

FAMU-FSU 2012 Solar Car Operations Manual

Senior Design Operations Manual – April 2012

By

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Startup / Run procedure:

Disclaimer: It is very important that the user of the vehicle not make contact with any but the mentioned electrical components. While the electrical components are all isolated from the user and covered by various insulations, it is still possible to come into contact with potential lethal amounts of current. The designer and builders of this car have taken great measures to ensure this will not happen, but nothing is fool proof. This being said, no changes should be made to the system without training in electrical safety and a thorough understanding of the overall system.

The following include the steps that should be undertaken to begin driving the vehicle. Only one person may occupy the vehicle at any given time, hence the reason there is only one seat, however it should be noted that at least three individuals will be required to ensure safest operation of the vehicle.

1. Place blocks or stops in front and behind one of the wheels to ensure the vehicle does not move while interacting with the bottom shell.
2. Un-latch and lift the top carbon fiber shell from the vehicle and secure the top with the mounted poles in the vehicle.
3. Ensure that the main contactor is in the off position before touching any of the components in the vehicle.
4. Once the contactor is off, verify that all wires appear to be securely connected and there are no extraneous or unplugged wires floating around in the bottom shell.
5. Ensure that the vehicle is free of all debris that could potentially get caught in moving parts or short circuit electrical elements.
6. One individual may take a seat in the vehicle and should buckle themselves into 5-point seat belt. The seat and Seat belt can be seen in the Figure below.



Figure 1 - Driver seat with 5-Point harness connected

7. Place the large three position switch located in the middle of the control panel (Switch 3) on the right of the driver to the middle position or neutral position



Figure 2 - Control Panel (from left to right switches are number 1-5 respectively)

8. Once the driver is securely fastened into the seat one another individual may flip the main contactor switch, at this point the power is active in the system and nothing else should be touched without specific direction.
9. The driver should now flip the far left switch (switch 1) to the up position for pre charging. Charging should take approximately 10 seconds(can be seen on test-board for safer starting)
10. Once the vehicle is pre-charged the driver can now switch the red switch (Switch 2) to the up position which flips the main relay and provides full battery voltage to the motor controller
11. Once the sound of the main relay is heard the far left switch (Switch 1) can be flipped to the down position. (This powers on the microcontroller for operation.)
12. The two other individuals can then carefully lower the top shell onto the bottom shell, ensuring that the top shell is latched to the bottom of the shell.
13. Once secure the wheel stops can be removed from around the tires.
14. The driver can use the middle switch(switch 3) to switch from forward operation to reverse operation by switching the middle switch up and down respectively
15. The driver can now use the throttle, braking, and steering to navigate to any desired location. The operation of the vehicle is similar to any commercial car and should be driven using the same road safety protocols.

16. While on operation the driver can flip the switches on the far right (Switches 4 and 5) to charge the vehicle while in motion. The green switches is the 12V power for the MPPT and Boost converter, the black switch is the power enable for the solar array.
17. Once the operation of the vehicle has stopped the wheel stops should be placed around the vehicles wheels.
18. The Forward/Reverse switch should be placed into the neutral or middle position.
19. Once wheels are secure the vehicle can be unlatched and lifted so the driver can exit
20. Once the driver exits the vehicle the all switches should be placed into the off position except the far left switch (Switch 1 should be left in the up or pre-charge mode to discharge the motor controller for safe operation.
21. DO NOT close the top of the vehicle until latch insert is in place, once in place the lid is free to close without an operator in the vehicle.

TO CHARGE THE BATTERIES

1. Make sure the main contractor is flipped to the on position.
 2. Flip both the far right switches (Switches 4 and 5) The green switches is the 12V power for the MPPT and Boost converter, the black switch is the power enable for the solar array.
 3. Monitor the solar output and Boost converter output using the test panel on the vehicle.
 4. Once charged flip the two switches down into the off position
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Operational Description

Upon entering the “cockpit,” the driver should execute a startup procedure to bring the car into a drivable state. The driver uses a forward/reverse switch to choose the longitudinal direction of the vehicle and the steering wheel to control the latitudinal direction, one pedal on the right of the cockpit floor to control acceleration and another on the left to control braking. There will also be a kill switch within reach of the driver that will remove power from all of the electrical systems. All other systems are automated, but should report their state to the driver where applicable.

Testing Environment

The solar car shall be able to operate in standard North American climates. The car is able to withstand normal wear and tear with seasonal changes that a commercial automobile would encounter in this area. The car is resistant to rain, dust, debris, etc. The cars electronics are

protected and able to operate in wet humid conditions as well as dry hot environments. The car will not be built to operate in extreme conditions such as mountainous terrain or heavy snowfall; however the car can handle up to a 12 percent grade, which can be found on residential roads.

The vehicles current progress in meeting all testing environment requirements is 90 % completed. It was not this phase of the projects objective to meet all environmental requirements but was considered in all decisions made. This year’s team has determined that future teams must complete three tasks to make the vehicle completely resistant to all environments. The first task is to add a final protective layer over the entire top of the solar array. The next task would be to add a top lip that circumferences the vehicle at its joint, preventing water and debris from entering the vehicle from the top. The third task next year’s team could complete is adding wheel wells in the vehicle to stop road debris and water from entering from the bottom of the vehicle.

Functional Diagram

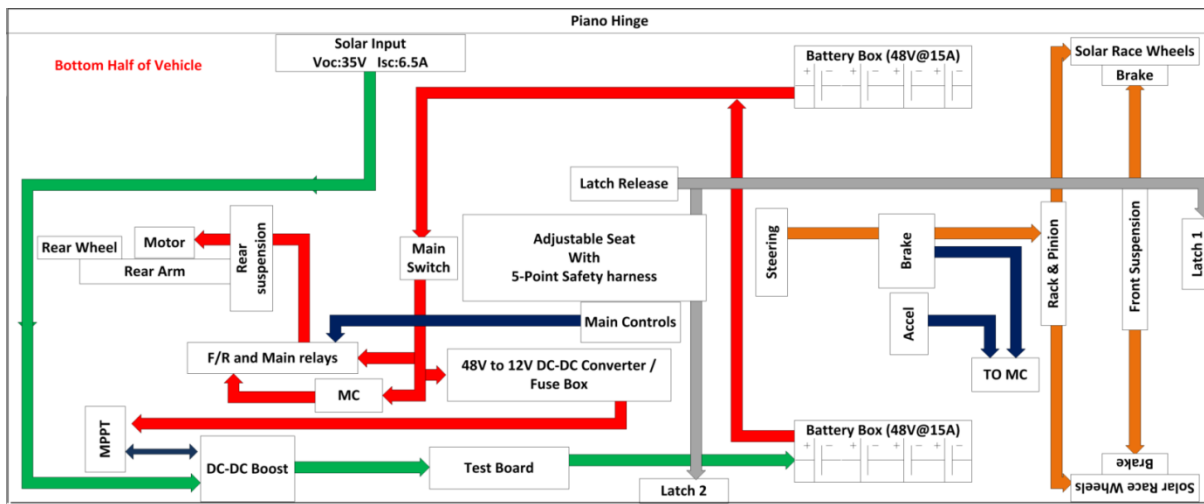


Figure 3 - Top Level Functional Diagram

Motor and Motor Controller Operation

The motor in this vehicle is a Lynch Motor Company model LEM200-127 DC brushed motor and the Kelly Controller KDZ48201. The motor (LEM200-127) is a 48 volt rated motor. The rated efficiency of the Lemco motor is 88% at peak efficiency. However, this is a moot number because we will never be providing the motor enough current to reach the peak efficiency of the motor. This motor is rated at 215 amps and in peak conditions, our system will

only be able to output 15-20 amps during normal operating conditions and 30 amps maximum at startup. The vehicle is capable at traveling at between 35 and 40 mph at this amperage. The motor is mounted to the rear suspension and connected to the rear wheel via belt drive with a 3:1 gear ratio for maximum torque at startup.

The motor controller chosen was the Kelly Motor Controller (KDZ48201) with an input of 48V. The Kelly Motor Controller was chosen not only for its compatibility with the LEM200-127 motor but also because of its ability to utilize regenerative braking. In normal operation when the pre-charge is initiated, one should see a red light on the motor controller. When the power relay is switched one should still see a red light on the motor controller until the motor controller is switched to the on position on the control panel. To avoid giving the motor controller an excess amount of current upon start up, the engineers have designed a pre-charge circuit consisting of a large resistor that prevents the motor controller from receiving an excess amount of current. Please note that this is a vital component as delivering too much current to the motor controller upon start-up can damage the motor controller. The motor controller reads the potentiometers in the foot pedals at a voltage range from 0-5V and infers how much voltage to provide the motor. The brake pedal works the same way with an exception. The brake pedal has a switch installed on it and when the pedal is pressed, a circuit is closed that tells the motor controller to use the motor as a generator by converting the mechanical energy of the rotor into electrical energy in the stator.



Figure 3 - Left: LEM200-127 DC brushed motor. Right: Kelly controller KDZ48201

Solar Array

The solar array is mounted to the upper surface of the vehicle and wired beneath the shell with by-pass and protection diodes. The modules were mounted with spray adhesive and solar mounting tape. Each tab of the modules has been color coded, green, yellow, red, and black wires for ease of installation and replacement. There are 31 parallel-paired modules in the array string, supplying 30.8 rated volts at 2.5 rated amps. The solar car utilizes the PT15-300 solar module with a voltage rating of 15.4V and 200mA rated current. 62 modules use a total of 4.5m² of solar cells. The modules are paired up to make panels and parallel stringed to deliver 191W of rated power. The solar panels consisting of two modules each share a printed circuit board consisting of three diodes. The diodes were chosen to provide protection to the solar array and were sized accordingly. Two diodes will be used to solve partial shading and loss of delivered power and the third diode will serve as a protection diode for the unwanted flow of current back into the modules.

Batteries

The motor was picked to run on a 48V battery system using Thunder Sky LiFePO₄ Power Batteries. This decision was the best choice not only because it was the easiest to implement but at 48V the team could split the batteries and supply 30A which with the 4 to 1

gear ratio chosen could give more than enough torque to overcome the stall torque needed to propel the vehicle in a given direction.



Figure 14 - Thunder Sky LiFePO4 Power Batteries

Maximum Power Point Tracker / Boost Converter

Boost Converter Topology

The boost converter is used to bring the voltage of the solar array (32.4 V nominal) up to the voltage of the batteries (48 V nominal) 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. Figure 15 illustrates a typical boost converter circuit topology, including a DC input, an inductor, a switch, a diode, a capacitor, and a load. The boost converter and controller are always connected to the battery terminals through the output of the boost converter. The input of the boost converter, which is the solar panel output, can be switched on and off via the switch labeled 'solar' on the control cluster. The solar switch is the bottom right switch on the control cluster board. The microcontroller can be turned on or off through another switch in the control cluster labeled, 'MPPT'. The MPPT switch is directly to the left of the 'solar' switch. The boost converter and

microcontroller may be removed by disconnecting the quick connect terminals on the solar power, battery, and 12V supply wires.

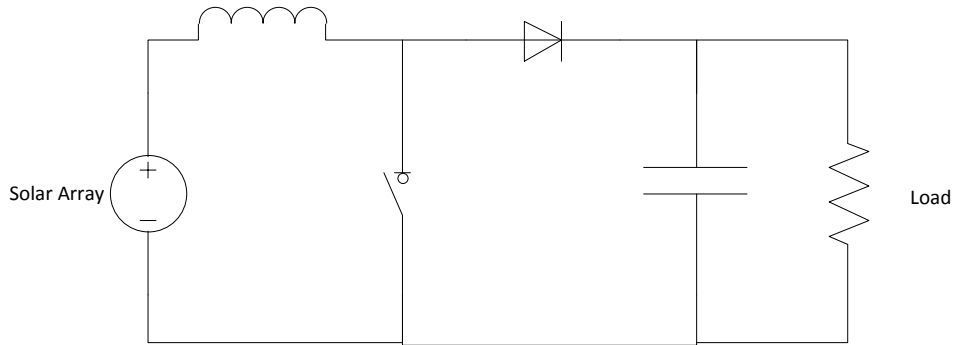


Figure 15 – Boost Converter topology.

The Boost converter was realized using a 1.8 mH inductor, rated at 15 amps with a core saturation rating of 10 amps; a NTE2394 power mosfet, rated at 100 Volts and 10 amps; a 10SQ080 diode, rated at 10 amps; a 1.5 mF capacitor, rated at 250 volts with a ripple current rating of 4 amps peak to peak. All electronic parts but the power mosfet were purchased through Digikey, while the mosfet was purchased through Allied Electronics. Datasheets for individual components can be found on the team’s website (link is provided in the reference section), and part numbers are shown below in Table 1.

Table 1 – Component Part Numbers

Part	Manufacturer	Manufacturer Part #	Vendor	Vendor Part #
1.8 mH Inductor	Bournes Inc.	5723-R3	Digikey	M8727-ND
1.5 mF Capacitor	Panasonic-ECG	EET-UQ2C152JA	Digikey	P13774-ND
Diode	HY Electronic	10SQ080	Digikey	-

Power Mosfet	Corp. NTE	NTE2394	Allied Electronics	70215907
Current Transducer	CUI Inc.	SCD10PUN	Digikey	102-1052- ND
Microcontroller	Arduino	Uno	Radioshack	-

The boost converter is controlled by the PWM from an Arduino Uno microcontroller, which also reads the voltage of the panels using a simple voltage divider, with a maximum loss of 25 mW, and the current of the panels using a current transducer which provides a maximum of 3.3 V output when reading 10 amps. The arduino board is powered by the 12 Volt auxiliary that was made available during the design of the electrical system of the Solar Car. The wiring diagram of the boost converter and the Arduino Uno is seen in Figure 16.

