Hyperloop Power Supply and Generation
Mock Design Review

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1.0 Block Diagram

2.0 Circuit Schematic

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.tran 0 1000u 0 10u

V1

V1 36

C2 10μ

L1 35.9μ

SW

D1

D

C1 35μ

R1

R=limit(1, V(V1)**2/3600, 2)

PULSE(-1 1 5u 0 0 5u 10u 1000

.model SW SW(Ron=500u)
```
3.0 Boost Converter Calculations [1]

\[ V_{in} = 36V \]
\[ V_{out} = 72V \]

Frequency = \( f = 100kHz \)

Efficiency = \( \eta = 70\% = 0.7 \)

\[ I_{out,max} = 50A \]

Duty Cycle = \( D = 0.5 \)

\[ V_{out,max} = 75.6V \]
\[ V_{out,min} = 68.4V \]

\[ P_{total} = 21.6kW \]

\[ P_{per\ Arx\ Pax} = \frac{21.6kW}{6} = 3.6kW\ per\ module \]

\[ \frac{P_{per\ module}}{V_{out,max}} = \frac{3.6kW}{75.6V} = 47.61A \]
\[ \frac{P_{per\ module}}{V_{out,min}} = \frac{3.6kW}{68.4V} = 52.63A \]
4.0 Plot of Boost Converter Waveform
5.0 Block Description

5.1.1 Battery Management System

The BMS will maintain cell balance, monitor State of Charge, Voltage, Current, and Temperature. It will also communicate these values to the microcontroller. In the final implementation of the Hyperloop pod, these values will be utilized by the computing subsystem (outside the scope of this project) to determine control of the pod.

5.1.2 High Battery Pack

This battery pack will provide power to the levitation system. It will be 36 V and must be capable of delivering approximately 30 kW continuously for 5 minutes. It will consist of multiple strings of 10 3.6 V rechargeable battery cells in series. Each string will be connected in parallel to obtain the desired power and energy density.

5.1.3 Boost Converter

A boost converter can step up the voltage of a power source, in this case it is the high battery power supply. This will be used for our High battery to power a load that requires approximately 72V with 21.6kW. We will be delivering a very high amount of current to this circuit due to our predicted load value being about .25Ω, thus giving us a current of 300 amps.

5.1.4 Low Battery Pack

This power supply will power our small onboard electromechanical components, for purposes such as brake actuation. It will be 14.4 V and must be capable of delivering 200 W continuously for 5 minutes. It will consist of 4 3.6V rechargeable cells in series.

5.1.5 Buck Boost Converter

This converter can be used to regulate voltage to a certain level, in this case our 12V output supply. With a 12V input supply we can regulate the output voltage to be constant using this converter. The 12V will be used for our battery management system. We expect a power consumption of no more than 5 W from the BMS.

5.1.6 Buck Converter

A buck converter can be used to step down the voltage of a source, we will be using it for when one of the batteries is powering some of the small system components.
of our circuit. This will be used to step down our low battery 12V to 5V to be used on several of the computing components. During our part of our testing phase and during this courses final presentation, we will use this to power our microcontroller. We expect a power consumption of no more than 15 W from the computing components.

5.1.7 Computing Battery Pack

This power supply will power our 12 V and 5 V systems. It will be 14.4 V and must be capable of delivering 20 W for 90 minutes. It will consist of multiple strings of 4 3.6V rechargeable cells in series. Each string will be connected in parallel to provide the needed energy capacity.

5.1.8 Microcontroller

The Microcontroller will be used to configure the duty cycle to specify what type of signal is being sent to our converters. This allows us to move away from a more difficult analog design to digital. The microcontroller will also collect data from the BMS as a proof of concept for later integration into the Hyperloop pod.

5.1.9 Safety Controls

There are controls implemented to ensure protections within our system. We will use fuses to protect against too high input currents and save our system from breaking down. These high ampere rated fuses will be used across all of our converters to ensure safety with all branches in our circuit.
6.0 Requirements and Verifications for Boost Converter

A boost converter can step up the voltage of a power source, in this case it is the high battery power supply. This will be used for our High battery to power a load that requires approximately 72V with 21.6kW. We will be delivering a very high amount of current to this circuit due to our predicted load value being about .25Ω, thus giving us a current of 300 amps. We are planning on using 6 Arx Pax branches to handle this current flow and make it 50A per line.

The load will range from 52.63 amps to 47.61 amps given our 72V±5% limit and thus 108 Watt pk-pk range of output power. We must be able to make sure our components and inductor can handle this level of change of current.

Requirements:
1. Output 72 V +/- 5%
2. Efficiency > 70%
3. Keep our values (Voltage, Current, Power) consistent/steady to within +/-5% of their expected values

Verification:
1. Input 36V and measure output voltage, input 0V and measure output voltage, input battery voltage at 20% SoC and measure output voltage.
2. Measure V and I for the inputs and measure V and I across the load.

(3)
1. Use a variable load to simulate 6 different load values: 0ohms, 1ohm, 1.44ohms (ideal load), 1.448 (with/wire resistance), 2ohms, 5ohms
2. Iin: Use an oscilloscope to verify steady current
3. Iout: Use an oscilloscope to verify ripple. (50.1 A +/-2.5A)
4. Vin: Use an oscilloscope to verify steady input voltage of 36V.
5. Vout: Use an oscilloscope to verify ripple. (72V +/-3.6V)
6. Pout,max and Pout,min: Use a meter to verify power (3.6kW +/- 180W)
7. Temp: Use a temperature reader to make sure our devices do not go above 30 degrees C.
7.0 Safety Statement

Safety

The IlliniHyperloop Power Supply is capable of producing fatal amounts of current, and should be handled with the utmost care. Any exposed wiring may pose a hazard. Given the use of electrolytics, these hazards may persist long after the disconnection of a power source (either internal batteries or an external power supply to be used for testing purposes). As such, the following protocols are to be observed at all times:

- Wear High-Voltage gloves while handling the power supply.
- Do not allow the power supply or individual components to come into contact with water or other potential short hazards.
- Ensure proper current limits have been imposed on external power supplies before testing.
- Cover all exposed wiring and terminals before storage. Terminals shall be covered with rubberized caps. Each component with stored energy shall be stored so that they are electronically isolated from other components, and cannot be accessed by persons not conscious of the risks associated with this project.

This project will also be using Lithium Ion batteries, which are particularly sensitive components [2]. To avoid damage to the batteries and remove potential health hazards, the following protocols shall be implemented:

- Do not charge batteries above their maximum voltage
- Do not discharge batteries below their maximum voltage
- Ensure Battery Management system is operational and properly installed before charging or discharging batteries.
- Do not charge or discharge batteries at a rate greater than their rated currents.
- Do not allow the batteries to exceed their operational temperatures.
- Do not allow the batteries to come into contact with water or other potential short hazards.
- Ensure proper battery installation. Reverse polarity and loose or open contacts are to be avoided.
- Use a charger approved for use with the batteries.
- Do not use the batteries in an environment with high static-electricity or magnetic fields.
Citations: