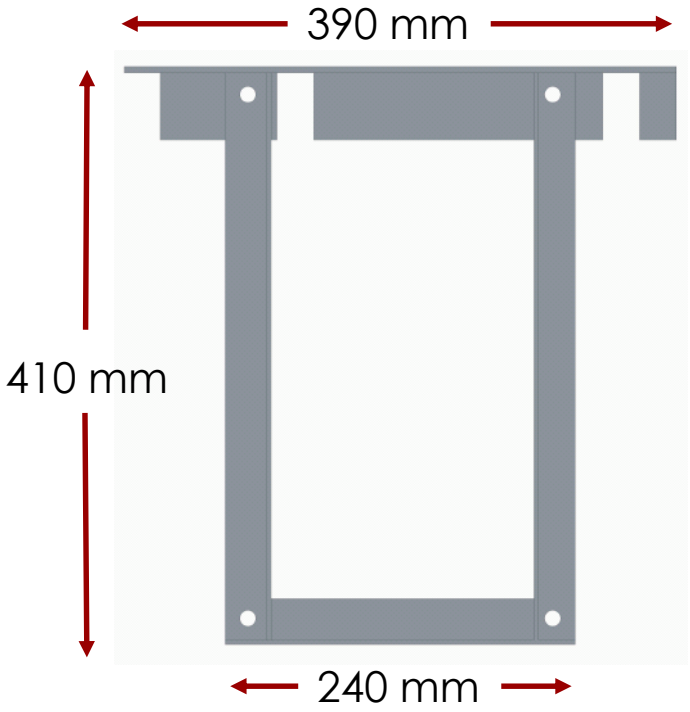



Figure 9. Final generator mount design.

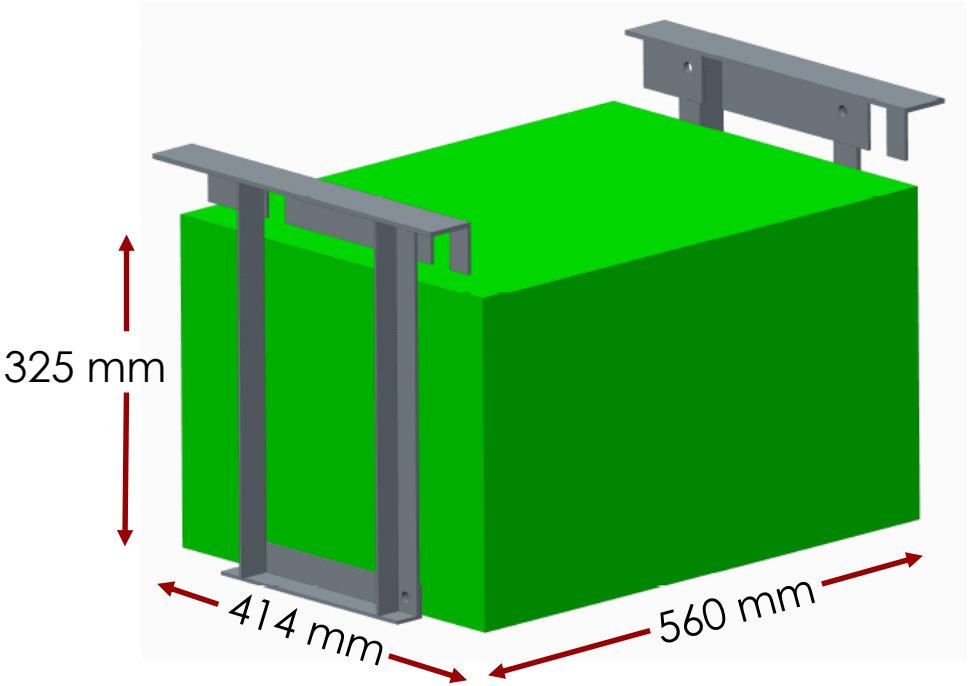



Figure 10. Assembly of mount attached to generator.

# Generator Mount Analysis



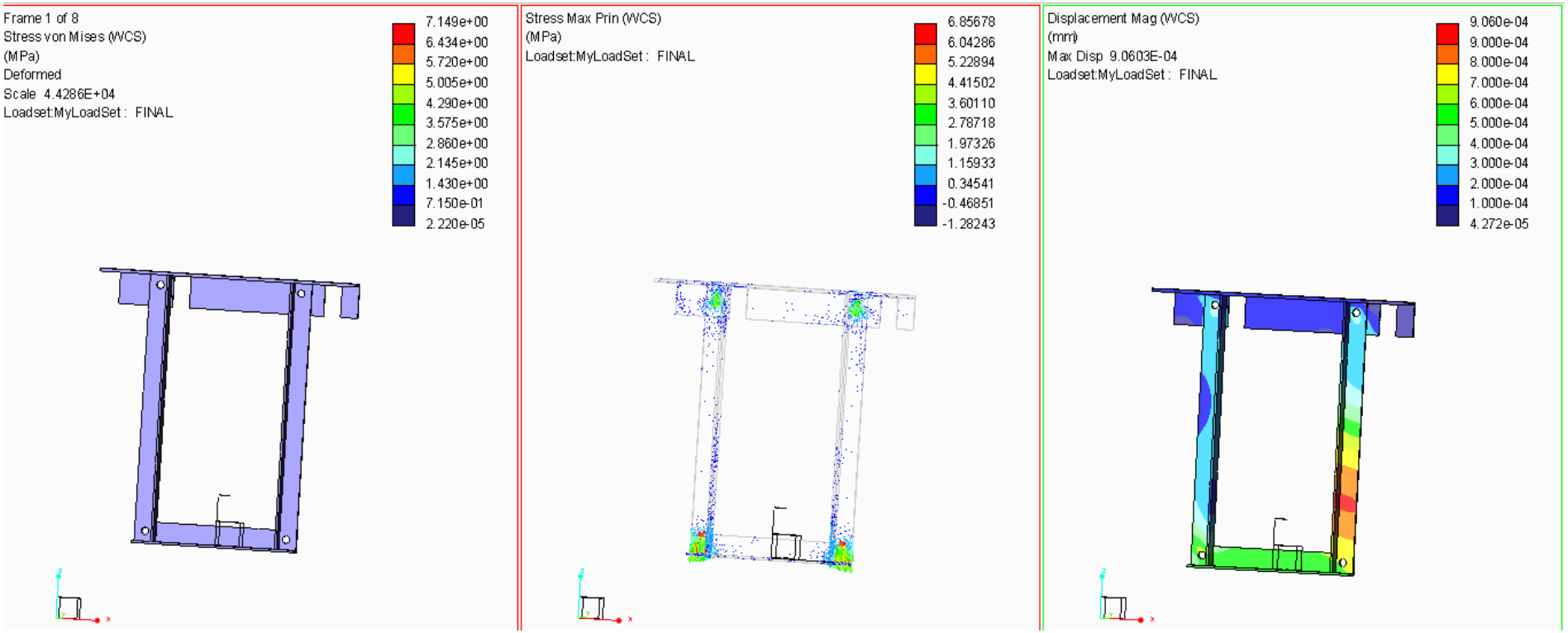



Figure 11. FEA stress and displacement analysis of final mount design.

# Mount Technical Specifications



- 1 ¼" x 1 ¼" x ⅛" and 2" x 2" x ⅛" Steel Angle
- Hot rolled, low carbon steel
- Its 90 degree angle adds strength and rigidity
- Fastened together with 3/8" grade 8 bolts
- Lock washers and Loctite Threadlocker to prevent bolts from unfastening from vibrations.

Figure 12. Photograph of generator mounted to rear of cart.

# Propane Tank Mount



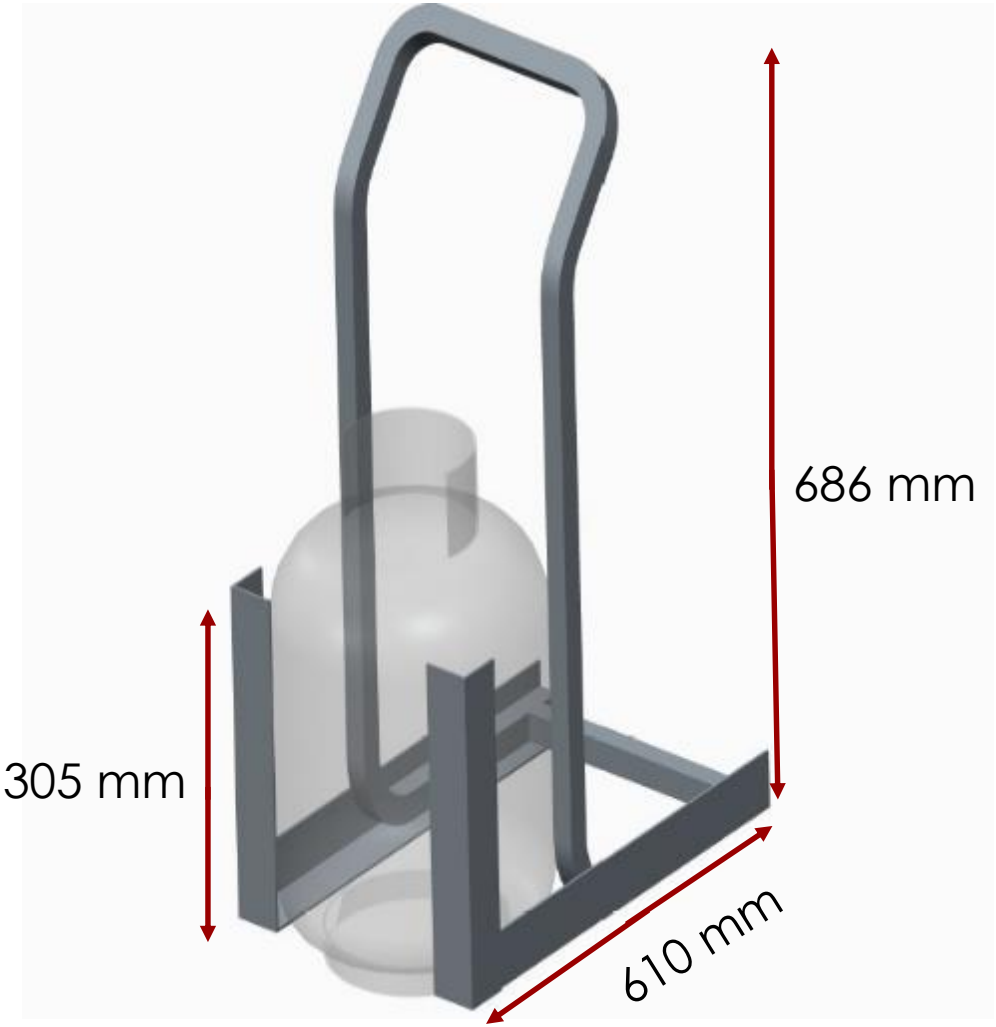



Figure 13. Propane Tank Mount

Figure 14. Rear of cart with propane tank mounted.

