Team #2: Solar Car System Level Design

COE Advisors:

ECE Department

- Dr. Simon Foo
- Dr. Jim Zheng
- Dr. Mike Frank

ME Department

- Dr. Pat Hollis
- Dr. Kamal Amin

Team Members:

Matthew Bosworth – EE

Christopher Dresner – EE

Ahmad Farhat – EE

Daniel Green – ME

Joseph Petit-Homme – ME

Thierry Kayiranga – EE

Clay Norrbin - ME

The Team

Matthew Bosworth
Project Manager and EE Lead

Christopher Dresner
EE Business Admin.

Ahmad Farhat
EE Finance Manager

Thierry Kayiranga
Secretary

Clay Norrbin
ME Lead

Daniel Green
ME Business Admin

Joseph Petit-Homme
ME Finance Manager

Clay Norrbin

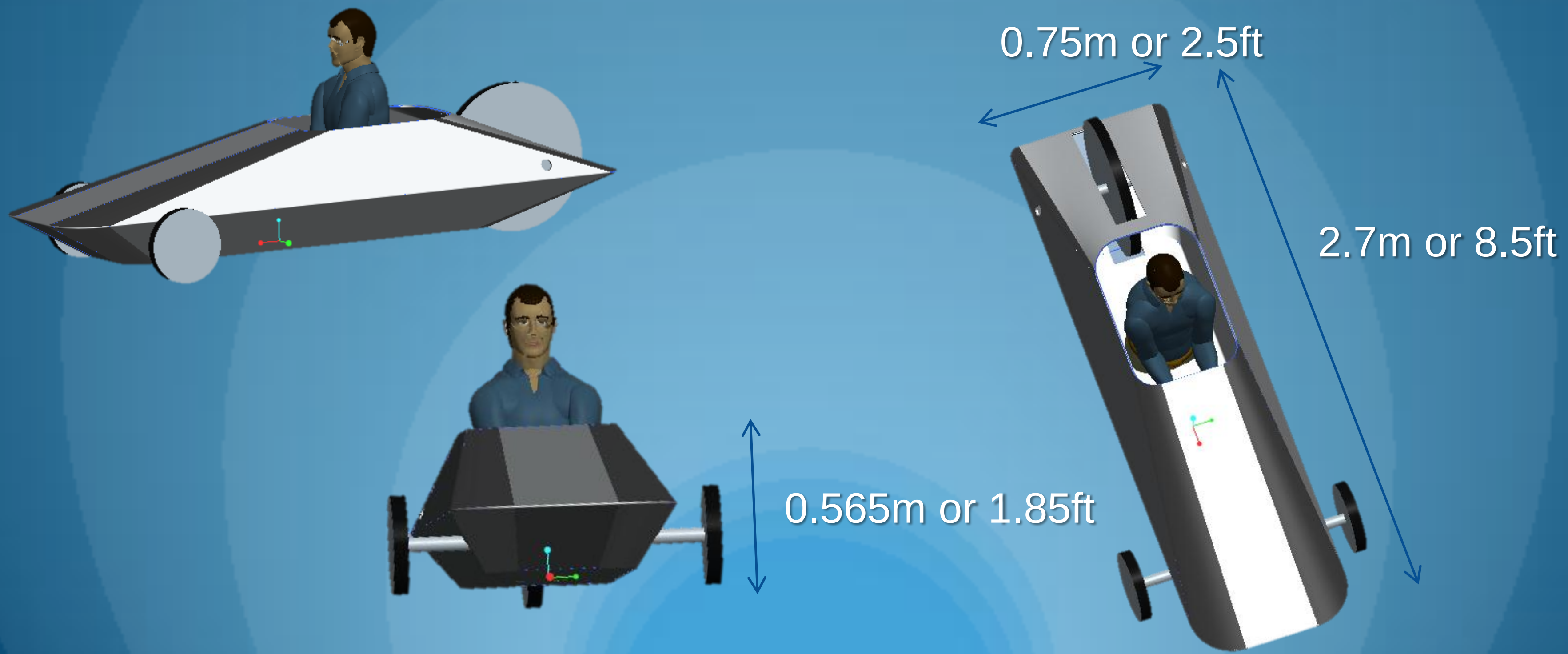
Chassis

Last Year

First Prototype

Clay Norrbin

Smaller Body Shape Due to Less Solar Panels.

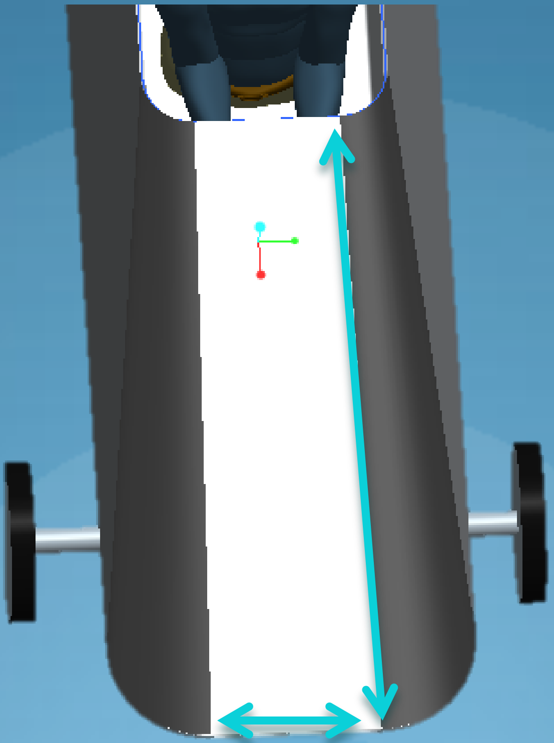


Clay Norrbin

Solar Panel Space

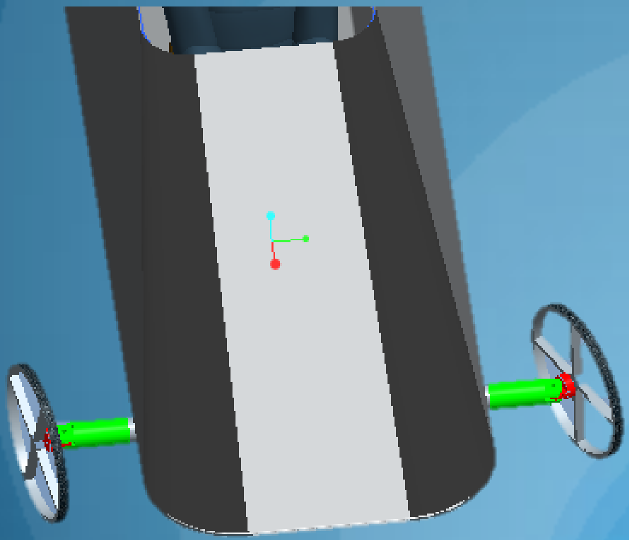
Area = 0.4m^2

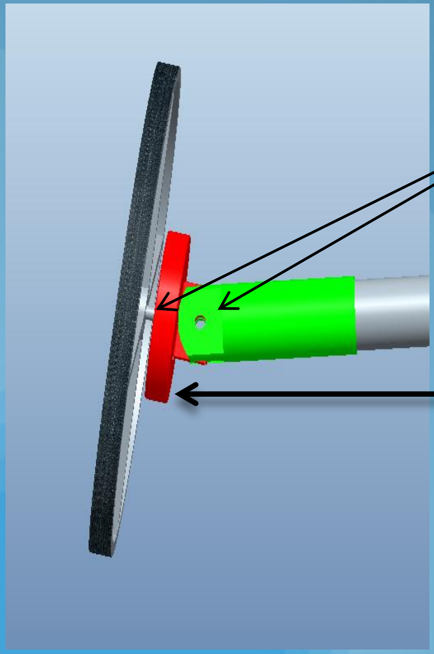
Needed Area = 0.17m^2



Steering

- Front Steered
- Restrictions for turning radius from Shell Eco-marathon
  - Turning radius of 6m





Clay Norrbin

Risks:

Technical

- Aluminum Honey-Comb might be harder to connect than previously thought.
- The predetermined strength of the car could be weaker than predicted.
- Rigid suspension can cause vibrations and resonance to produce parts to fail
- Steering could be under design requirements

Budget

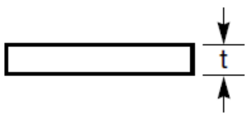
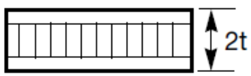
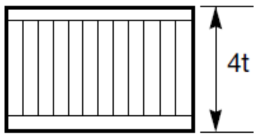
- Carbon Fiber is extremely expensive

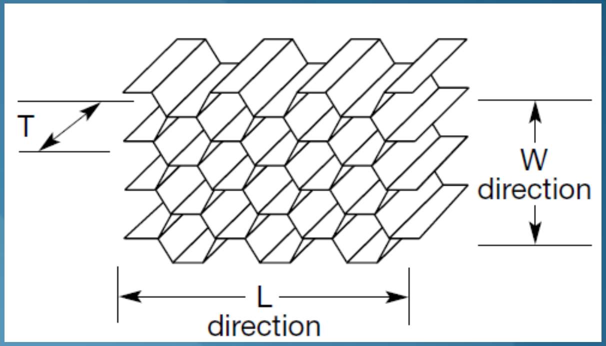
Schedule

- Chassis manufacturing time

Joseph Petit-Homme

Aluminum Honeycomb Structure:

	Solid Metal Sheet 	Sandwich Construction 	Thicker Sandwich 
Relative Stiffness	100	700 7 times more rigid	3700 37 times more rigid!
Relative Strength	100	350 3.5 times as strong	925 9.25 times as strong!
Relative Weight	100	103 3% increase in weight	106 6% increase in weight



Aluminum Honeycomb
- relatively low cost
- best for energy absorption
- greatest strength/weight
- thinnest cell walls
- smooth cell walls
- conductive heat transfer
- electrical shielding
- machinability

Honeycomb stiffens a structure without materially increasing the weight.

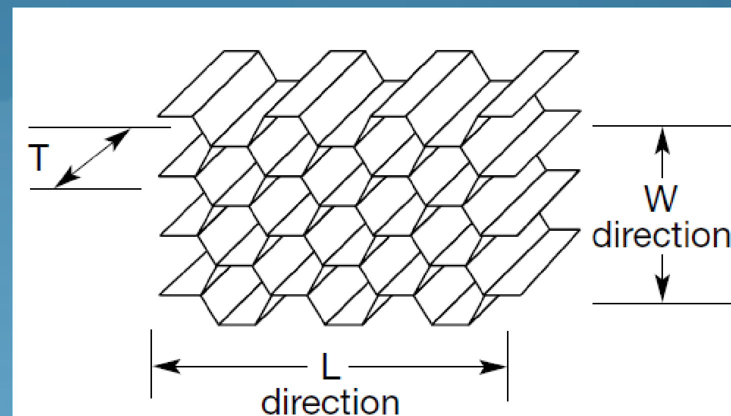
Joseph Petit-Homme

Aluminum Honeycomb Structure:

Determining Which Type of Honeycomb

Cost vs. value/performance

- Piece size
- Density
- Strength
  - Compressive
  - Impact
  - Fatigue
- Cell wall thickness
- Flammability/fire retardance
- Electrical conductivity
- Wall surface smoothness
- Cushioning
- Machinability/Formability



Aluminum Commercial Grade (ACG) for 3000 Series Alloy

Hexcel Honeycomb Designation Material – Cell Size	Nominal Density pcf	Compressive			Crush Strength psi	Plate Shear			
		Bare	Stabilized			L Direction		W Direction	
		Strength psi	Strength psi	Modulus ksi		Strength psi	Modulus ksi	Strength psi	Modulus ksi
		typ	typ	typ	typ	typ	typ	typ	typ
ACG – 1/4	4.8	630	660	148	245	365	70	215	38
ACG – 3/8	3.3	340	370	92	120	230	45	130	22
ACG – 1/2	2.3	190	205	40	60	140	28	80	14
ACG – 3/4	1.8	120	130	24	45	100	20	65	11
ACG – 1	1.3	80	85	16p	25	65	14	45	7

Joseph Petit-Homme

Risks: Technical

Description:

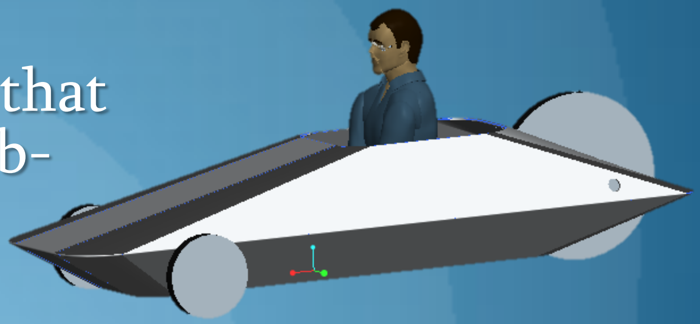
- Pro/E and Comsol integration and testing

Probability: Moderate

- Assistance needed in using different features with the software

Consequences: Moderate

- 3D representation and stress testing that will be performed for the car and sub-systems will be delayed



Solution:

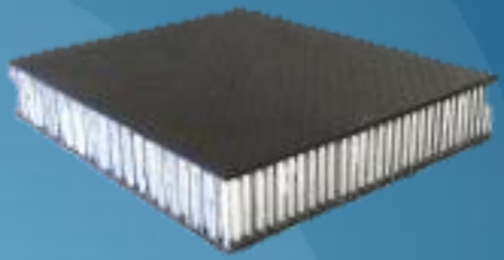
- Speaking with advisors and others that have an extensive background in using these software.

Joseph Petit-Homme

Risks: Technical

Description:

- Meshing the Aluminum honeycomb to the CF that will be used for the monocoque .



Probability: Low

- Assessment of the materials

Consequences: High

- The monocoque will not stick and chassis will be incomplete and cause a delay in manufacturing time.

Solution:

- Reach out to experts in this area and consult with them on ways to adhere the materials together or other viable options.

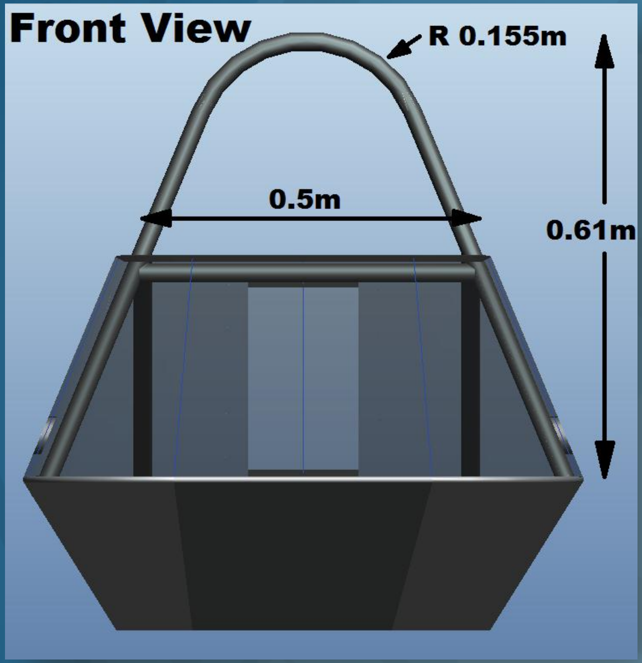
Daniel Green

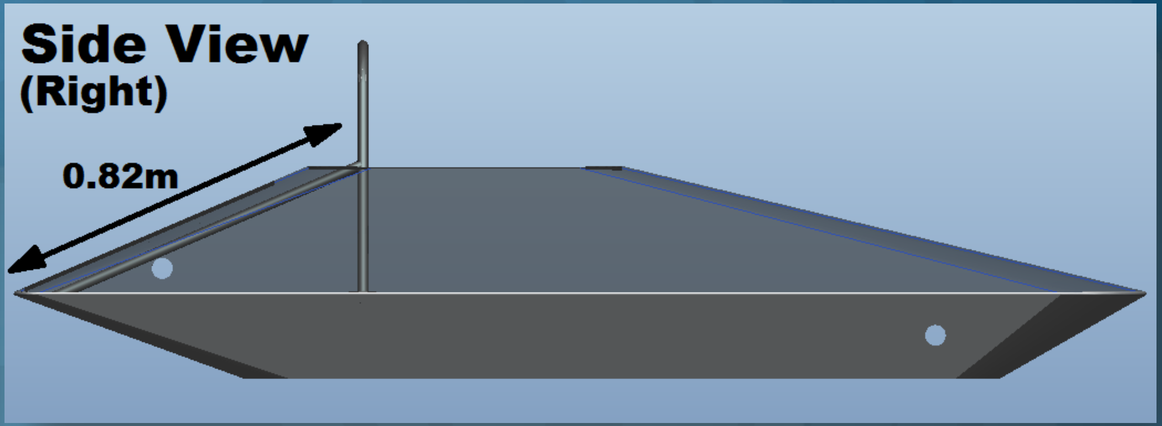
Roll Bar

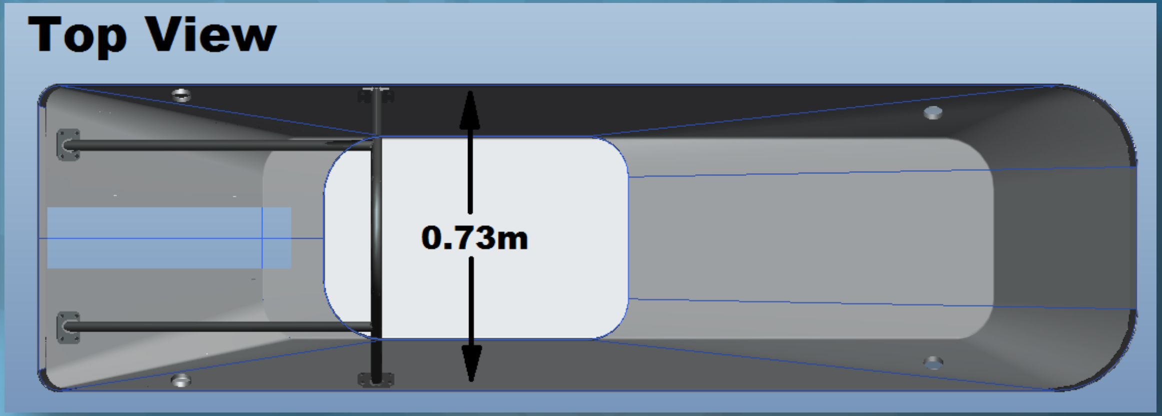
- Consulted SCCA & NHRA specs
- 4130N Chromoly steel tubing, 1.25” x 0.065”
- 0.8226 lbs. per foot
- $5.28 per foot
- Easily withstand 70kg without deformation

Daniel Green

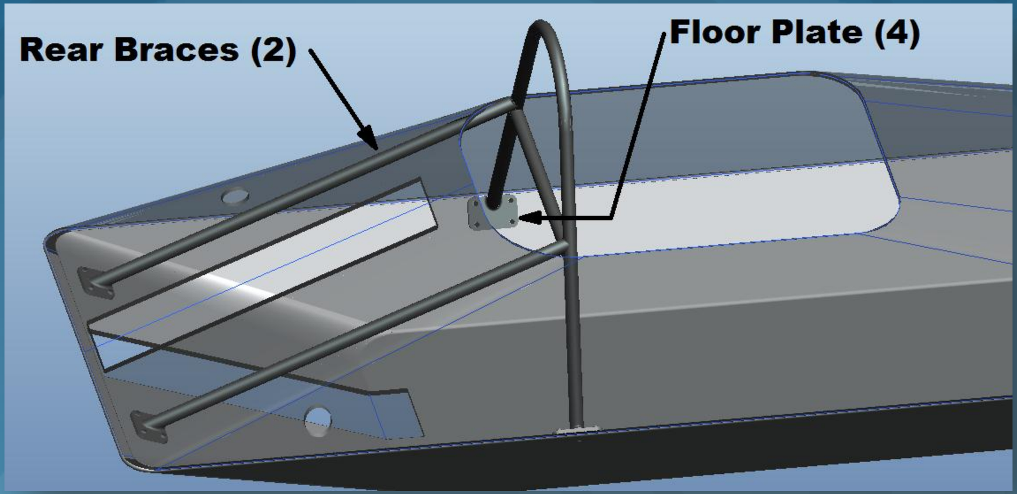
Roll Bar Design

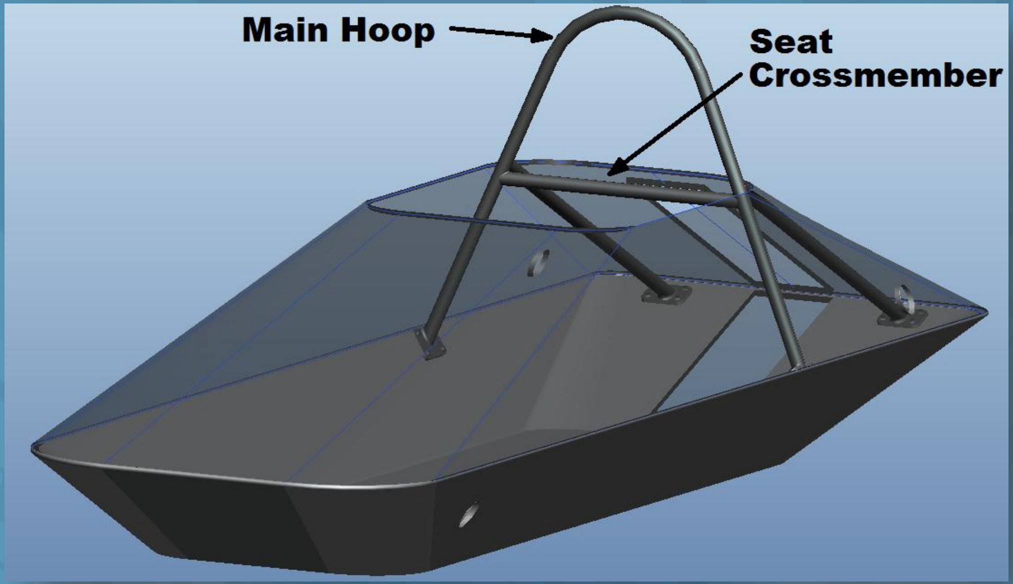






Daniel Green

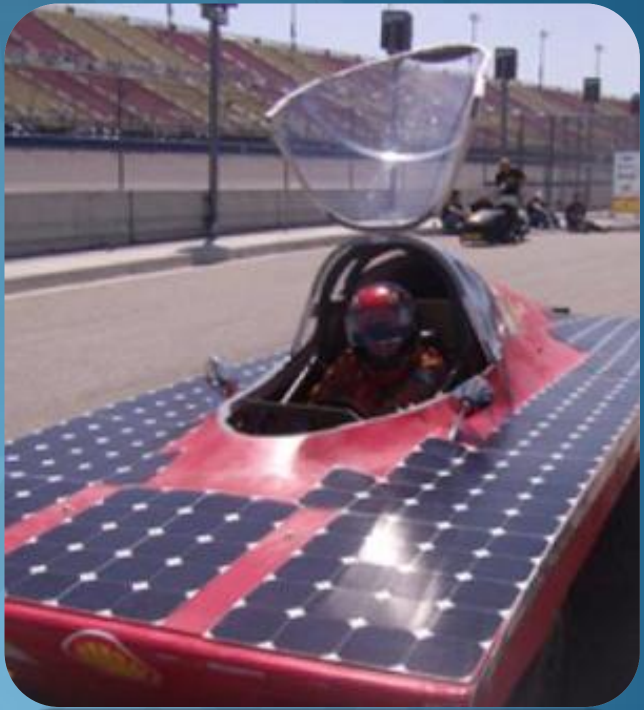




Daniel Green

Hatch

- Unnecessary to overall design
- Consulted Shell Eco-marathon ® guide
- Article 30: cockpit enclosure optional
- Elimination of hatch from final design
- Benefits?



Daniel Green

Without Hatch

- Significant weight decrease
- Decreased escape time
- Instant cockpit ventilation
- Decreased spending
- Less chance of error
- Decreased production time
- Negligible aerodynamic effect

Daniel Green

Risks:

Technical

- Possibility of roll bar failure

Budget

- Uncertain of total TIG welding and heat treatment costs

Schedule

- Delay due to roll bar design complications and/or adjustments as vehicle comes together

Christopher Dresner

Battery System

- 24 V, 20 Ah Battery Pack
  - Estimated that 6.71 Ah needed for race
  - Low size, weight, and cost
  - BMS and Charger

Christopher Dresner

Battery Options

	Elite Power Solutions ($LiFeMnPO_4$)	Electric Rider ($LiFePO_4$)	Electric Rider ($LiMnCO_2$)
Cost	$450	$500	$900
Weight (lbs)	13	10	9
Dimensions (in)	2 x (7 x 3 x 6.5)	6 x 10.25 x 3.5	5.25 x 9.5 x 3.25
BMS	No (Cell Balancers and SOC meter)	Yes	Yes
Continuous Current	-	98 A	195 A
Power	-	2,352 W	4,680 W

Christopher Dresner

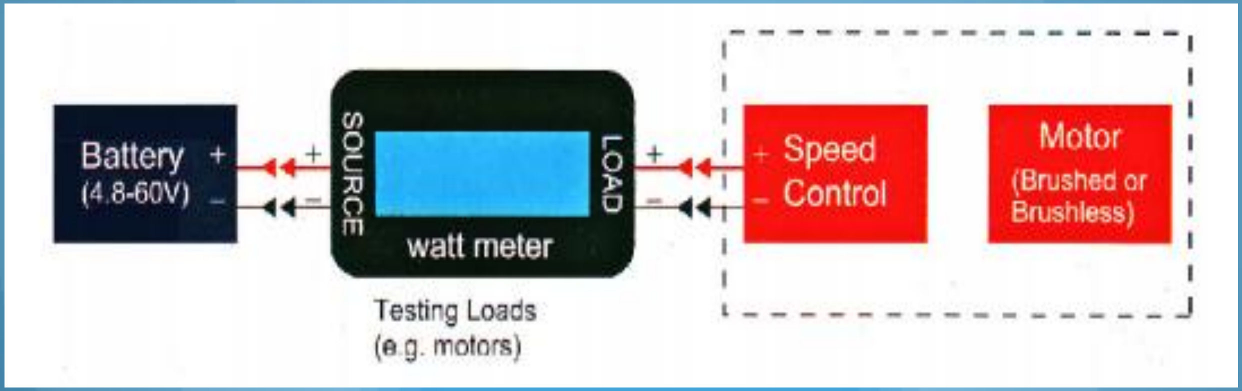
Battery Selection

Scale 1:10	Cost	Performance	Safety	Size	Weight	Total
Elite Power Solutions (LiFeMnPO4)	8	7	6	4	6	6.3
Electric Rider (LiFePO4)	**7**	**7**	**7**	**8**	**8**	**7.5**
Electric Rider (LiMnCO2)	3	9	7	8	8	6.5
Weighting	0.3	0.1	0.1	0.2	0.3	

Christopher Dresner

Turnigy Watt Meter and Power Analyzer

Measures:
0~130A, resolution 0.01A
0~60V, resolution 0.01V
0~6554W, resolution 0.1W
0~65Ah, resolution 0.001Ah
0~6554Wh, resolution 0.1Wh
Screen: 16x2, backlit LCD display
Size: 85x42x25mm
Weight: 82g



Christopher Dresner

Risks:

Technical

- Lithium batteries require a proper battery management system to protect individual cells and the entire battery pack

Thierry Kayiranga

Energy Conversion

Overall view of functionality

MPPT Algorithm

- Observe & Perturb
- Incremental Conductance

Boost Converter

- SPV1020
- *TPS55340
- *TPS61170
- *LMR64010
- *LMR62014
  - 2M72442

Thierry Kayiranga

Overall view of Functionality

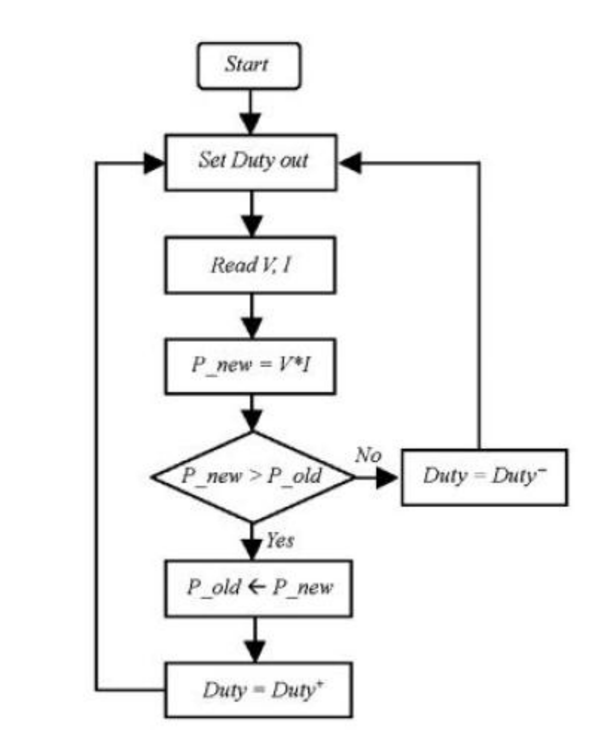
A DC-DC boost converter is used to bring the voltage of the solar array, 12V maximum, to the voltage of the batteries, 24V, in order to act as a dual source during operation of the solar vehicle, and to charge the batteries when the vehicle is not in use. The Boost converter is realized using a power MOSFET and is controlled by the PWM from the microcontroller

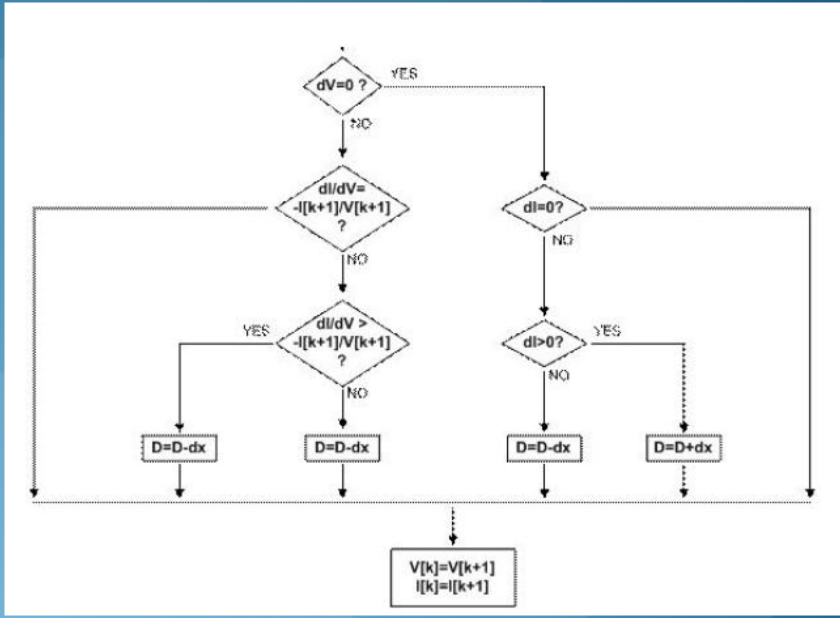
Thierry Kayiranga

MPPT Algorithm

Observe & Perturb

periodically perturbs and compares the terminal voltage to its previous value





Incremental Conductance

compares the derivative of the power curve with respect to voltage to zero.

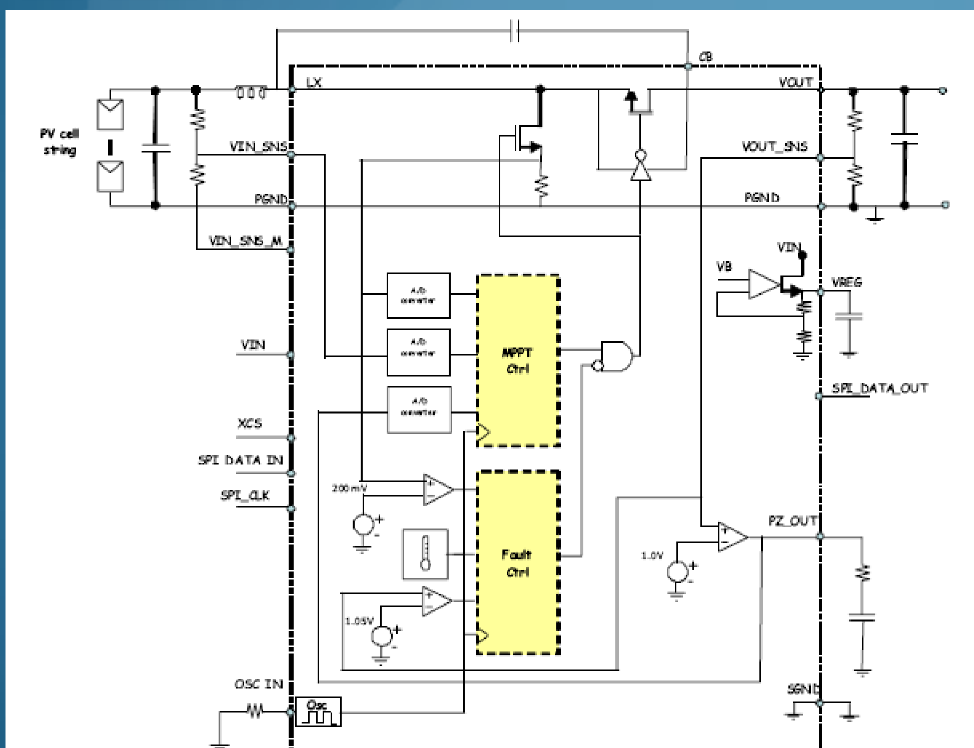
Thierry Kayiranga

Boost Converters

SPV1020

The monolithic 4-phase interleaved DC-DC boost converter from ST Microelectronics is designed to maximize the power generated by photovoltaic panels independent of temperature and amount of solar radiation.