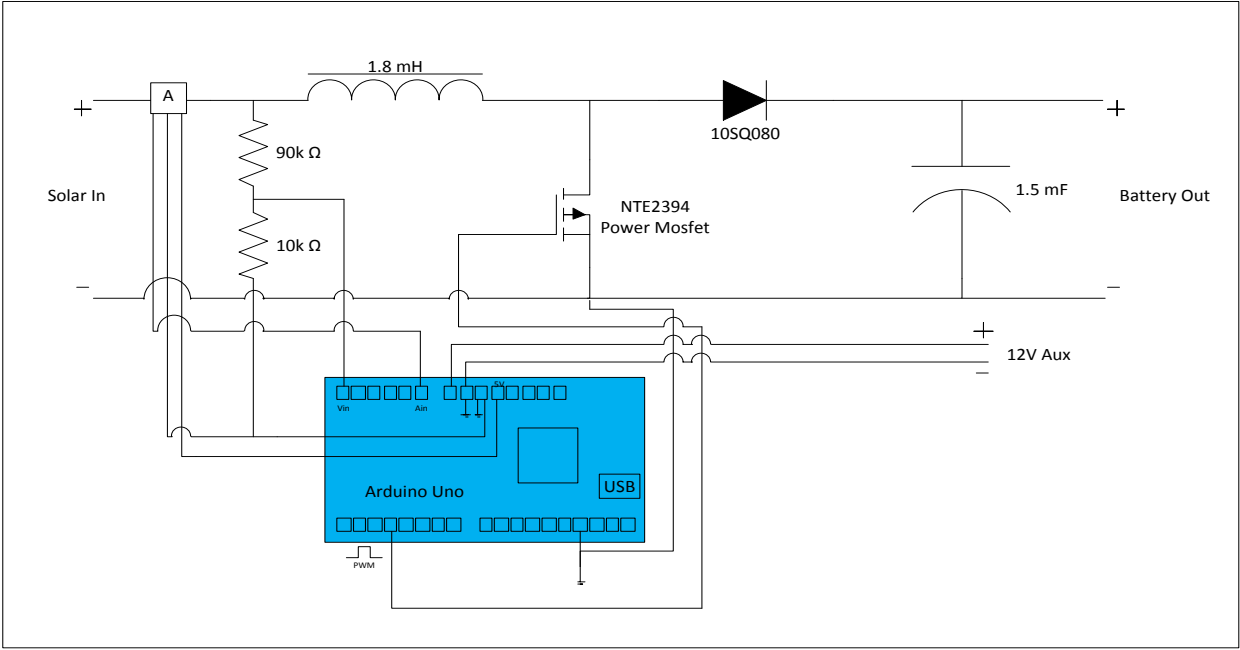


Figure 16- Wiring diagram of boost converter and Arduino Uno.

The Arduino board utilizes a simple perturb and disturb algorithm that calculates the current power output of the panels and compares it to the previous power output. If the current output is the same or lower than the previous output the duty cycle is lowered by approximately 1%, if the current output is higher the duty cycle is increased. This cycle closed loop and requires no input from the driver in order to function.

Figure 17 provides a picture of the final construction of the boost converter and controller. The components were placed onto a prototyping board and standoffs were used to mount the Arduino Uno and the boost converter to a non-conductive base board. All of the components were housed within an aluminum casing complete with cooling fans which are powered by the 12 Volt auxiliary power from the electrical system. The USB connection of the Arduino Uno has been extended to the test board at the side of the vehicle so that the Arduino can be reprogrammed without opening the housing of the converter.

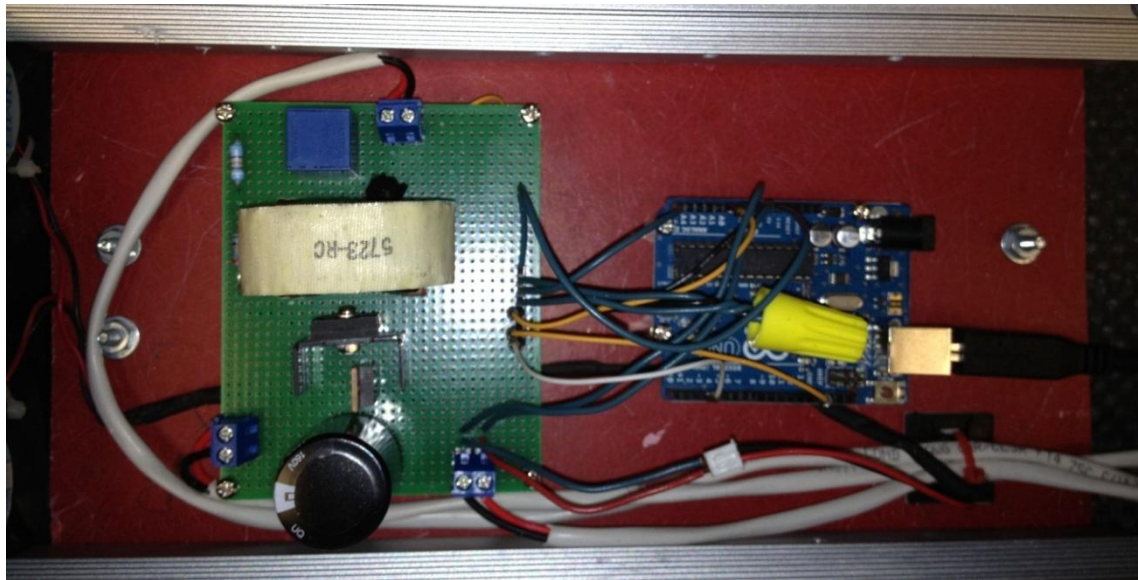


Figure 17 - Final construction of boost converter and controller

Hood Scoop

Basic Functionality

The hood scoop is mounted on the top half of the car in the space left between solar panels. While the car is in motion, the hood scoop allows for approximately 0.2 kg/s mass air flow to enter the cabin. This type of ventilation allows for the system to operate without drawing any power from the electrical system and without driver assistance. The scoop only requires that the mesh grill be checked for debris before operation.

Functional Diagram

The functional diagram below gives an overview of how the hood scoop is implemented onto the rest of the car. As seen below, the hood scoop is attached directly onto the carbon fiber top using brackets and is not reliant on any other part of the system.

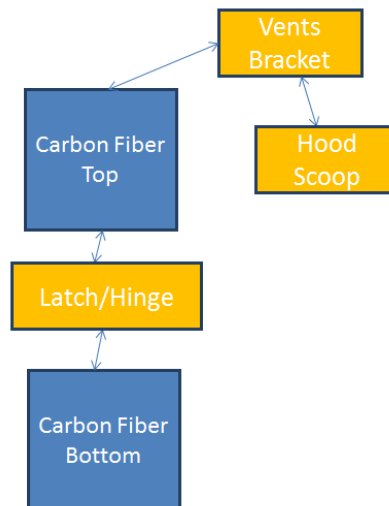


Figure 48: Functional diagram of hood scoop

Major Components

- Pilot Automotive Pro Street hood scoop
 - o Part Number: CZ-288B
 - o Cost: \$35.99
- 3M tape (1/4in x 18 in)
- M6 bolts (x2)

Instructions of Assembly

The hood scoop is one solid piece and does not require assembly. It was mounted onto the car by drilling two holes on each front corner of the scoop and tightening on the underside of the car lid. There is 3M tape surrounding each edge of the hood scoop, giving additional support and providing a seal.

Safety Information

The mesh screen of the hood scoop requires periodic checking to remove all, if any, debris that could become lodged inside the mesh. This is to ensure the maximum possible air flow into the cabin and to keep temperatures at a reasonable level.

Driver Enclosure

Basic Functionality

The driver enclosure serves multiple purposes. Since the car sits very low to the ground, it allows for protection of the driver and cabin from debris that may kick up into the cockpit. The Plexiglas material is also tinted to block sunlight. The enclosure also serves to increase the aerodynamic profile of the solar car and reduce overall drag.

Major Components

- Plexiglas bubble (custom)
- Base (custom)
 - o Cost: \$215.00
- 2x4 wood 30in. (x2)
- 2x4 wood 24 in.
- 2x4 wood 20in.

Instructions of Assembly

- Screw wood frame together to fit the bubble cutout on the body using wood screws.
- Attach bubble to wood frame using wood screws.
- Attach enclosure to body of car using M6 bolts.
- Use solar mounting tape to create a seal around the wood platform.

Safety Information

The enclosure is made of a shatter resistant Plexiglas material; however it still needs to be checked periodically for cracks. The base of the enclosure must be checked to ensure that no bolts are coming loose, and that the platform is securing mounting to the body of the car.

Latch & Hinge

Basic Functionality

Because the body of the car was cut in two halves, it was necessary to attach the top to the body to increase the stability of the car during operation. Previously, the top of the car sat inside a very small lip with no secure fastening. By using 4ft. piano hinges and double-point remote-release cable latch, the car is now one solid piece and is able to be opened up to allow the driver to enter and exit the vehicle, and so the components inside the car can be modified without having to remove the lid entirely. Due to the inaccurate cutting of the carbon fiber body, the car rim has jagged edges and the lid does not have a flat spot to rest on the bottom. Therefore, L-bracket rails were implemented along certain parts of the rim to allow the lid to sit flush with the bottom.

Major Components

- Double-point remote-release cable latch (x1)
 - o Strike plate (x2)
 - o Latch actuator handle (x1)
- 8ft L-shape rails (x6)
- 4ft piano hinge (x2)

Instructions of Assembly

- Cut the 8ft L-shape rails into 4ft sections, leaving one 8ft piece intact.
 - o Cut one L-shape rail into two 2ft sections for the front of the car.
- Mount L-shape rails on top and bottom of car.
 - o Front and back have one 4ft piece centered with the 2ft rails in the front spaced evenly, leaving a 4in. gap for the latch.
 - o Each side has 4ft rails spaced evenly with the single 8ft rail on the top centered over the bottom where the side latch is located.
 - o Mount strike plates and latches in gaps between L-shape rails. Be sure to align the strike plates and latches for full contact.

Assembly on Vehicle

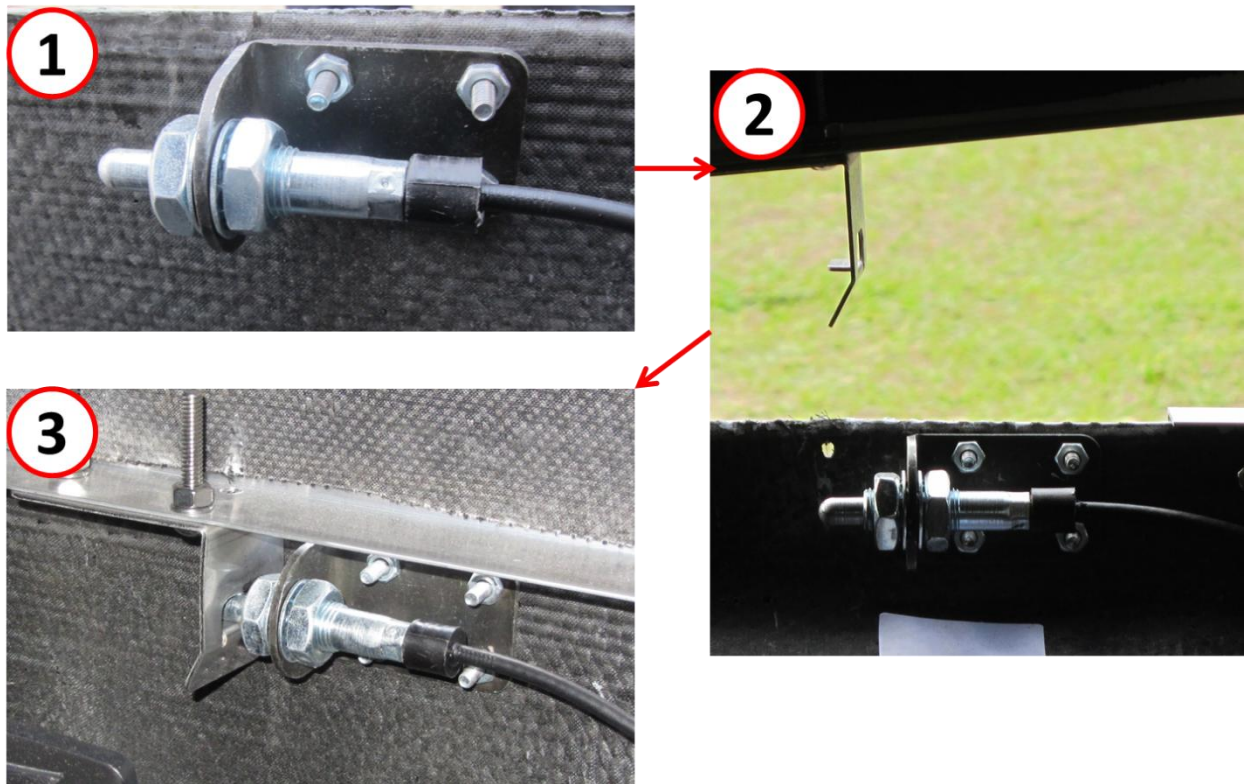


Figure 19: Latch assembly and operation



"Latched" position

T-handle with insert to keep in "unlatched" position

Figure 20: Latch T-handle assembly and operation

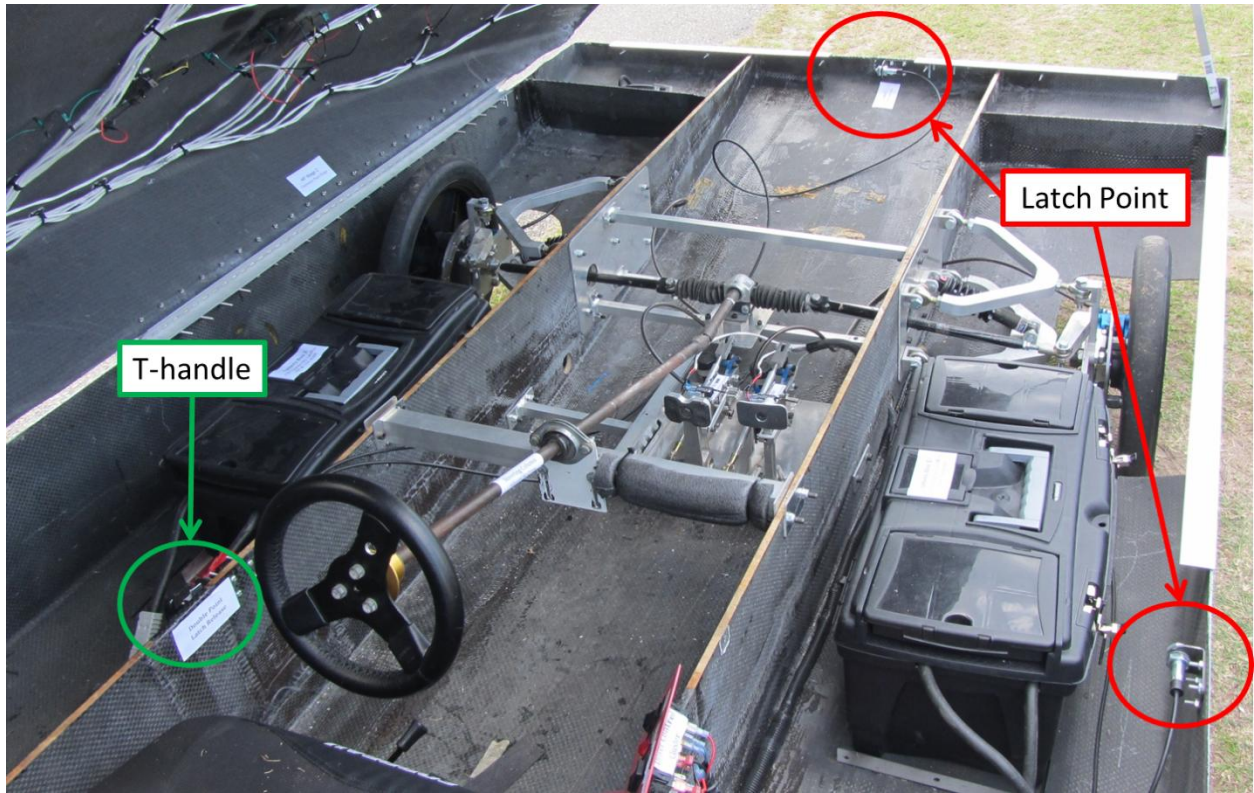


Figure 21: Latch placement



Figure 22: Hinge placement

Safety Information

Because the hinges are mounted to keep the two parts of the body together, the bolts used to mount them need to constantly be checked to ensure all are tightened. If these were to come loose the top half could shift while driving, injuring the driver or damaging electronics. The L-shape rails are what allow the unevenly cut body to sit flush and let the latch fully engage.

Rear Suspension

Basic Functionality

The basic functionality of the rear arm and suspension is to stabilize the vehicle while holding the motor that propels the car.