# Generator Battery and Power Supply Mount



Key
- Power Supplies
- Generator Battery

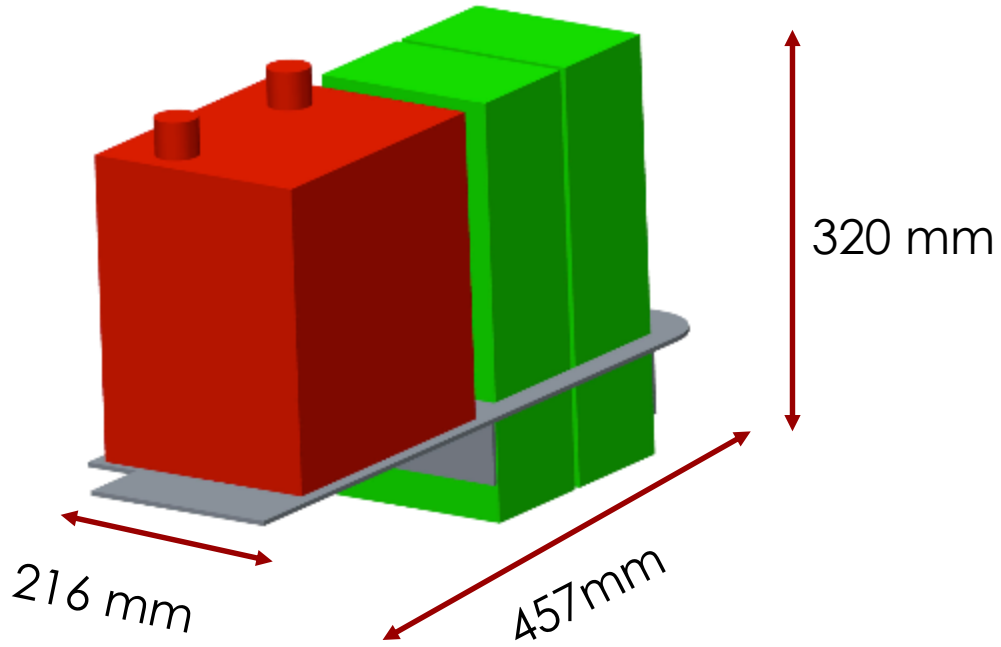



Figure 15. Generator battery and power supply mount

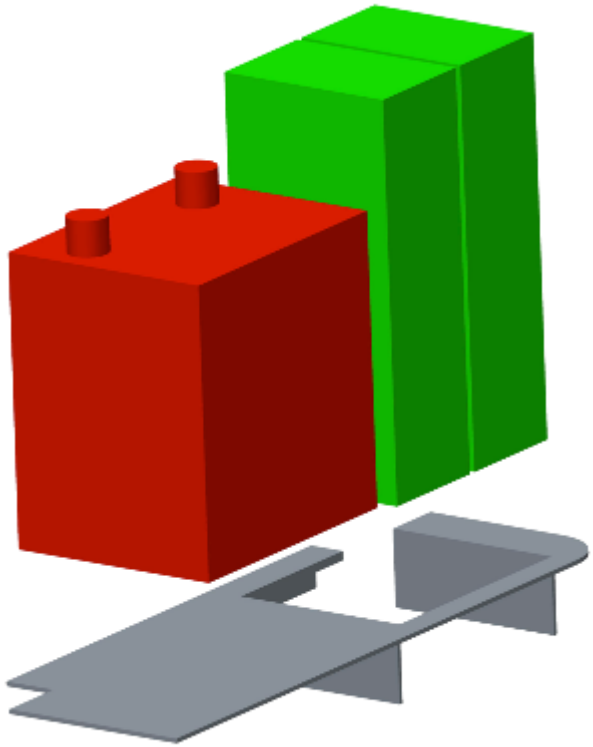


Figure 16. Exploded view of mount.

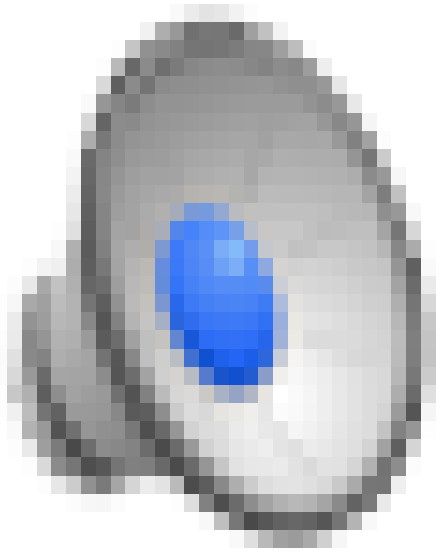
# Generator Battery and Power Supply Mount




Figure 17. Photograph of the power supplies and battery mounted in the golf cart without golf cart batteries installed.

Figure 18. Photograph of the power supplies and generator battery mounted in golf cart with golf cart batteries installed.

