

# Electric Vehicle Optimization Team 2

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



- 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  $-29^{\circ}\text{C}$  ( $-20^{\circ}\text{F}$ )

## 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  $-29^{\circ}\text{C}$ .
- Document the current system performance.
- Incorporate a generator.
- Integrate a battery monitoring system.
- Model design for ISX-15 diesel engine.
- Ensure the vehicle can charge while running.

## Current Features

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

## To Be Added

- Generator
  - ✦ Battery Monitoring System
- New Batteries
  - ✦ Selected by independent EE team.



Figure 1. Picture of golf cart

# Design Concepts

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Table 2. Morphological Chart

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

 Selected Option



Figure 2. Photo of the back of the golf cart with recessed region under the rear seat.

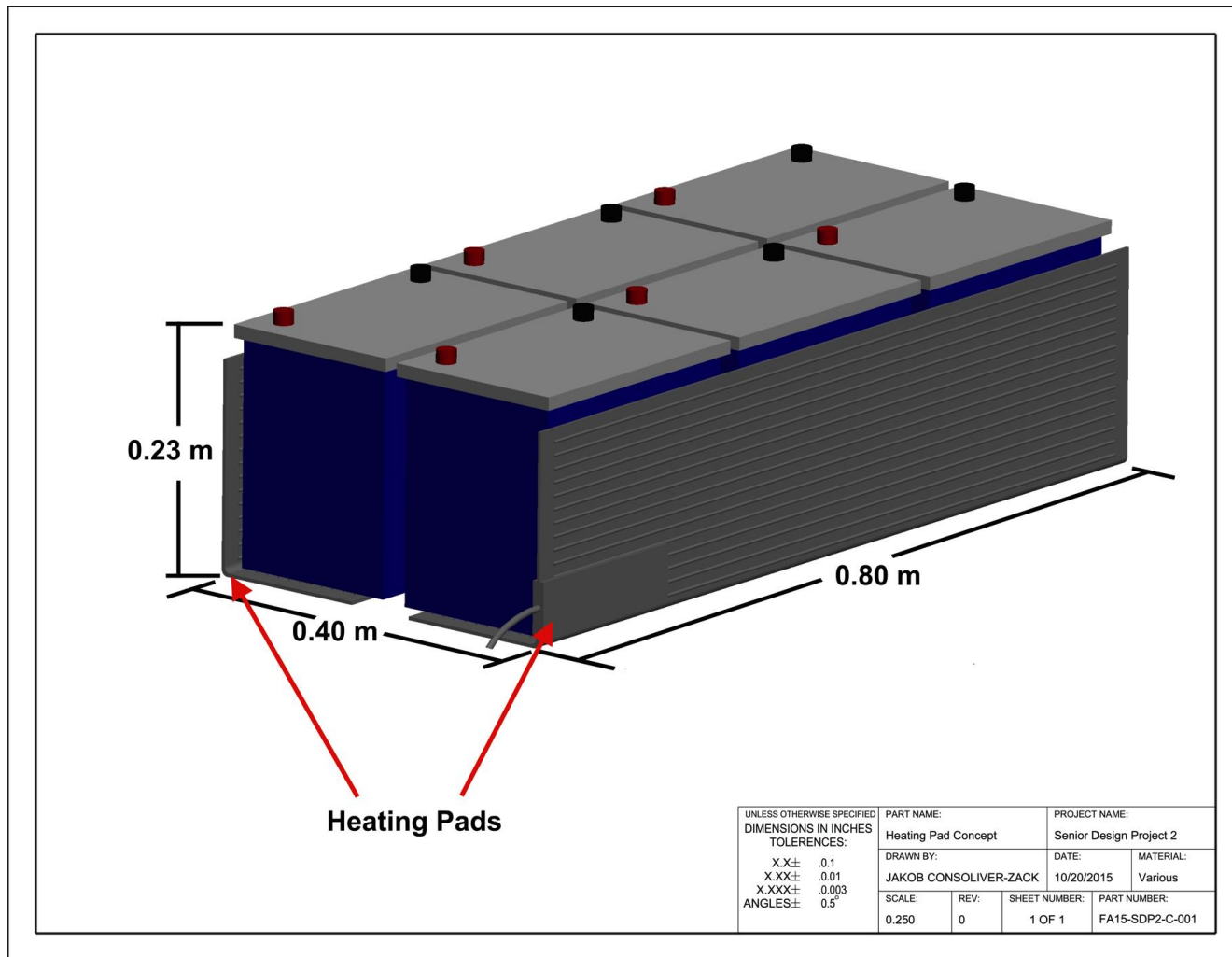


Figure 3. Initial concept of batteries and heating pads.

# Proposed System

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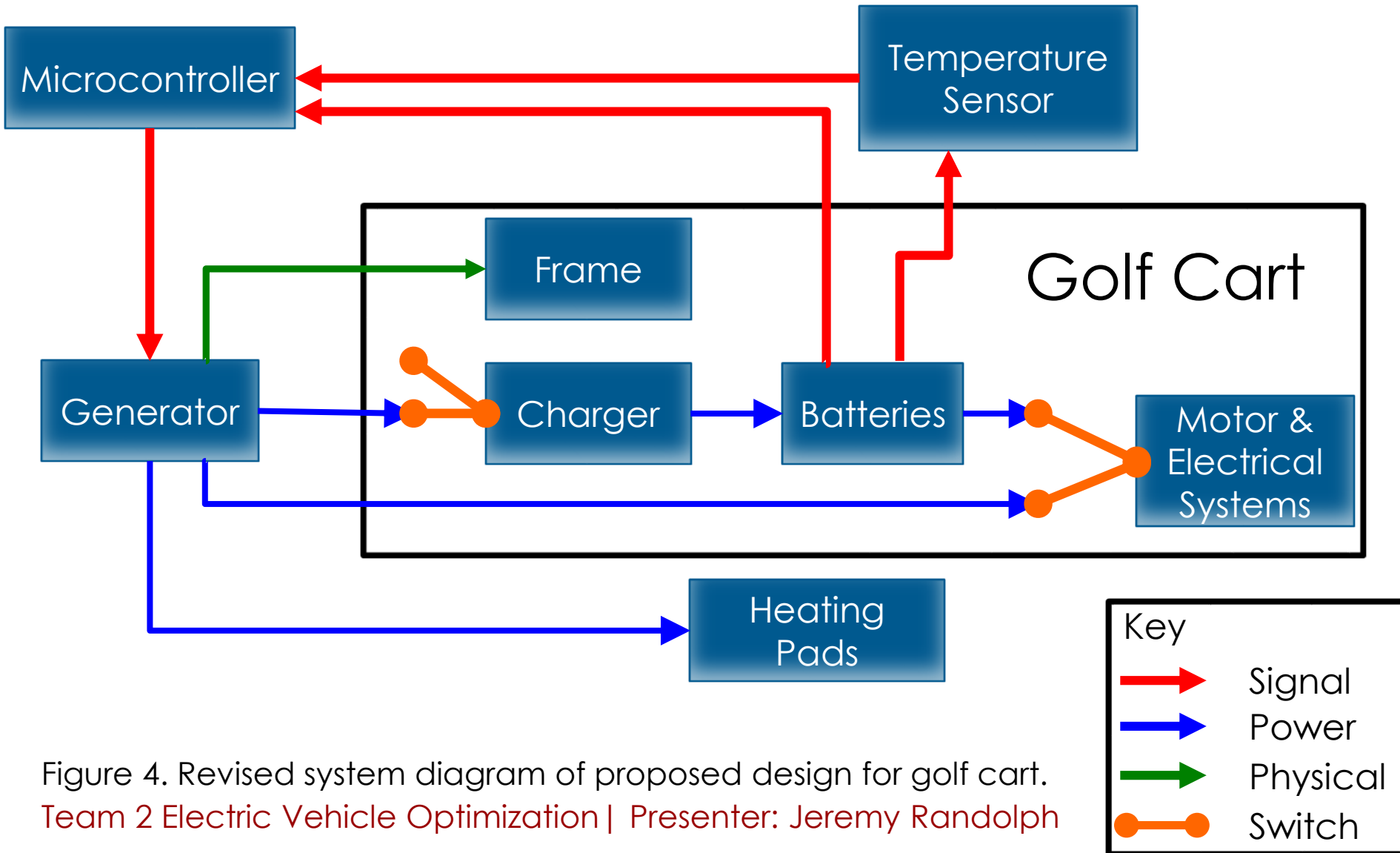


Figure 4. Revised system diagram of proposed design for golf cart.  
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# Proposed Truck Charging System

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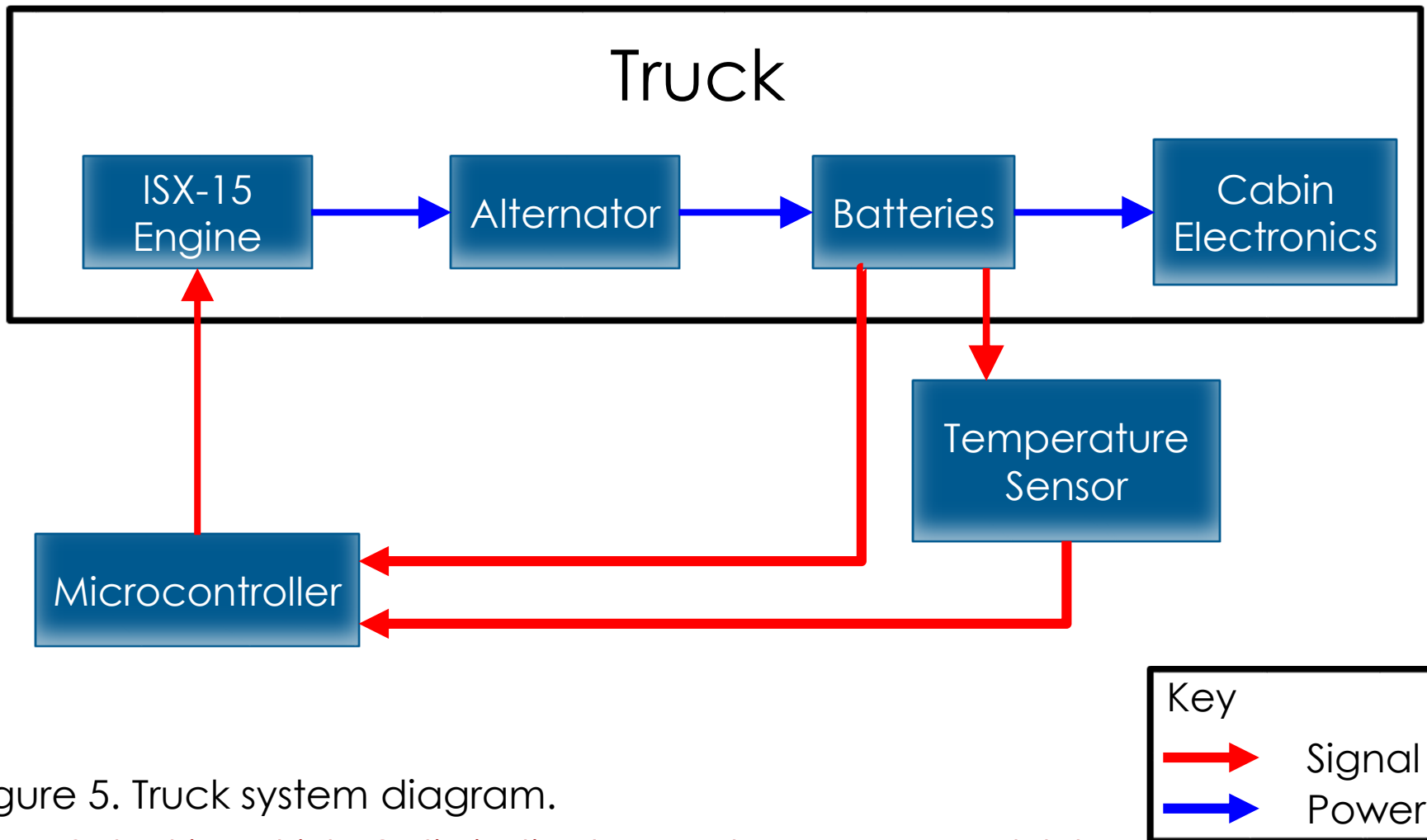


Figure 5. Truck system diagram.