Advantage: Built-in MPPT algorithm. Type: Perturb and Observe.



$$\frac{R1}{R2} = \frac{V_{inmax}}{1.25} - 1$$

$$\frac{R3}{R4} = \frac{V_{outmax}}{1.02} - 1$$

Thierry Kayiranga

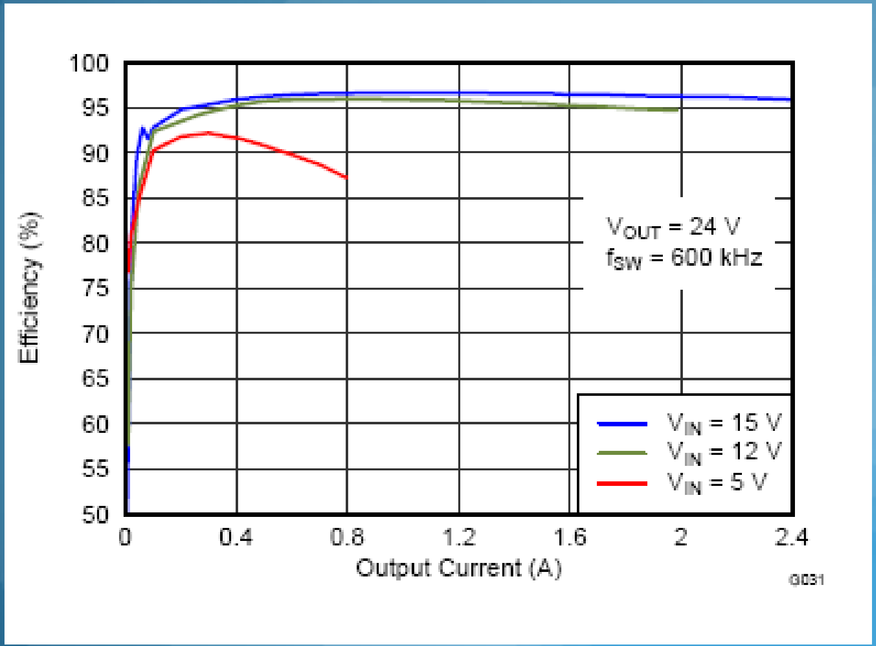
Boost Converters

TPS55340, TPS61170, LMR64010, LMR62014

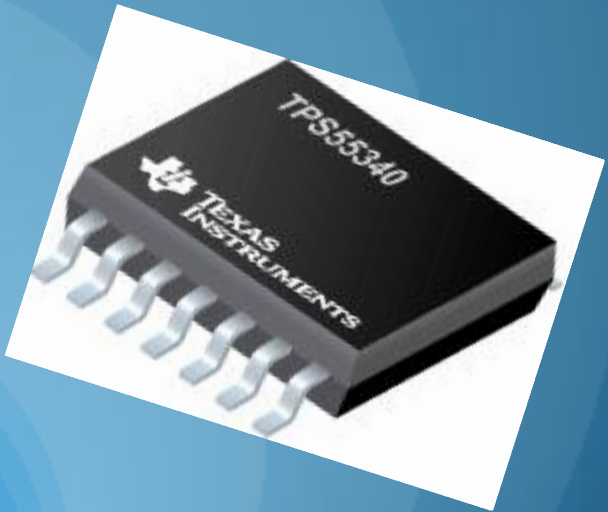
Provided by Texas instruments, these boost converters are good for the design and only differ and output voltage capabilities.

Advantages: Very high efficiency > 93% , over-current protection, under-voltage lockout, thermal shutdown, and soft-start programming.

Disadvantage from SPV1020: Not built-in algorithm



TPS55340 Curve

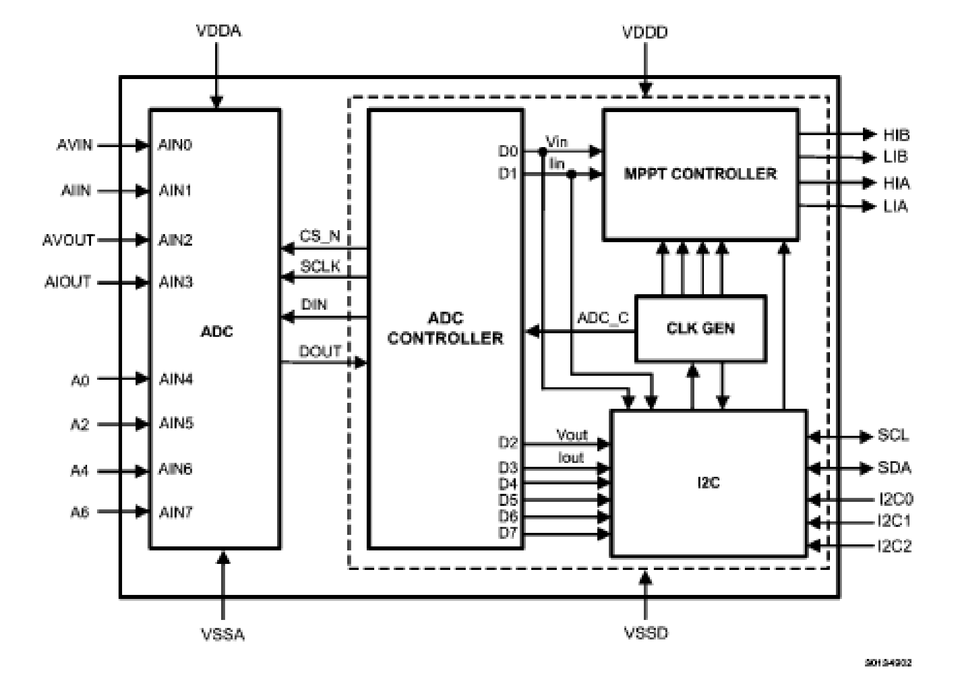


Thierry Kayiranga

MPPT Controller: 2M7442

A Programmable Maximum Power Point Tracker Controller from Texas Instruments, this chip is capable of controlling up to four PWM channels for basic converter and creates a solution for an MPPT configured DC-DC converter with efficiencies up to 99.5%. This controller is also specially made for PV.

Note: Accompanies the TPS55340, TPS61170, LMR64010, and LMR62014



Thierry Kayiranga

Risks:

Technical

- Development/Testing of PCB layout
- Pin assignments

Budget

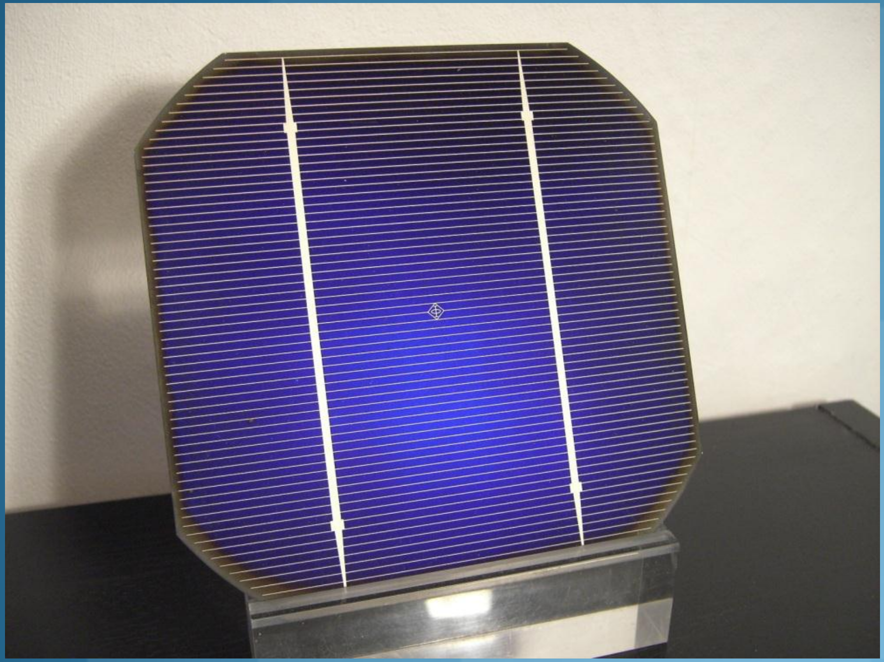
- SPV1020: None
- TPS55340, TPS61170, LMR64010, LMR62014: None
- 2M72442 (MPPT Controller) : None