# Systems Testing



# Presentation Outline



- Project Scope
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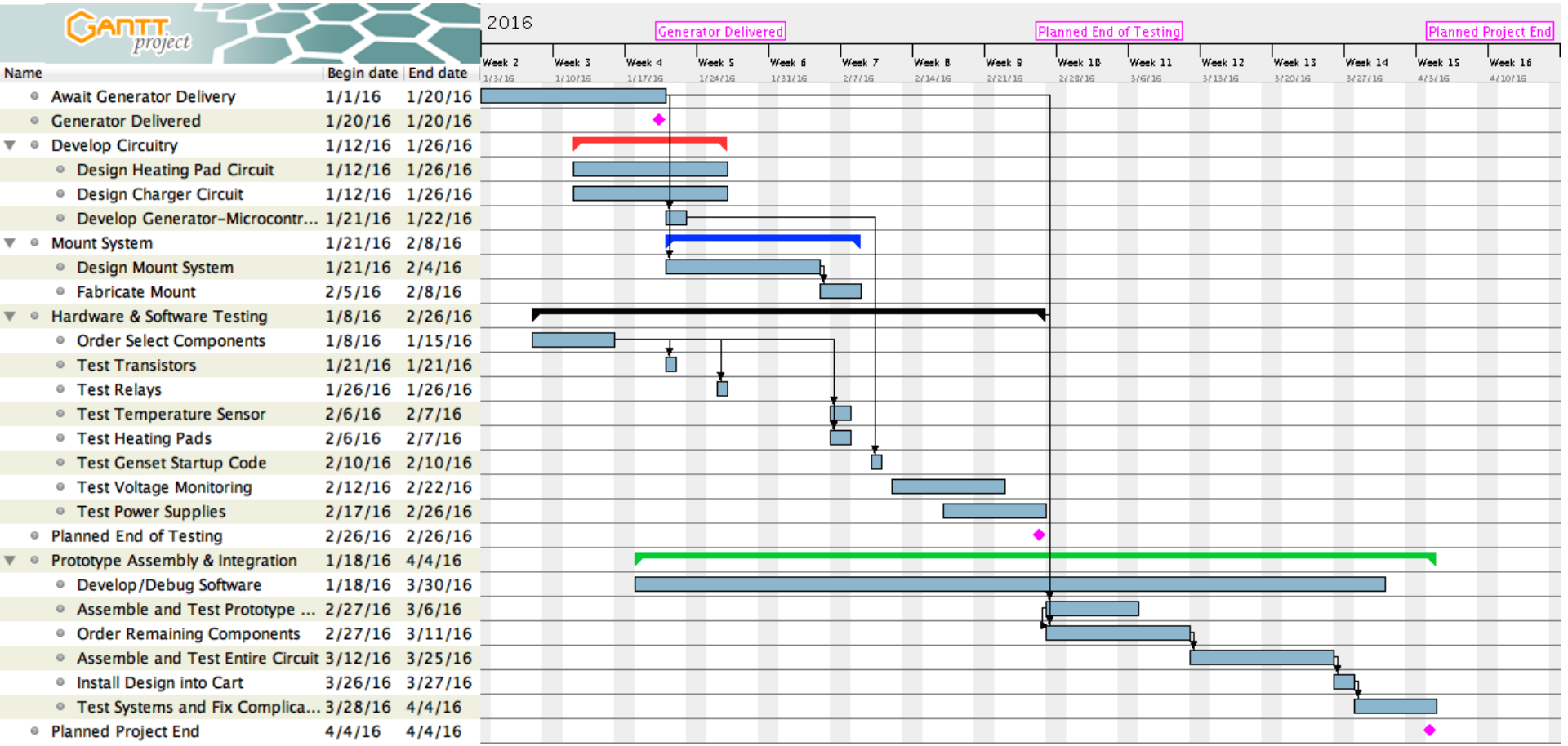
- **Project Management**

# Gantt Chart






| Name | Begin date | End date |
|---|---|---|
| Await Generator Delivery | 1/1/16 | 1/20/16 |
| Generator Delivered | 1/20/16 | 1/20/16 |
| Develop Circuitry | 1/12/16 | 1/26/16 |
| Design Heating Pad Circuit | 1/12/16 | 1/26/16 |
| Design Charger Circuit | 1/12/16 | 1/26/16 |
| Develop Generator-Microcontr... | 1/21/16 | 1/22/16 |
| Mount System | 1/21/16 | 2/8/16 |
| Design Mount System | 1/21/16 | 2/4/16 |
| Fabricate Mount | 2/5/16 | 2/8/16 |
| Hardware & Software Testing | 1/8/16 | 2/26/16 |
| Order Select Components | 1/8/16 | 1/15/16 |
| Test Transistors | 1/21/16 | 1/21/16 |
| Test Relays | 1/26/16 | 1/26/16 |
| Test Temperature Sensor | 2/6/16 | 2/7/16 |
| Test Heating Pads | 2/6/16 | 2/7/16 |
| Test Genset Startup Code | 2/10/16 | 2/10/16 |
| Test Voltage Monitoring | 2/12/16 | 2/22/16 |
| Test Power Supplies | 2/17/16 | 2/26/16 |
| Planned End of Testing | 2/26/16 | 2/26/16 |
| Prototype Assembly & Integration | 1/18/16 | 4/4/16 |
| Develop/Debug Software | 1/18/16 | 3/30/16 |
| Assemble and Test Prototype ... | 2/27/16 | 3/6/16 |
| Order Remaining Components | 2/27/16 | 3/11/16 |
| Assemble and Test Entire Circuit | 3/12/16 | 3/25/16 |
| Install Design into Cart | 3/26/16 | 3/27/16 |
| Test Systems and Fix Complica... | 3/28/16 | 4/4/16 |
| Planned Project End | 4/4/16 | 4/4/16 |

Figure 19. Project timeline

# Budget Analysis

Table 2. Budget Analysis

| Budget Breakdown | |
|---|---|
| **Parts** | **Cost** |
| Circuit Components | $1084.20 |
| Batteries & Cables | $1427.98 |
| Hardware | $280.58 |
| **Total Used** | **$2792.76** |
| **Budget Remaining** | **$78.24** |

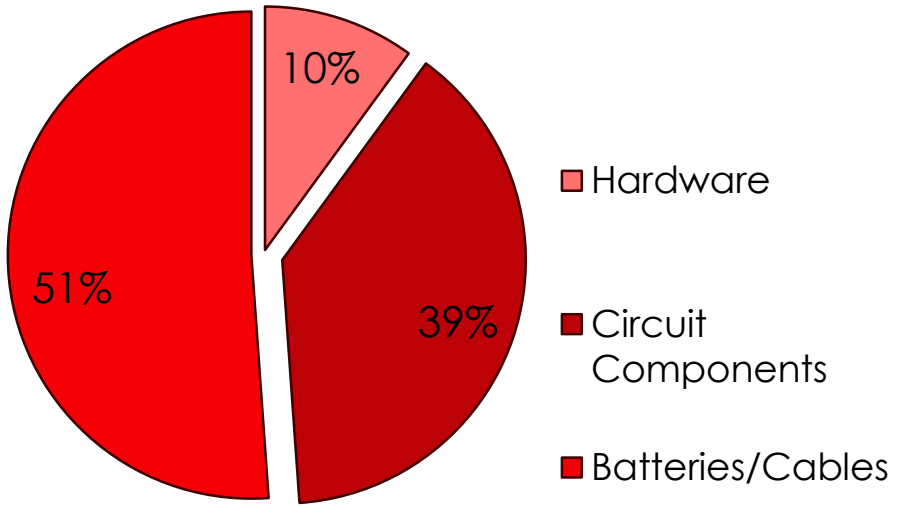



Figure 20. Budget Chart

# Conclusion & Lessons Learned

- Conclusion
  - Have a functioning prototype.
  - Finished slightly behind schedule.
  - Developed design while staying under budget.
- Lessons Learned
  - Importance of background research
  - Get extra parts if possible
  - Assembly takes a lot longer than you would think
- Future Work
  - Determine future of prototype
    - Project continued into next year?
    - Return to sponsor?
    - Store in COE facility?
  - Develop method to determine battery state of charge

# References



[1] Cummins. *RV Generator Set Quiet GasolineTM Series RV QG 2800*. N.p.: Cummins, n.d. *Cummins Powersuite*. Cummins. Web. 20 Oct. 2015.

[2] Kiessling, Reiner. "Lead Acid Battery Formation Techniques." Digatron Firing Circuits (n.d.): n. pag. Web. 4 Nov. 2015.

*[3] Handbook for Stationary Lead-Acid Batteries*. N.p.: GNB Industrial Power, Feb. 2012. Pdf.

[4] *Zerostart Blanket Style Battery Heater*. Digital image. *Partdeal*. N.p., n.d. Web. 9 Nov. 2015.

[5] "Ruggeduino-ET." Rugged Circuits. N.p., n.d. Web. 09 Nov. 2015.

[6] "TMP36 - Analog Temperature Sensor." Adafruit. N.p., Web. 09 Nov. 2015.

[7] Sanders, Chris. Question mark. Digital image. *ON THE IMPORTANCE OF QUESTIONS IN AN INVESTIGATION*. N.p., n.d. Web. 20 Oct. 2015.

# Questions?



# Decision Matrices



Table A. Generator Location

| Criteria | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Cost | S | – | S |
| Weight | S | – | + |
| Noninvasive | S | – | – |
| Safety | S | – | – |
| Total | 0 | –4 | –1 |

Table B. How to warm the batteries

| Criteria | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Cost | S | + | + |
| Weight | S | + | + |
| Noninvasive | S | + | + |
| Safety | S | + | + |
| Total | 0 | +4 | +4 |

Table C. Ensure Generator Operation

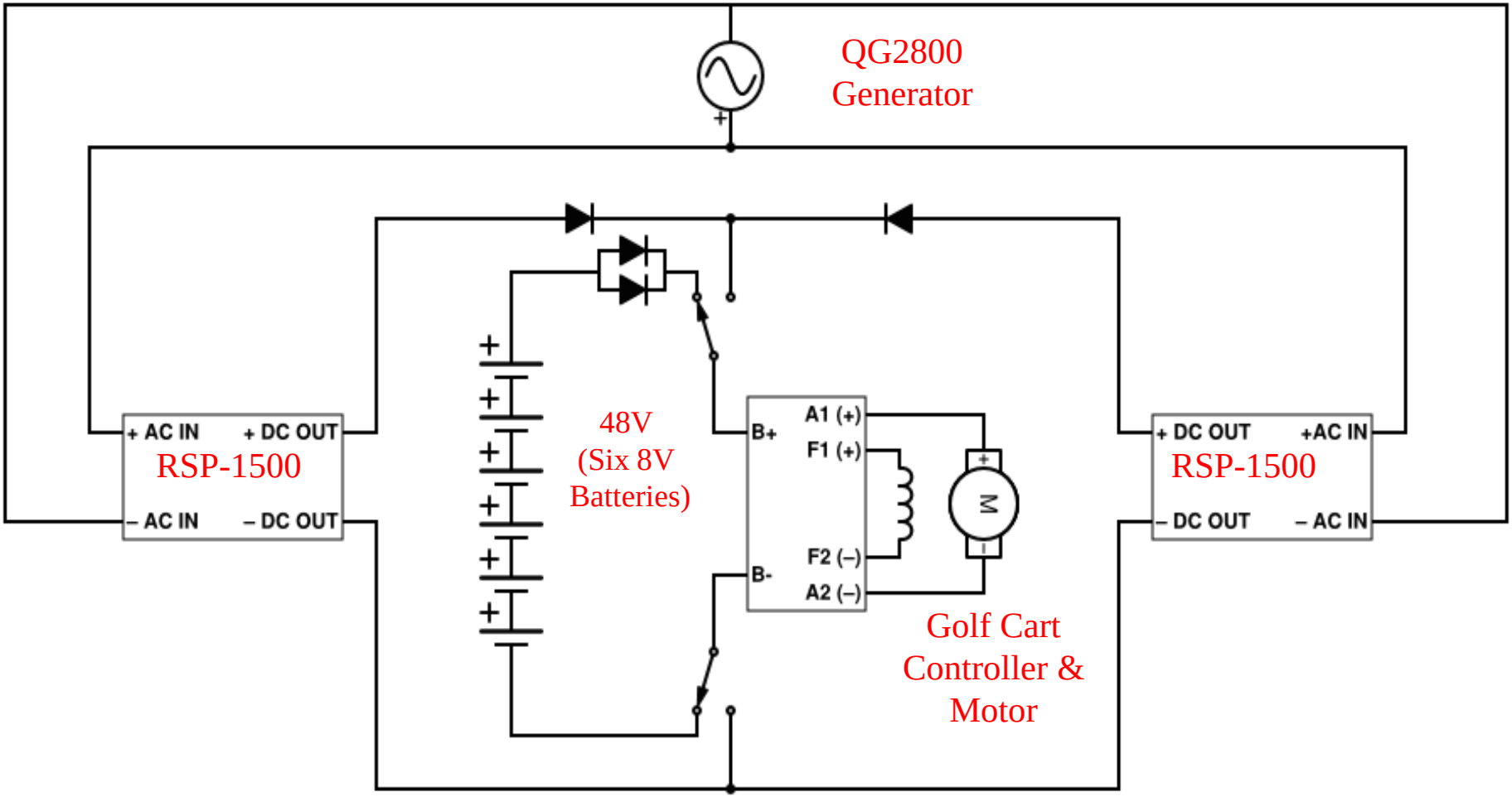
| Criteria | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Cost | S | – | – |
| Weight | S | – | – |
| Noninvasive | S | – | – |
| Safety | S | – | – |
| Total | 0 | –4 | –4 |

