Smart Grid Test Facility

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Introduction

- The **Smart Grid Test Facility** is an educational tool for engineering students, allowing them to test various circuitry in a small-scale classroom power grid.

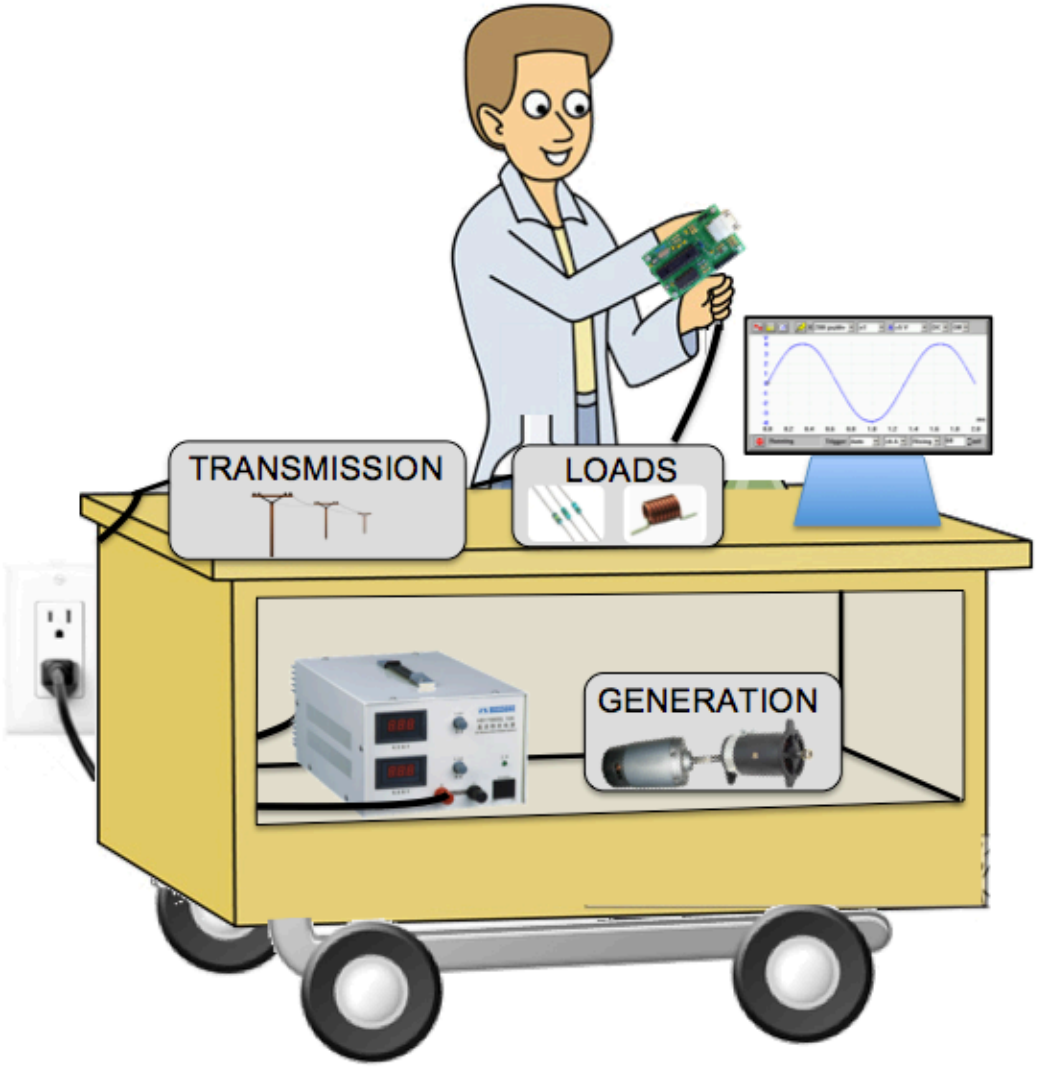
- Traditional energy sources, such as coal, present environmental and non-sustainable threats worldwide.

- In response, the power grid industry has begun turning to clean energy sources and Smart Grid technologies in order to improve efficiency, reliability, and cleanness of our electricity.

Problem Statement

- The **Smart Grid Test Facility** will provide a test environment for basic power grid experiments.
- Students will be able to simulate utility-grade transmission lines with single-phase power flow.
- A real-time data acquisition system will monitor the system's power flow and perform voltage-current analysis from generators to real and reactive loads.
- The Test Facility will provide a safe, user-friendly system with which students can learn about the power grid.
- This system also provides the infrastructure for integration of Smart Grid components by a future project team or class.

Visualization



Engineering Requirements

- Generation:
  - 12V AC (+/- 5%)
  - 60 Hz (+/- 5%)
  - 3 Generators: Minimum of 2 Motor-Alternator Sets
- Transmission:
  - Real-world, lumped-element per unit length parameters
  - 3+ lines
- Loads:
  - R, L, & C binary boxes (1 each)
- Safety:
  - Generators/pulleys inside isolatable enclosure
- DAQ:
  - Measure V and I
  - Measure Power Factor and Phase
  - Power Flow Metering