# Generator Selection

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Table 3. Generator Requirements Vs. QG2800

Selection Criteria	QG2800 Generator
Must output at least 2,200 W	Can output 2,800 W
Dimensions should not exceed: 685 mm x 360 mm x 400 mm	Dimensions: 560 mm x 415 mm x 325 mm
Must operate at -29°C (-20°F)	Can operate at -29°C (-20°F)
Lightweight	56.7kg (125 lbs.)
Inexpensive	Provided free of charge



# Heat Transfer Analysis

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- Average heat capacity of lead acid batteries. [2-3]

- ✦  $C_p = 1,985 \frac{J}{kg^{\circ}C}$

- Mass of 6 lead acid batteries.

- ✦  $m = 192 \text{ kg}$

- 1 heating pad supplies 160W to the batteries.

- ✦  $P_{\text{total}} = 960 \text{ W}$

Table 4. Time needed to heat batteries

Parameters	Ideal	Goal
Initial Temperature	-29°C	-29°C
Final Temperature	20°C	-10°C
Heat Required $q = C_p m \Delta T$	19,253 kJ	7,466 kJ
Time = $\frac{q}{P_{\text{total}}}$	5 hrs 34 min	2 hrs 9 min

# The Current Problem...

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- Initially the design would not allow the batteries to be heated and charged at the same time.
- Time required to heat batteries is way too long.
- **Solution:** heating pads will be used to prevent temperature from dropping below 10°C.



Figure 7. Heating pad for single battery. [4]

# Mechatronic System Objectives

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- 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

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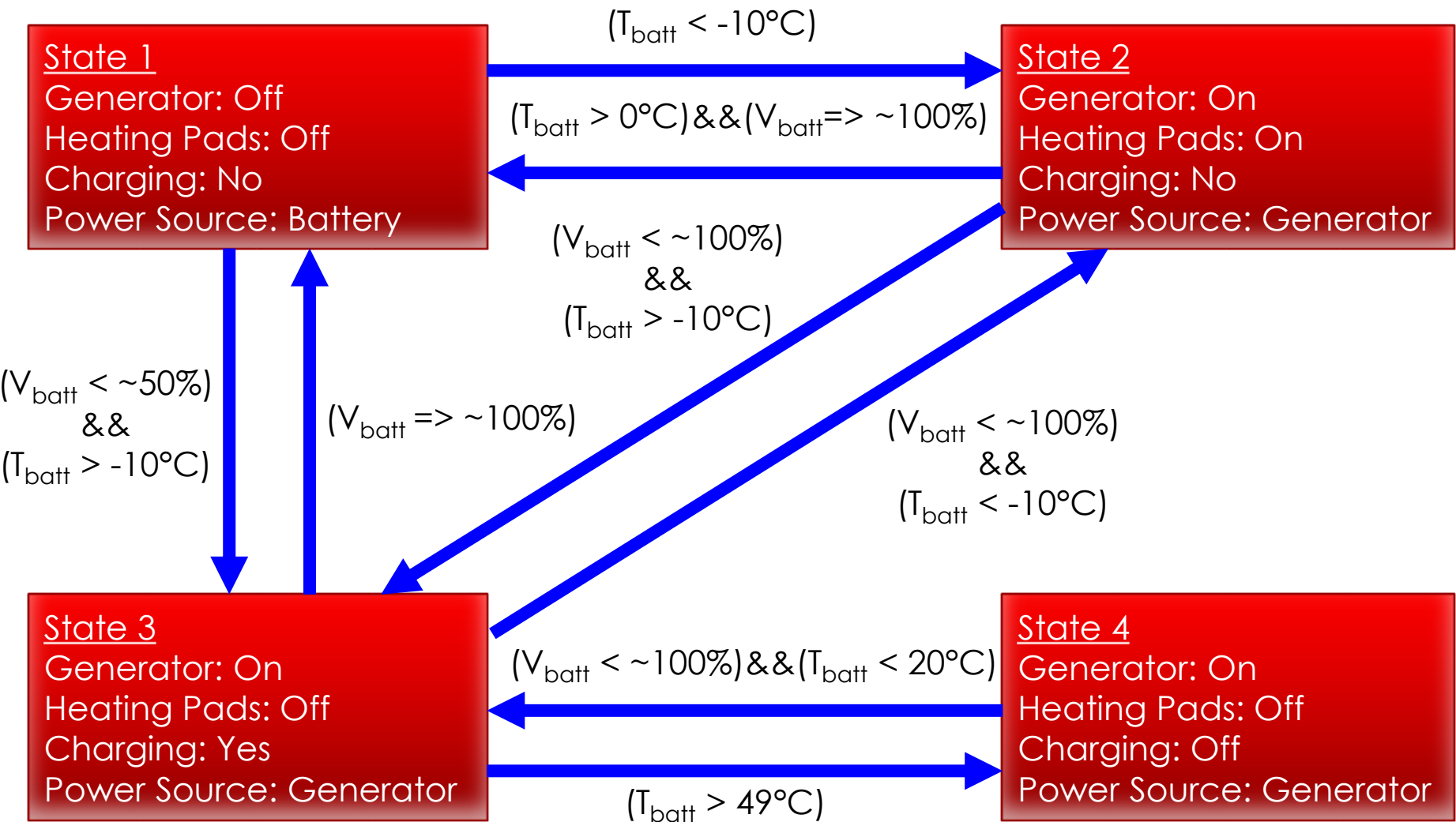


Figure 8. State Diagram of the proposed mechatronic system.

# Detailed System Diagram

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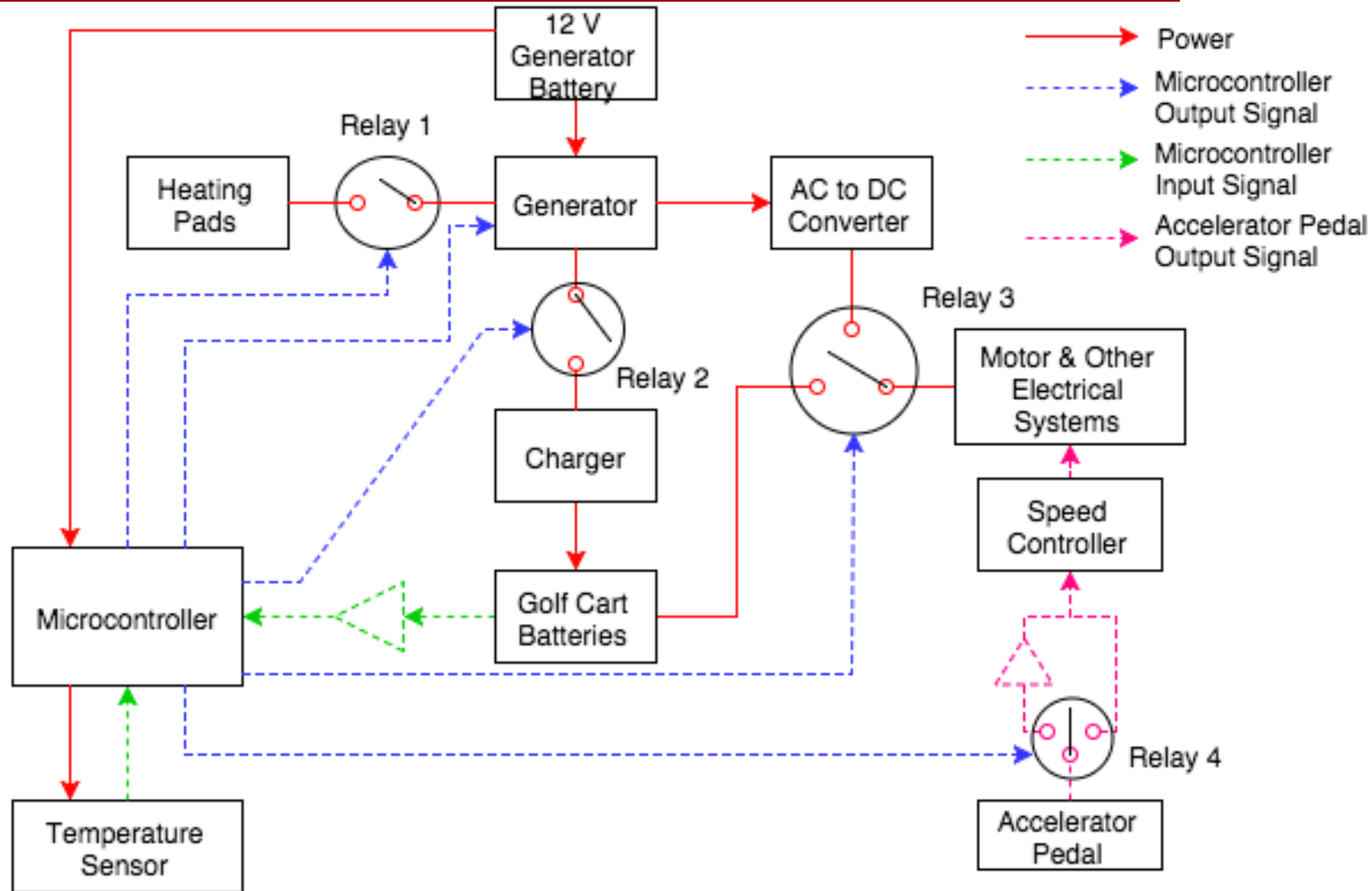
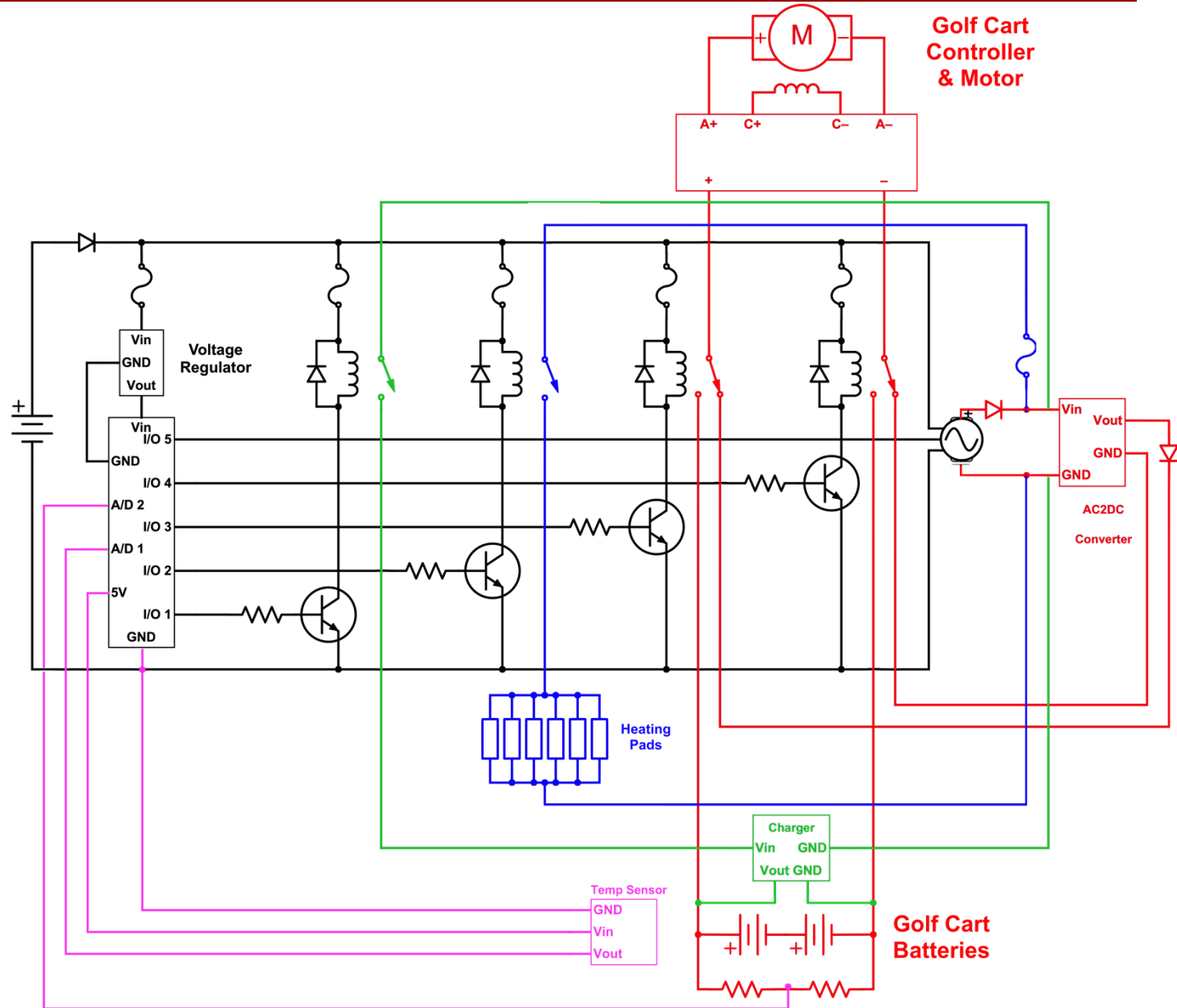