Table D. Charging System

| Criteria | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Cost | S | – | – |
| Weight | S | S | S |
| Noninvasive | S | S | + |
| Safety | S | + | + |
| Total | 0 | 0 | +2 |

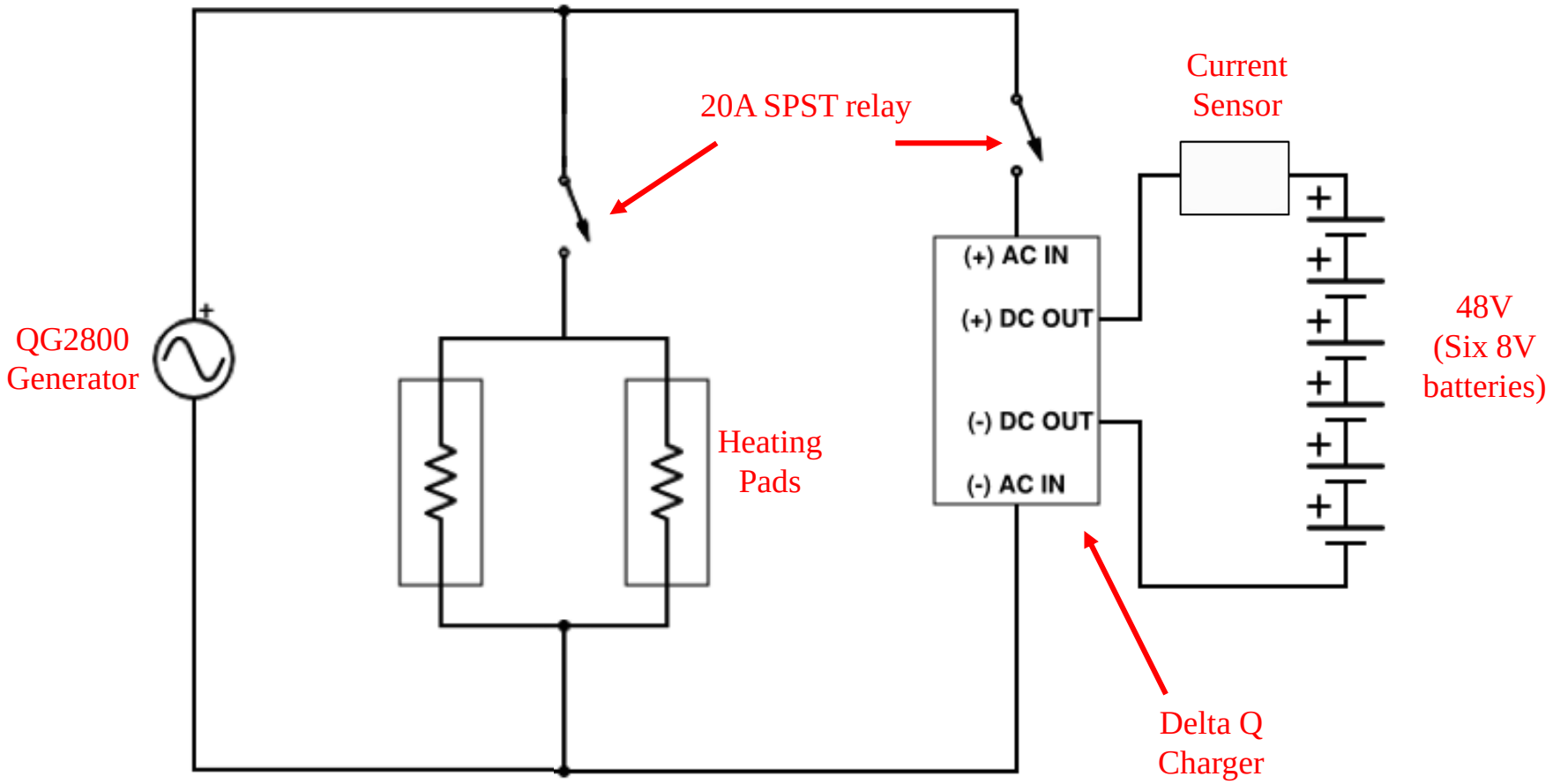
# Motor Power Supply Circuit





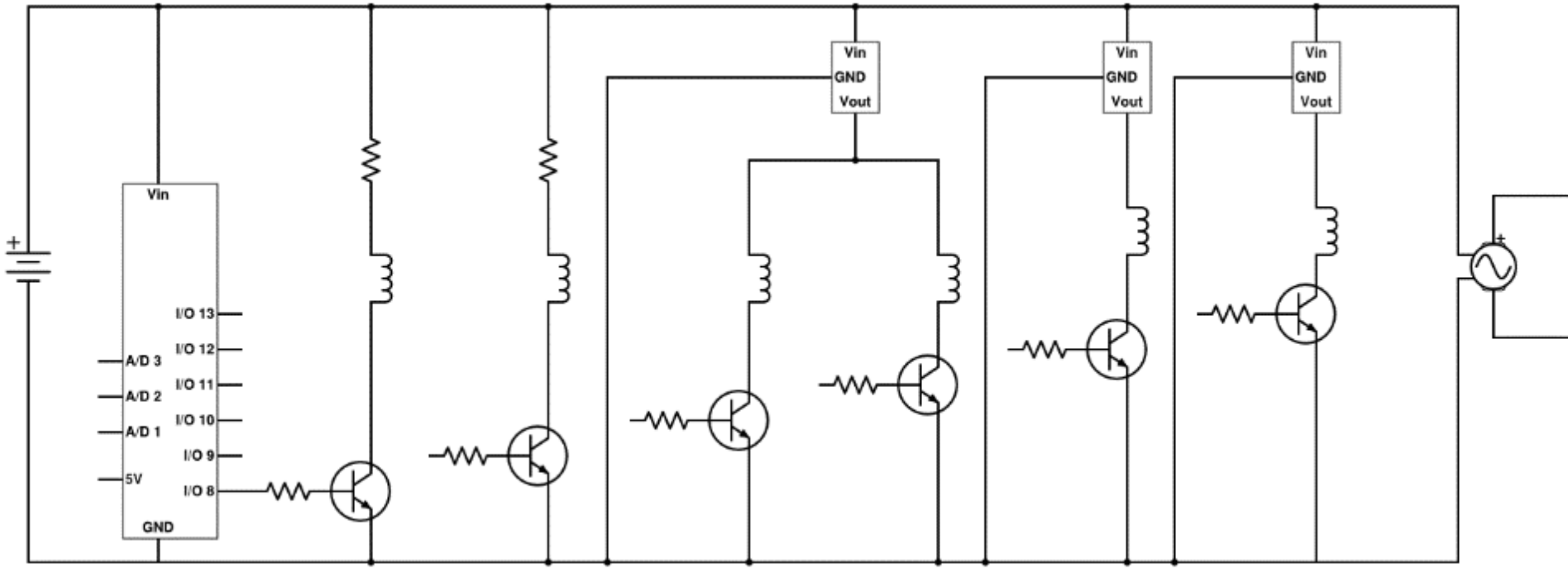
# Heating Pad and Charger Circuit





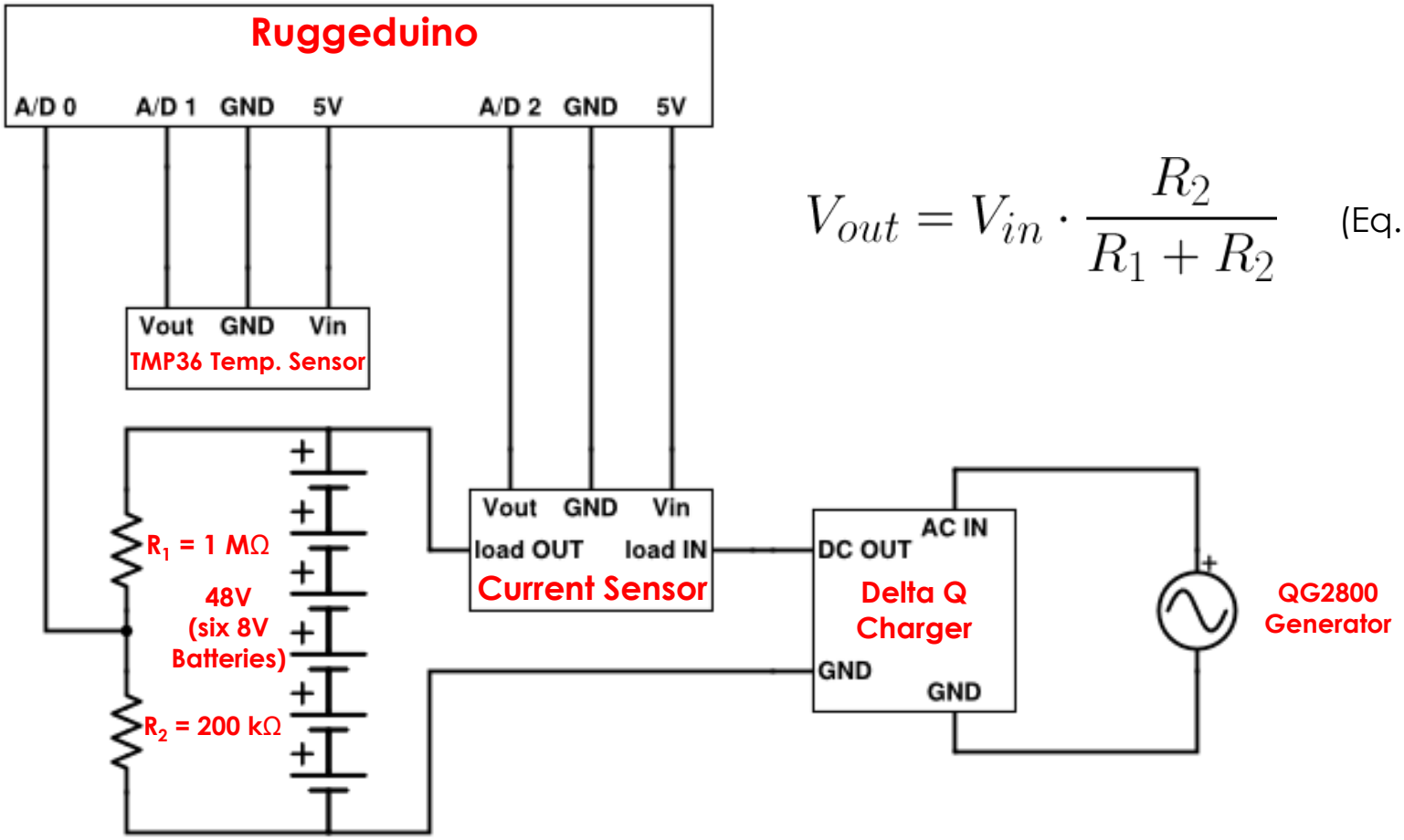
# Control Circuit





# Sensor Inputs






$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2} \qquad \text{(Eq. 1)}$$

# FMEA



| Component | Potential Failure Mode | Potential Failure Effects | Severity | Potential Causes |
|---|---|---|---|---|
| What is the primary component affected? | In what ways can the component fail? | What is the impact of this failure mode? | How severe is this failure to the user? | What causes the component to fail? |
| Heating pads | Not activating | Batteries will not be heated in cold climates | Medium | Loose wire<br>Inaccurate temp. sensor reading<br>Damaged Relay |
| | Remaining active | Heating pads will stay on<br>Might overload the generator if charger is active.<br>Could overheat the batteries | High | Damaged transistor<br>Damaged relay |
| Charger | Not activating | Batteries aren't receiving a charge | High | Loose wire<br>Lack of power from generator |
| | Remaining active | Charger remains active, but won't overcharge batteries | Low | Damaged transistor<br>Damaged relay |
| Generator | Not starting | Generator is inactive, but the system will still switch to generator powered state | High | Loose wire<br>Low/no oil<br>No/poor propane connection<br>Insufficient battery charge<br>Circuit breaker tripped |
| | Won't shut off | Generator will remain on unnecessarily, potential damage to generator | Medium | Damaged transistor<br>Damaged Relay |

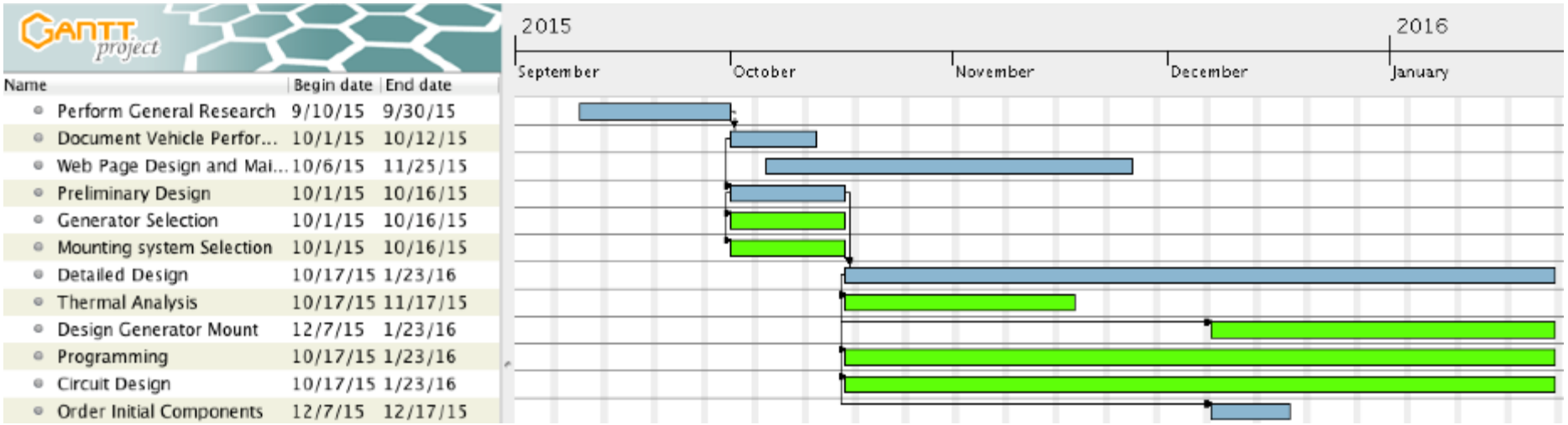
# FMEA Continued



| Component | Potential Failure Mode | Potential Failure Effects | Severity | Potential Causes |
|---|---|---|---|---|
| Power supplies | Not activating | Power supplies will be inactive | High | Loose wire |
| | Remaining active | Power supplies will remain active, potential damage to power supplies | Medium | Generator won't turn off. (see generator failure modes) |