} +/- 5%

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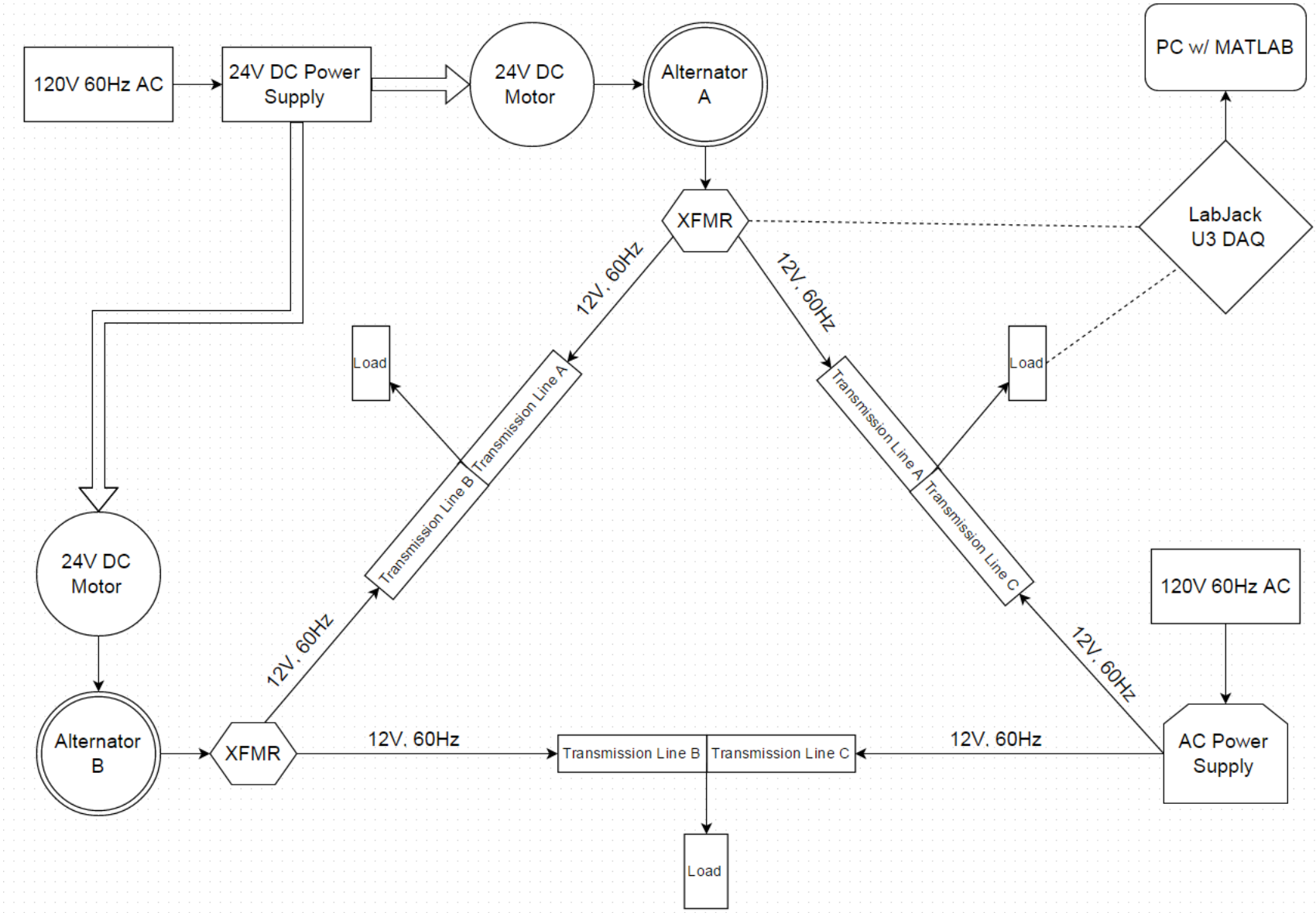
Level 0
Block Diagram

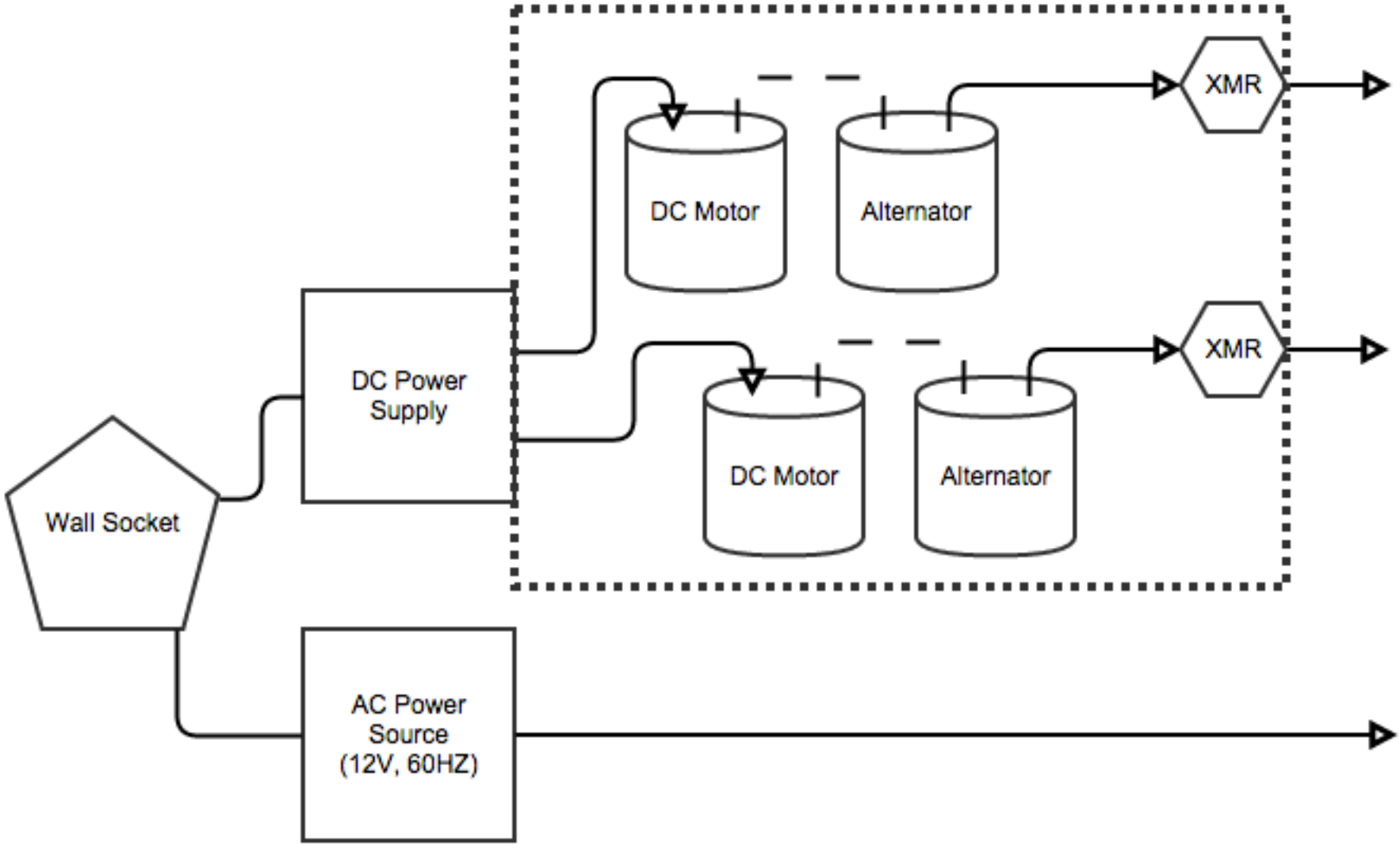


Generation System

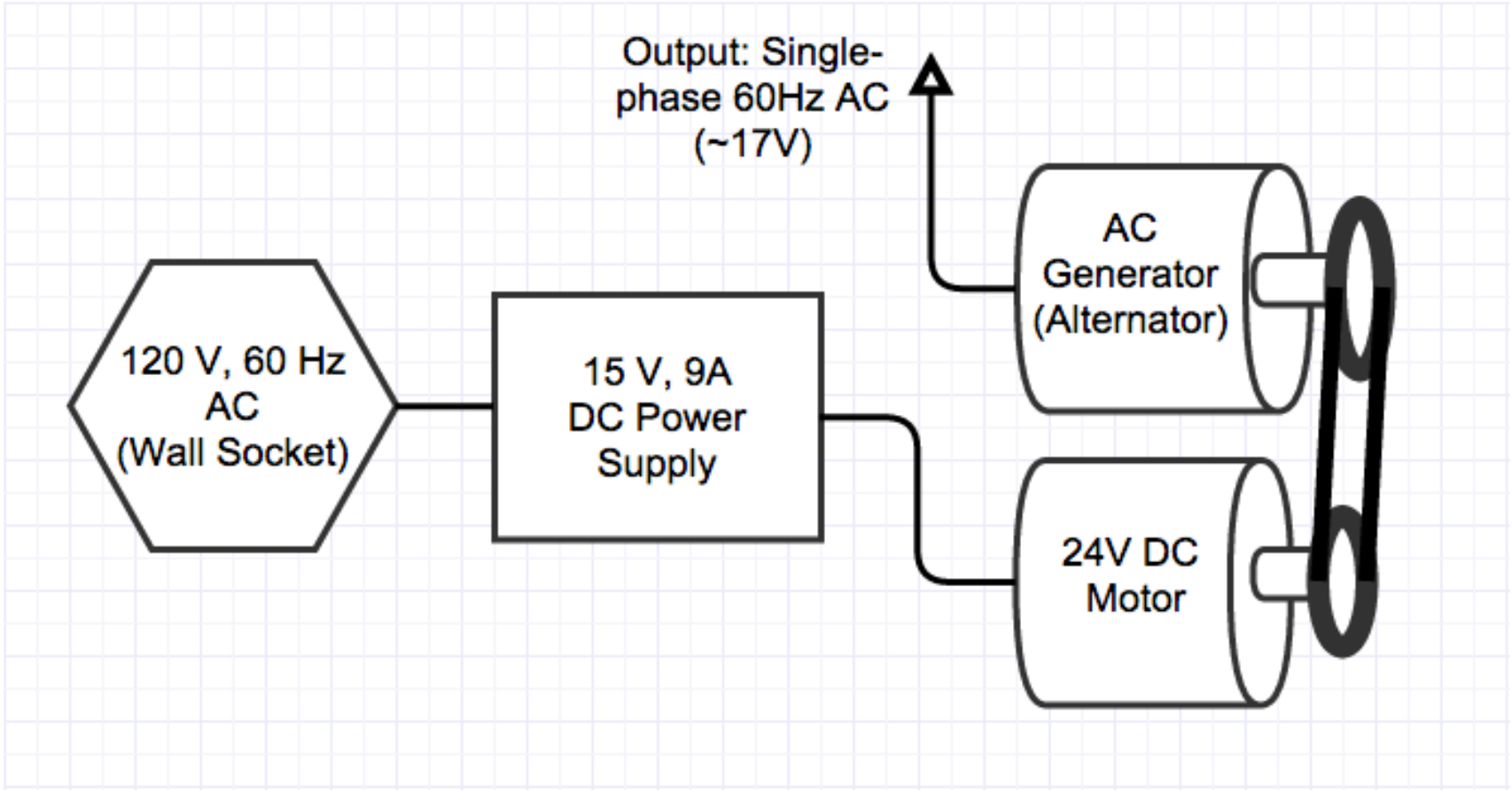
Work Completed

- Finalization of generation scheme
- Selection and purchase of…
  - 24V, 20A DC Power Supply
  - 24V 1/18HP DC Motor
- Wind Turbine Alternator
- Testing of generation components
- Initiation of design/manufacturing process at EPIC lab
- Funding allocation

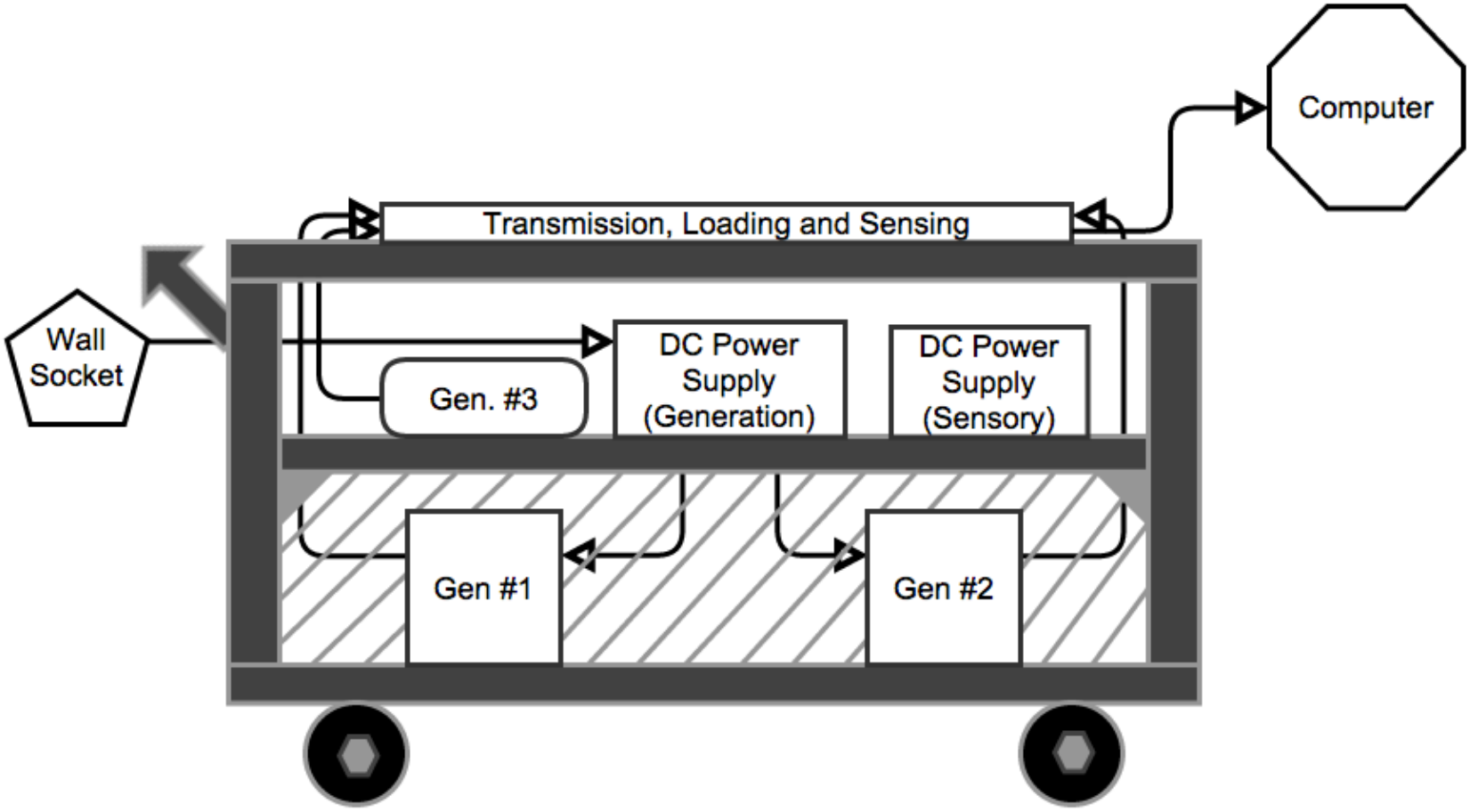
Generation Layout



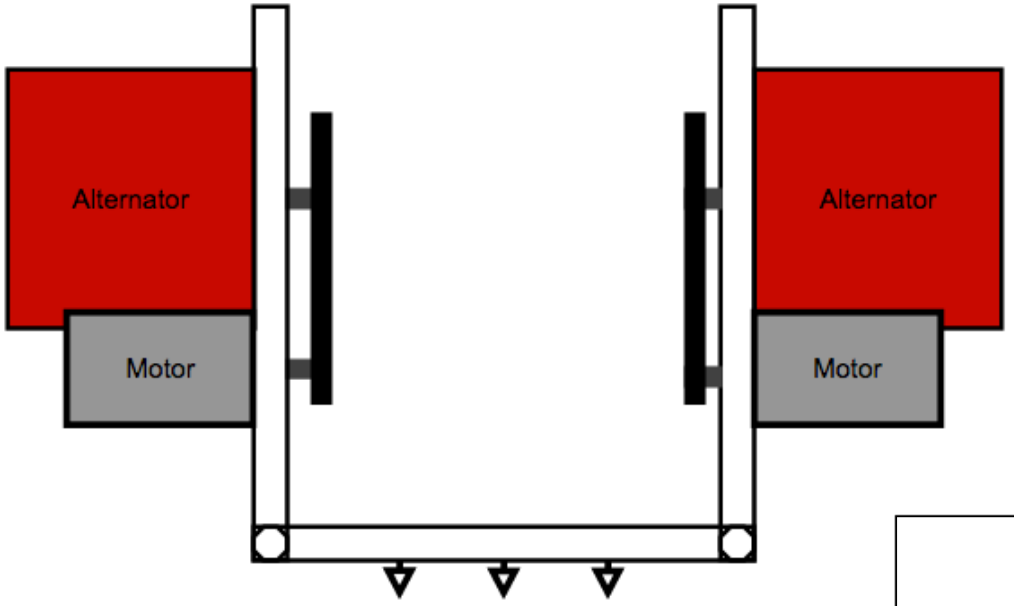
Motor/ Alternator Detailed Layout

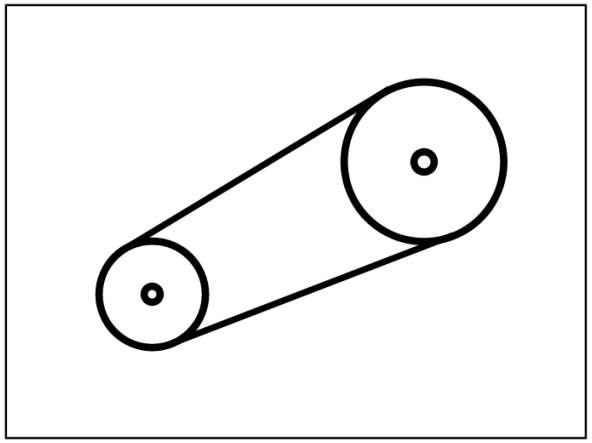


Cart Setup


Computer
Transmission, Loading and Sensing
Wall Socket
Gen. #3
DC Power Supply (Generation)
DC Power Supply (Sensory)
Gen #1
Gen #2

Motor/ Alternator Connection





Remaining Work

- Finalization of synchronization and frequency feedback design
- Testing synchronization and feedback designs
- Purchasing of…
  - Another set of motor/alternator
  - Transformers
  - Materials for housing/brackets
  - Encoder
  - Bulbs/switches
- Manufacturing brackets and safety enclosure
- Assembling with all components
- Final testing of components

Frequency Control

Rotary Encoder:

Purpose:

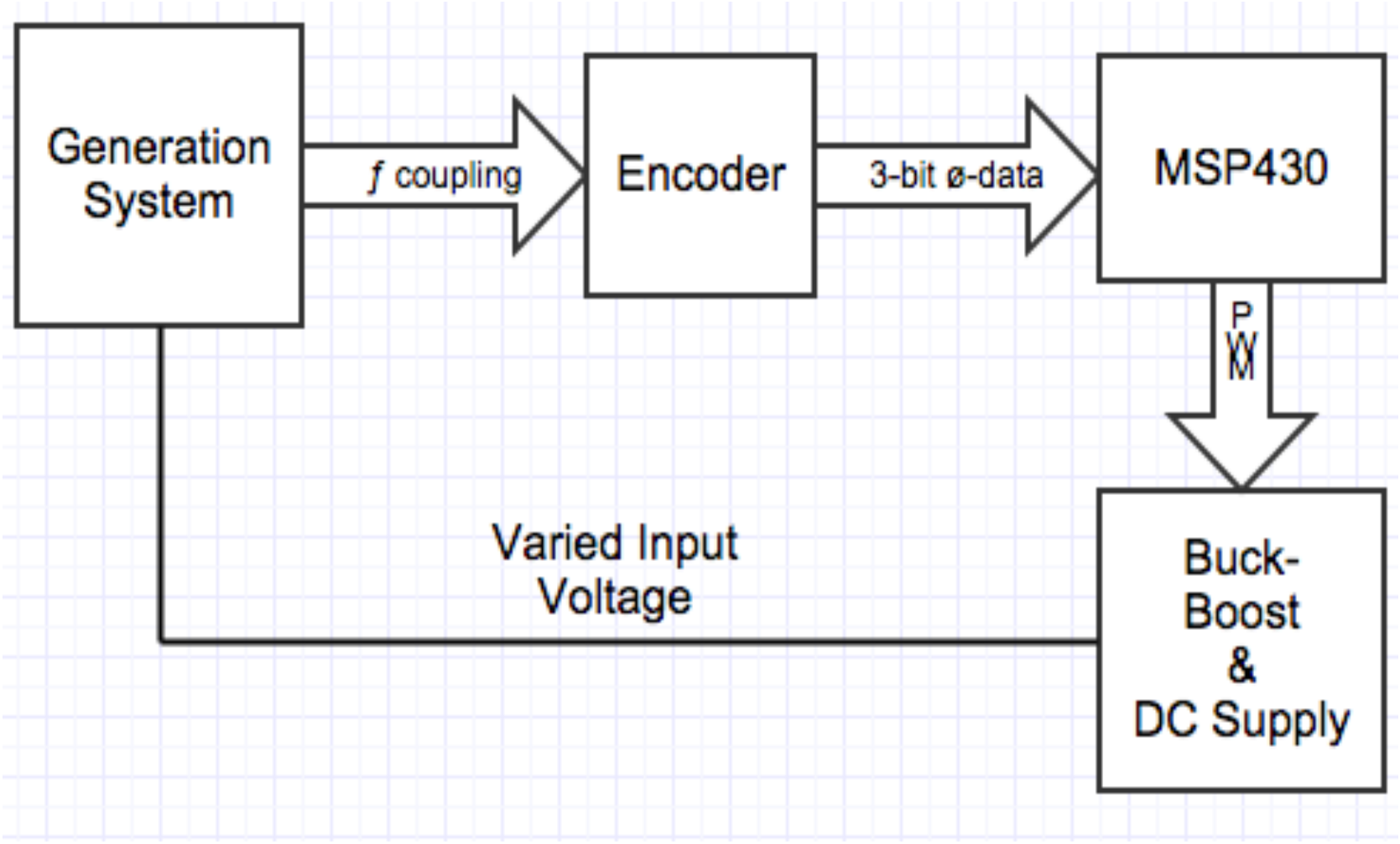
- Uses photodiode to track motion of concentric casks
- Reports 3-bit information about phase difference of casks.

MSP430:

Purpose:

- Feedback Controller
- Takes rotary encoder input and measures f of generation system.
- Produces PWM signal to drive Buck-Boost converter
- Controlling frequency through voltage/torque/frequency relationship.