Schedule

- 2M72442 (MPPT Controller) : without this component the vehicle will not be able to use solar energy.
- PCB manufacturing/ordering

Ahmad Farhat

125x125 Mono-Cystalline Solar Cells



Parameters

•Voltage (oc): 0.6 V

•Current (sc): 6.8 A

Rated Operation

•Voltage Rating: 0.53 V

•Current Rating: 5.2 A

Module Size

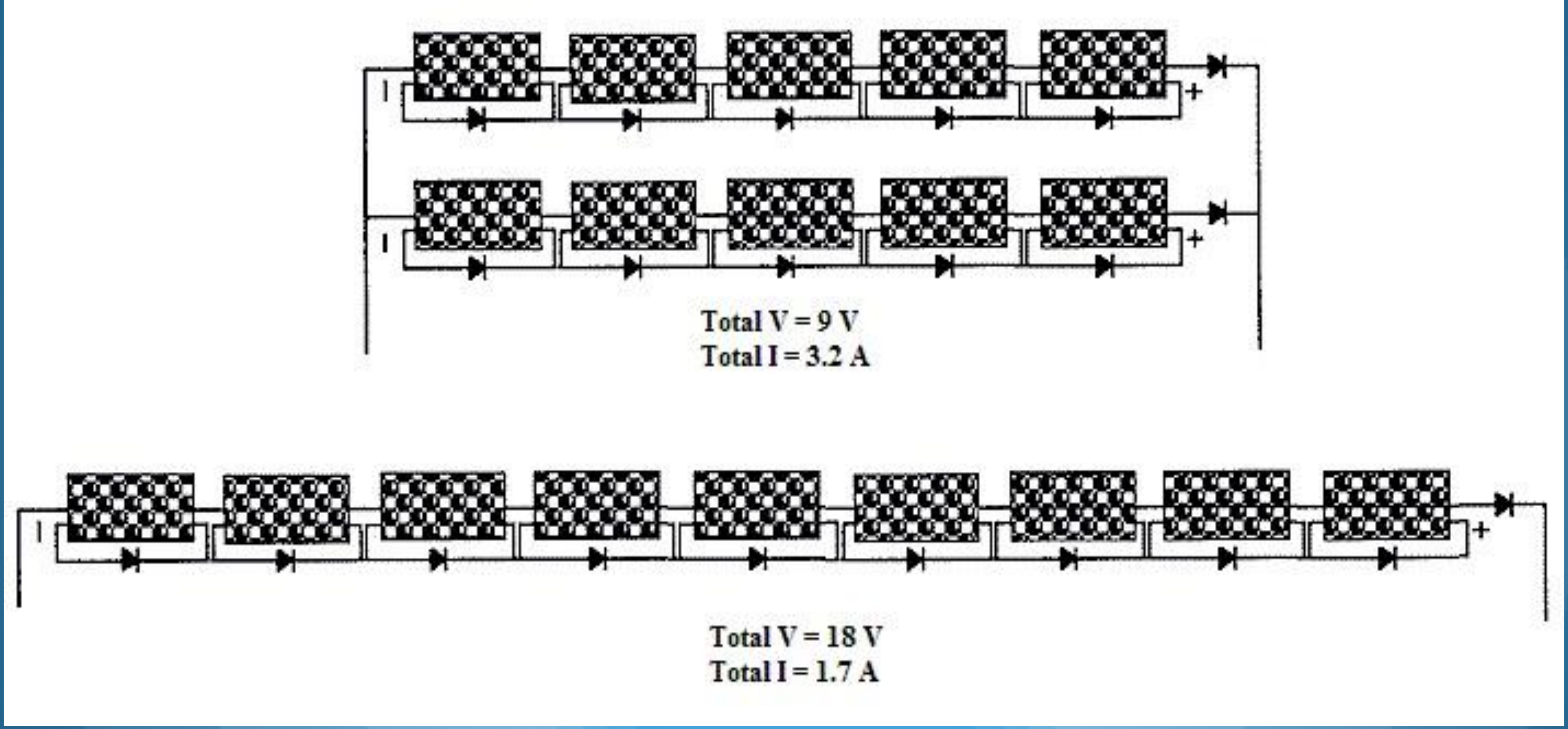
•Format: 125 x 125 mm

•Diameter: 150mm (Round Chamfers)

Weight: 6.7g

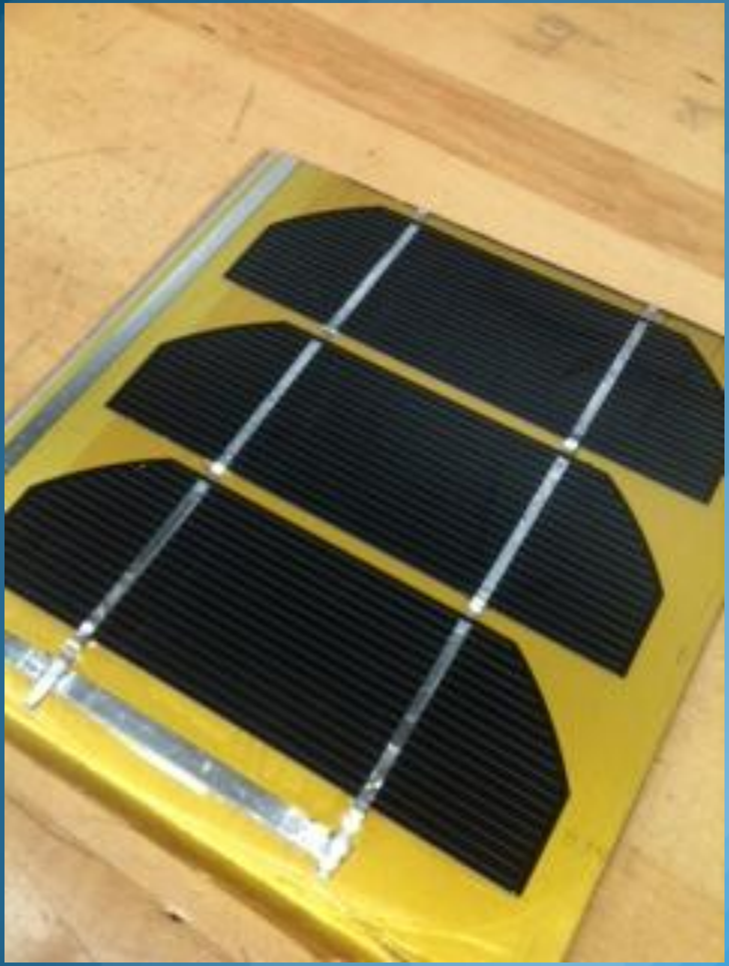
Ahmad Farhat

Module Connection Design Circuit Diagram



Ahmad Farhat

Solar Cells Final Specification



Cut each Cell into 3 parts

Final Module Specification

- Voltage (oc): 1.80 V
- Current (sc): 2.27 A
- Rated Operation
- Voltage Rating: 1.59 V
- Current Rating: 1.73 A