| Microcontroller | Not turning on | System won't function | High | Installation error<br>Improperly code<br>Damaged pins<br>Sensor error |
| Temperature sensor | Not giving accurate temperature readings | System will incorrectly switch states | Medium | Manufacturing defects<br>Improperly coded<br>Installation error |
| Current sensor | Not giving accurate temperature readings | System will incorrectly switch states | High | Manufacturing defects<br>Improperly coded<br>Installation error |

# Fall Gant Chart






| Name | Begin date | End date |
|---|---|---|
| Perform General Research | 9/10/15 | 9/30/15 |
| Document Vehicle Perfor... | 10/1/15 | 10/12/15 |
| Web Page Design and Mai... | 10/6/15 | 11/25/15 |
| Preliminary Design | 10/1/15 | 10/16/15 |
| Generator Selection | 10/1/15 | 10/16/15 |
| Mounting system Selection | 10/1/15 | 10/16/15 |
| Detailed Design | 10/17/15 | 1/23/16 |
| Thermal Analysis | 10/17/15 | 11/17/15 |
| Design Generator Mount | 12/7/15 | 1/23/16 |
| Programming | 10/17/15 | 1/23/16 |
| Circuit Design | 10/17/15 | 1/23/16 |
| Order Initial Components | 12/7/15 | 12/17/15 |