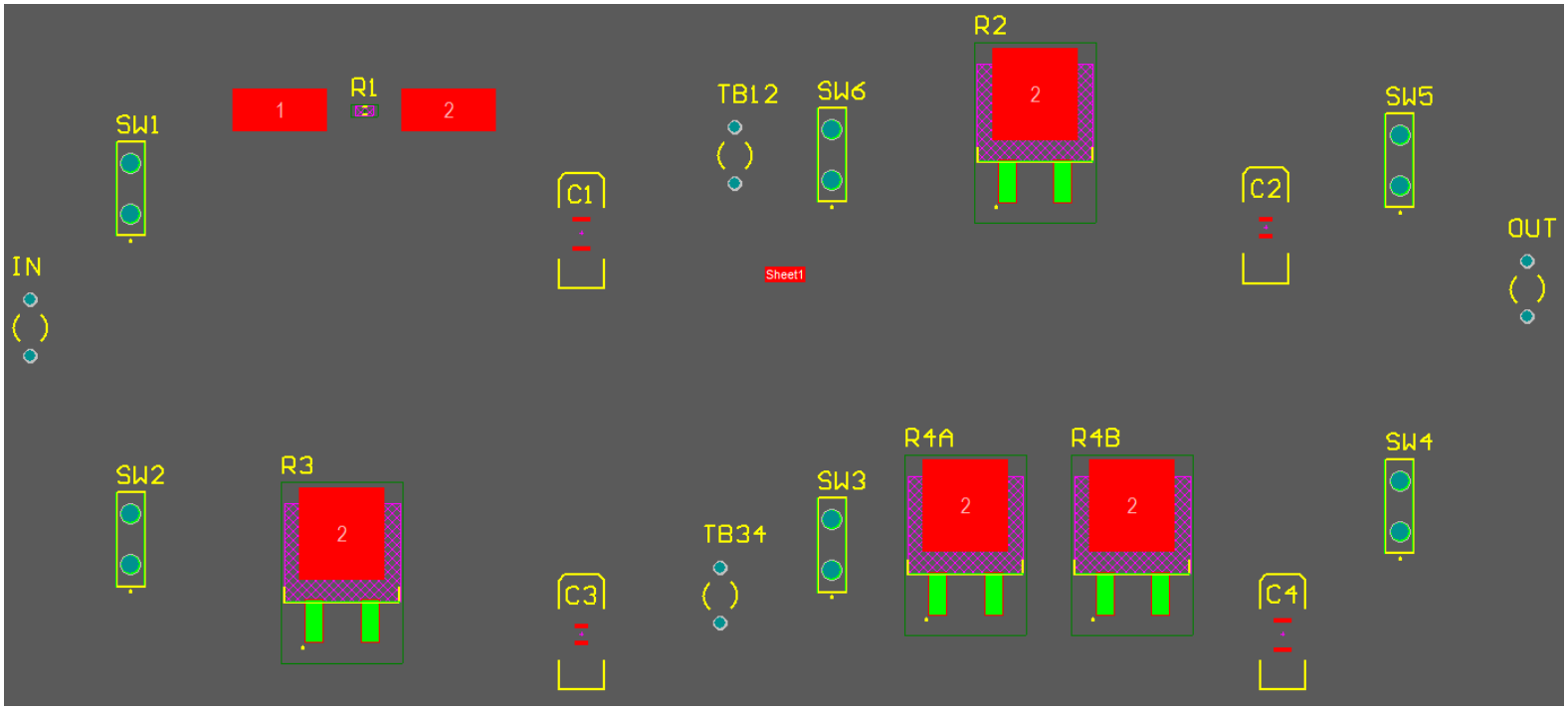
Feedback Control Loop



Transmission Lines

Work Completed

- Transmission Line Final Values
- Breadboard to PCB Conversion: Altium Designer Summer ‘09
- Digikey surface-mount components purchased
  - R, C, Switches, Terminal Blocks
- Footprints placed for 10/25/25/50 mile (4) line simulation



Data Collected

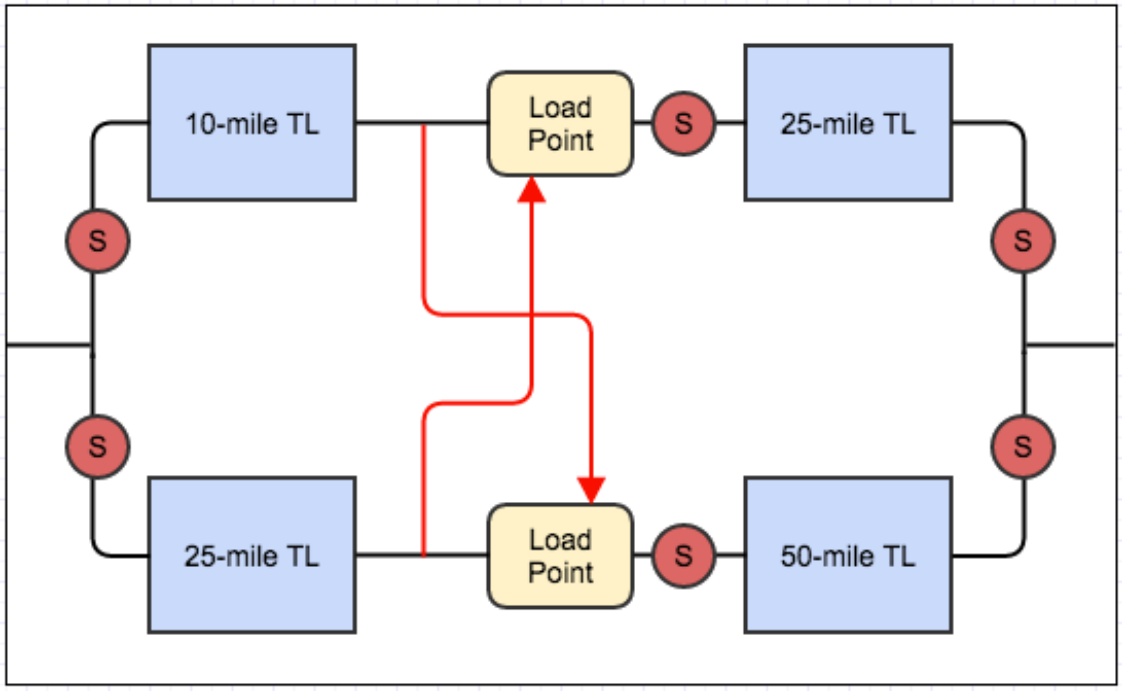
- Length of lines decreased to fit actual distances < 50 mi.
- Capacitance values remain low, nF level
- Verified RLCs with utility professionals
- Minimum resistance per line: 1.1Ω
- Generator-to-generator: 35/50/60/75 mile net distances

TRANSMISSION LINE CHARACTERISTICS		
R (Ω/mi)	L (mH/mi)	C (nF/mi)
0.1128	1.329	22

FINAL TRANSMISSION LINE SPECS				
TL No.	Length (mi)	R (Ω)	L (mH)	C (nF)
1	10	1.1	13.3	220
2	25	2.8	33.2	550
3	25	2.8	33.2	550
4	50	5.6	66.5	1100

Remaining Work

- In order to complete the transmission lines, the parts must be soldered to the PCBs.
  - This includes resistors, inductors, capacitors, terminal blocks, and switches.
- The PCBs must be integrated into the system by being affixed to the cart.



Loads

Work Completed

Binary Load Box:

Resistive:

- Design: completed and tested

Capacitive/Inductive:

- Design: completed and tested

Luminous Loads:

- Design: completed

Design Developments

A New Approach:

Citgo Sign:

– Previous Issues
  - •Wiring - untenable
  - •Power Requirements - unnecessarily complicated

– Solution
  - •Scaling back LED's – ~14 down from 40+
  - •Use of Clear Acrylic Façade

Hobby Lights & Motors:

– Scrapped for Cost

Magnetic Loads:

– Scrapped for Cost

Remaining Work

Binary Load:

– Resistive:

•Draw/Acquire/Test PCB

– Capacitive/Inductive:

•Draw/Acquire/Test PCB

Citgo Sign:

•Draw/Acquire/Test PCB

•Machine Façade

Data Acquisition System

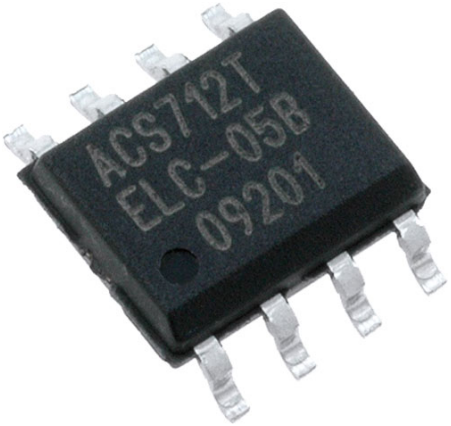
Work Completed

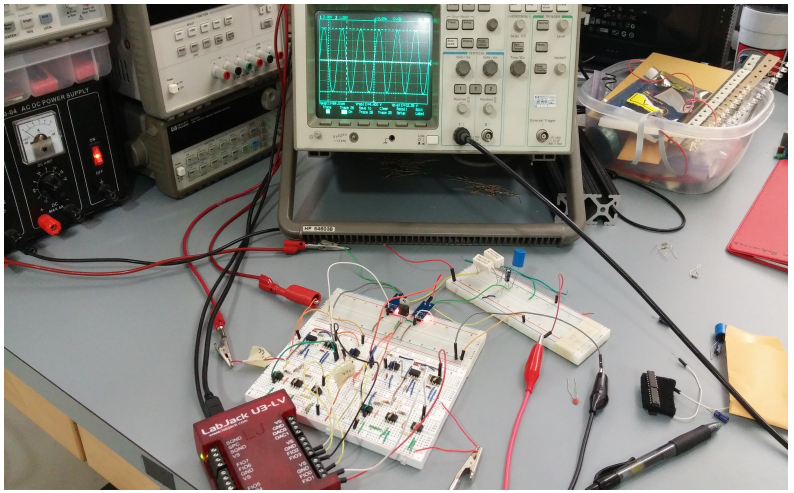
Current and Voltage Interfaces Prototyped

- JFET op-amps -> minimize noise and input biasing
- ASC712 Hall Effect Sensor
- SMD parts selected for PCB fabrication

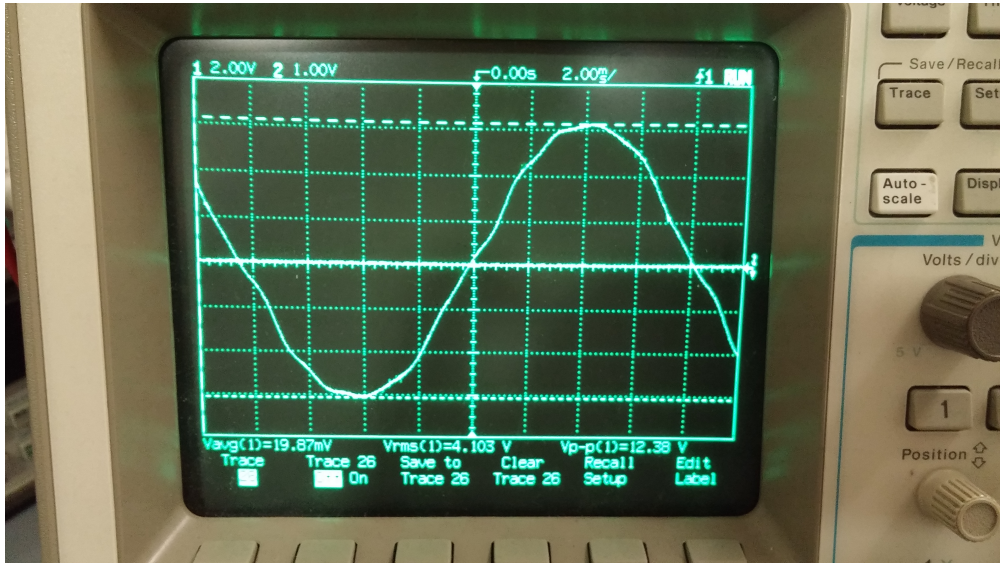
Basic Functionality MATLAB code prepared

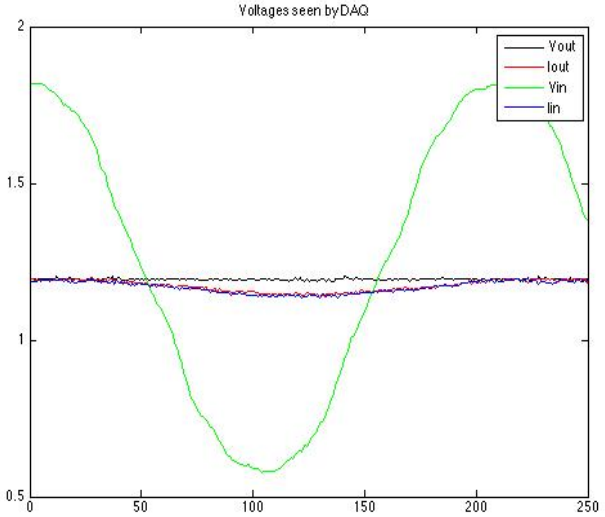
- Phase
- Magnitudes
- RMS values
- Power Factor





Data Collected & Remaining Work





Note: Noisy Ground

Remaining Work:

- Create PCBs
- Continue MATLAB work
  - Power Flow
  - GUI
- Integrate/Final Testing

Project Planning

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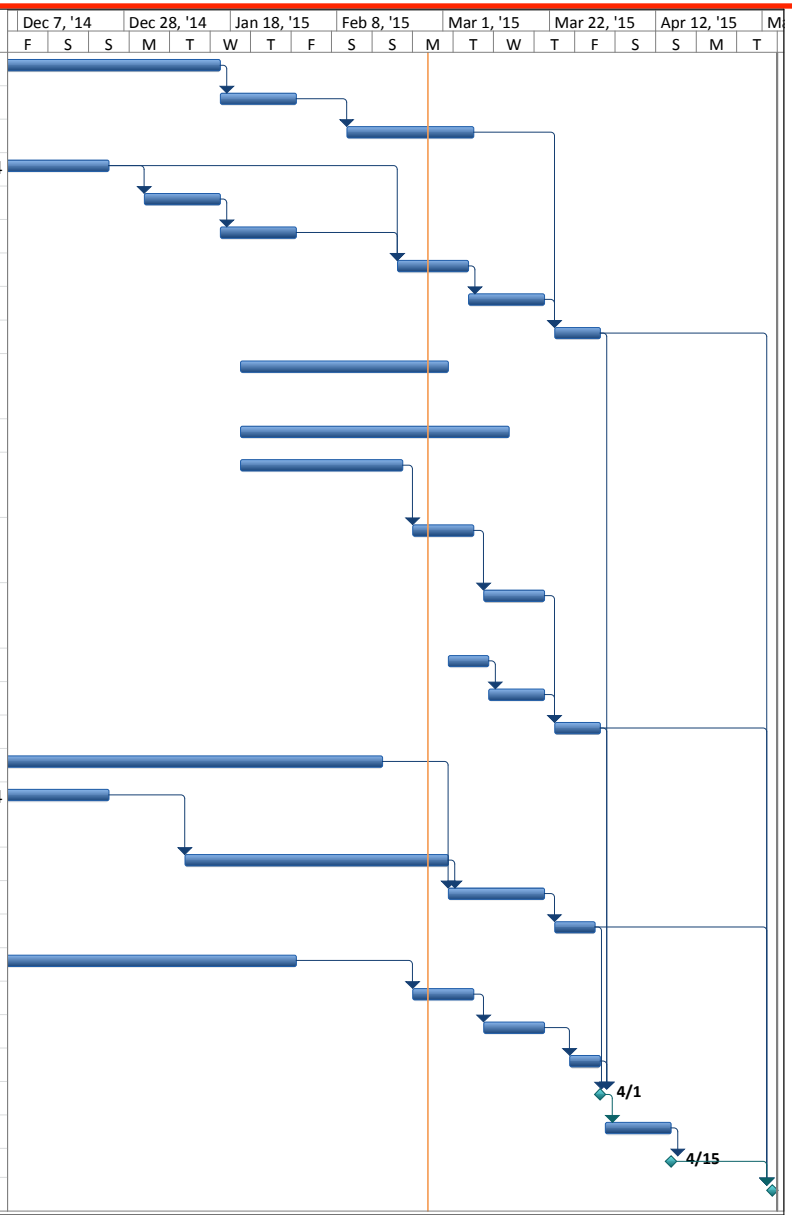
Gantt Chart

ID	Task Mode	Task Name	Duration	Start	Finish
1		(DAQ) Program Data Processing	34 days	Mon 12/1/14	Thu 1/15/15
2		(DAQ) Test Data Processing	11 days	Fri 1/16/15	Fri 1/30/15
3		(DAQ) Program and Test GUI	20 days	Tue 2/10/15	Fri 3/6/15
4		(DAQ) Pick Components	17 days	Tue 12/2/14	Wed 12/24/14
5		(DAQ) Design Interface Circuits	11 days	Thu 1/1/15	Thu 1/15/15
6		(DAQ) Test Interface Circuits	11 days	Fri 1/16/15	Fri 1/30/15
7		(DAQ) PCB Layout	11 days	Fri 2/20/15	Thu 3/5/15
8		(DAQ) PCB Fabrication	11 days	Fri 3/6/15	Fri 3/20/15
9		(DAQ) Project Integration	7 days	Mon 3/23/15	Tue 3/31/15
10		(Generation) Select Components	30 days	Tue 1/20/15	Sun 3/1/15
11		(Generation) Test Components	40 days	Tue 1/20/15	Fri 3/13/15
12		(Generation) Design Feedback and Synchronization System	24 days	Tue 1/20/15	Fri 2/20/15
13		(Generation) Pick Feedback and Synchronization Components	11 days	Mon 2/23/15	Fri 3/6/15
14		(Generation) Feedback and Synchronization Testing	10 days	Mon 3/9/15	Fri 3/20/15
15		(Generation) Design Enclosure	6 days	Mon 3/2/15	Mon 3/9/15
16		(Generation) Construct Enclosure	9 days	Tue 3/10/15	Fri 3/20/15
17		(Generation) Project Integration	7 days	Mon 3/23/15	Tue 3/31/15
18		(Transmission) Integration Design	56 days	Mon 12/1/14	Mon 2/16/15
19		(Transmission) Select RLC Components	18 days	Mon 12/1/14	Wed 12/24/14
20		(Transmission) PCB Layout	37 days	Fri 1/9/15	Sun 3/1/15
21		(Transmission) PCB Fabrication	15 days	Mon 3/2/15	Fri 3/20/15
22		(Transmission) Project Integration	6 days	Mon 3/23/15	Mon 3/30/15
23		(Load) Load Selection and Testing	45 days	Mon 12/1/14	Fri 1/30/15
24		(Load) PCB Design	11 days	Mon 2/23/15	Fri 3/6/15
25		(Load) PCB Fabrication	10 days	Mon 3/9/15	Fri 3/20/15
26		(Load) Project Integration	4 days	Thu 3/26/15	Tue 3/31/15
27		Project Functional Testing	0 days	Wed 4/1/15	Wed 4/1/15
28		Final Preparation/Details	9 days?	Thu 4/2/15	Tue 4/14/15
29		Delivery Day	0 days	Wed 4/15/15	Wed 4/15/15
30		ECE Day	0 days	Tue 5/5/15	Tue 5/5/15



Budget

Componential Description		Est. Price
Generation	Motors	$300
	Alternators	$300
	Transformers	$50
	Feedback System	$30
	Syncronization System	$30
	Enclosure/Bracket Materials	$300
		Total: $1010
Transmission Lines	PCB	$50
	Passive RLC	$70
	Additional Parts	$30
		Total: $150
Generic Loads	Passive Loads	$175
	Display Loads	$75
	PCB	$50
		Total: $300
Data Acquisition	DAQ	$120
	Sensor Boards	$75
	PCB	$35
	Power Supply	$35
		Total: $265
		Net Total: $1725
		ECE Funding: $350
		KHC Funding: $400
		Budgetary Total: $975


POWER
POOCHES