Ahmad Farhat

Protection Circuit

Solar Junction Box Specifications

Electrical Features

Current for PV Module: 7A
Rated Voltage: DC 1000V
Power Capacity: 40-50W Solar panel
Touch Protection Class: Ⅱ

Mechanical Features

Temperature Range: -40°C ~ 85°C
Diodes Details: 1pcs
Number of terminals: 3 rails
Wire Size: 1.5mm2__ 4mm2 or2.5mm2__ 4mm2
Contact Resistance: <5 Ohm
Protection Degree: IP65
Flame Class: UL94-V0

Ahmad Farhat

Risks:

Technical

- Wrong encapsulation process which will increase the chance of air bubbles that will effect the cells performance.
- Current flowing back into the solar module, and the partial shading of the solar cells.

Schedule

- Delays in the Solar Junction Box delivery.
- Delays in the modules manufacturing and encapsulation process.
- Damaging existing cells and modules after the manufacturing and encapsulation process.

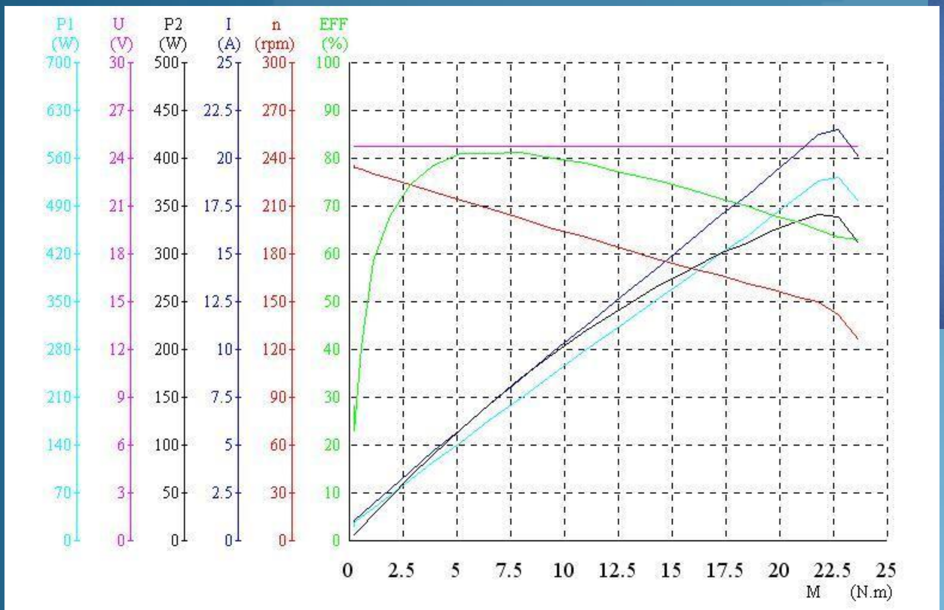
Matthew Bosworth

Motor Specifications and Selection

Matthew Bosworth

Motor Selection: ONHIS MOTOR

Brushless Hub Motor 24V 500W for Front Wheel



Description	U (V)	I (A)	P1 (W)	M (N.m)	n (rpm)	P2 (W)	Eff (%)
No Load	24.73	0.847	20.96	0.24	235.5	5.91	28.2
Max Efficient	24.74	8.408	208.0	7.99	201.8	168.8	81.1
Max Output Power	24.74	21.23	525.3	21.82	149.3	341.0	64.9
Max Torque	24.69	20.06	495.4	23.69	125.5	311.2	62.8
END	24.69	20.06	495.4	23.69	125.5	311.2	62.8

24"-26" Rear Wheel

- Aluminum AA 6061
- Double Wall
- 12 gauge Steel Spokes
- 7.5-8.1 kg Total Wt.
- Cable length 1.8 m

201.8 rpm = ~15 mph

149.3 rpm = ~12 mph

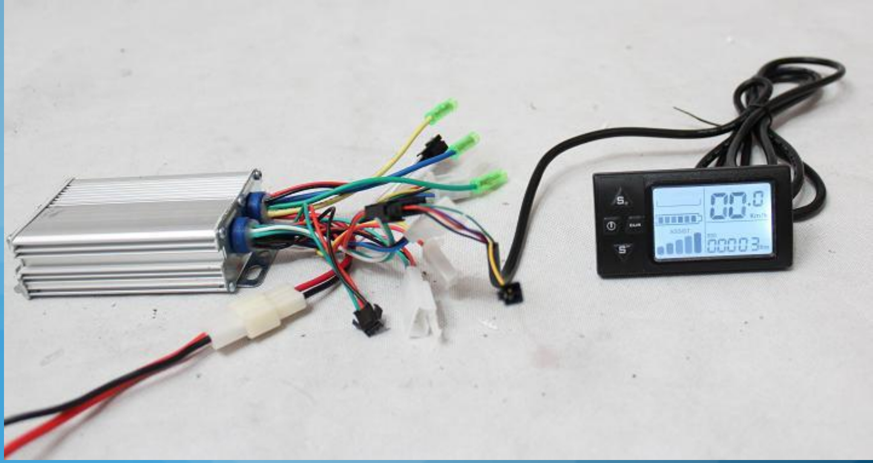
Matthew Bosworth

Motor Controller Selection:

24V 500W New Controller+24V New LCD Display:

LCD Panel Size: 86*45*15.5mm
LCD Display Size: 2.3"

Functions:
(1). Lamp control
(2). Power Gauge
(3). 5-speed level PAS (Off, 60%, 70%, 80%, 90%, 100%)
(4). Speed Display and Setting (current speed, max speed, average speed)
(5). Trip Range
(6). Failure tips



Connections:
Red Wire: Power supply positive pole +
Black Wire: Power supply negative pole -
Blue Wire: Controller electric key lock wire
Yellow Wire: Lamp control
Green Wire: Data receive
White Wire: Data send

Matthew Bosworth

Risks:

Technical

- Proper wiring of entire energy system
- Programming of motor controller
- Proper connection for throttle and brake pedals

Schedule

- Delays in the Motor/Motor Controller Delivery
- Setting up a testing scenario for the motor system

Matthew Bosworth

Budget

Part	Cost
Chassis Manufacturing	$3000.00
Suspension Manufacturing	$1000.00
Steering Manufacturing	$400.00
Roll Bar Manufacturing	$500.00
Latching/Locking Mechanism	$50.00
Solar Cells/Array Manufacturing	0
Solar Junction Box (x2)	$25.00
Boost Converter*	0
MPPT Controller*	0
Battery System w/ BMS	$550.00
Turnigy Meter/Analyzer	$50.00
Hub Motor/Wheel	$135.00
Motor Controller	$80.00
Throttle/Brake Pedal (x2)	$138.00
Total	$5928.00

Questions?