Figure 9. Detailed System Diagram

# Circuit Diagram

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- Ruggeduino-ET
  - ✦ 6 analog input pins
  - ✦ Can run on input voltage of 3.5V to 30V
  - ✦ Operable at temperatures from -40°C to +85°C
  - ✦ 68.6 mm x 54.4 mm



Figure 11. Ruggeduino-ET Board [5]

- TMP36 Analog Temperature Sensor
  - ✦ Low voltage operation (2.7V to 5.5V)
  - ✦ -40°C to +125°C temperature range



Figure 12. TMP Sensor. Quarter for scale [6]

# Potential Challenges & Risks

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- Presently the golf cart is not in working condition.
- Inductive kickback during power switching.
  - ✦ Ensure safeguards in circuit design.
- Difficult to test entire system at cold temperatures.
- Maximum Charge threshold value is a function of temperature.
  - ✦ Experimentally determine the relationship.
- Ensure design compatibility with ISX-15 engine.

# Gantt Chart

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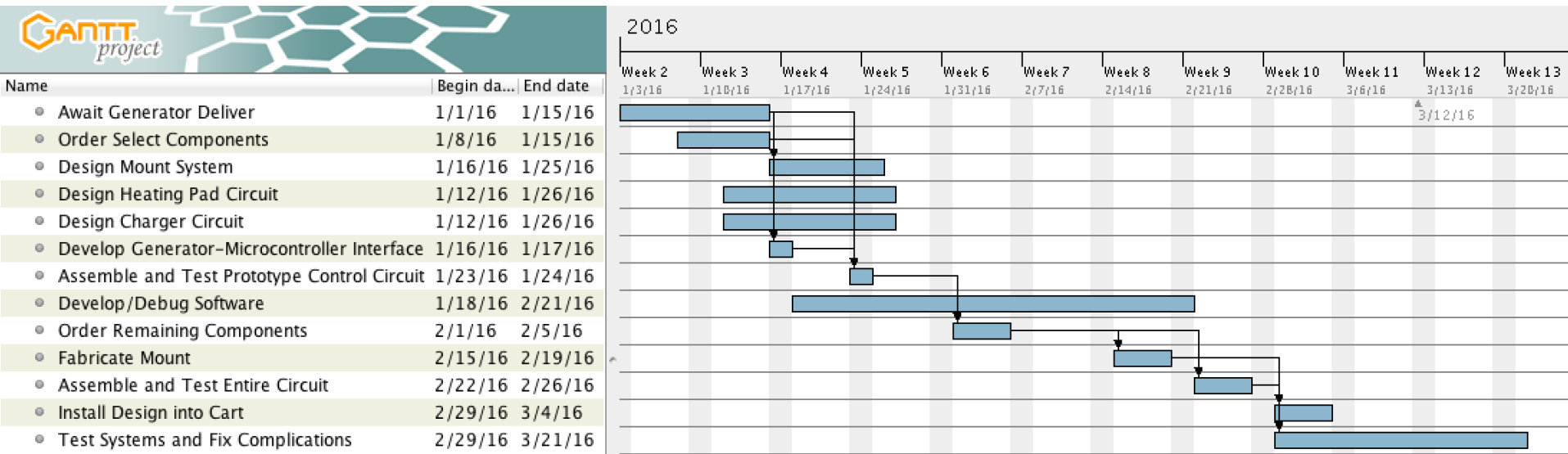


Figure 13. Project timeline

- Integrate a generator into the present system.
- Install new low-temperature batteries into the golf cart.
- Warm the batteries with heating pads.
- Model this technology for semi-trucks with ISX-15 diesel engine.

## Future Plans

- Create detailed design of how to mount generator to the cart.
- Work in tandem with EE team to finalize circuit design
- Begin programming mechatronic system for small scale model of design.

- [1] Cummins. *RV Generator Set Quiet Gasoline™ 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?

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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 C. Ensure Generator Operation

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

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 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