Assembled View

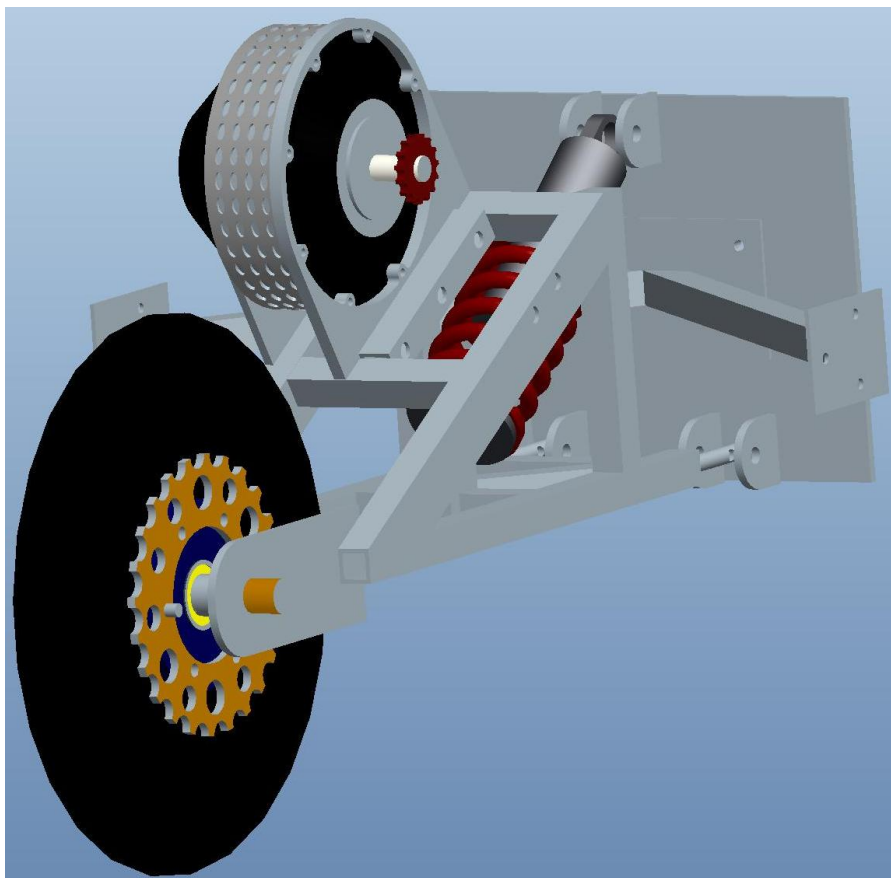


Figure 23: Pro/E of assembled rear suspension.



Figure 24: Assembled view of rear arm, suspension, and motor mount on car.

Functional Diagram

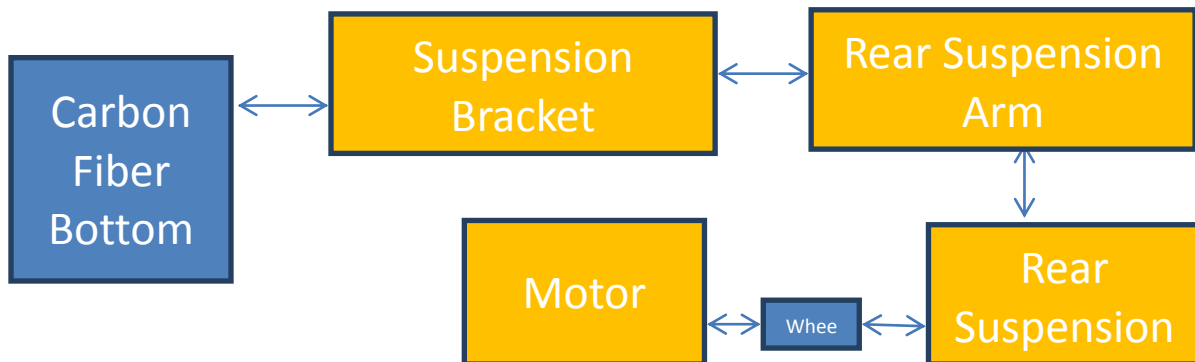


Figure 25: Motor and Rear Suspension

Major Components

- Back plate- 11" x 14" x 1/4" thick plate with inserts welded on for attachment points for arm and shock
 - o Cost: \$83.92
- Arm- 1" x 1" Aluminum tubing and welded together.
 - o Cost: \$27.25
- Wheel Hubs- 2 wheel hubs placed on each side of the tire to house the bearings
- Bearings- 2-1" inner diameter bearings.
 - o Part Number: 2780T66
 - o Cost: \$20.26 each
- Shaft- 12L14 Carbon Steel shaft.
 - o Cost: \$11.79
- Motor attachment- 2"x1" Aluminum tubing welded onto the top of the frame of the arm.
 - o Cost: \$24.39
- Motor Bracket- Attaches to motor using M6 x 20 bolts
- V-Bracket- Aluminum tubing welded at an angle to 1/8" thick plates which was used from old design
- Motor Sprocket- 1-15 tooth sprocket attached to motor.
 - o Cost: \$13.33
- Wheel Sprocket- 1-60 sprocket attached to wheel hub.
 - o Cost: \$45.31
- Shock- model # acquired from last year
- Motor- model #-LEM200.
 - o Cost: \$1,800

Instructions of Assembly

1. Bolt back plate to the wood on the car just behind the driver seat
2. Bolt the shock to the arm using aluminum spacer on each side of the shock
 - a. Slide the bolt through one side of the bracket on the arm and place on spacer just before sliding the bolt through the shock
 - b. After sliding the bolt through the shock place a second spacer just before the other bracket and slide the bolt completely through and tighten.
3. Bring the arm and the shock up to the back plate and line up each hole
 - a. Using the same procedure to attach the shock to the arm, begin to slide on bolt through one end of the bracket on the back plate and place one spacer on the bolt.

- b. Slide the bolt through one side of the spherical joint
 - c. Next place another spacer and a washer on the other side of the spherical joint of the arm and slide the bolt completely through and tighten.
4. Do the same procedure for the other side of the arm as done in step 3
 5. Attach the shock to the top of the back plate also using the same procedure as done in step 3 only without the use of the washer after the second spacer.
 6. To place the wheel on the arm line up the holes of the bearings and the holes of the plates.
 7. Slide the threaded end of the shaft all the way through and line up the head of the shaft with the hole on the side of the plate and bolt it to the plate to secure the shaft in place
 8. Finally, use the castle nut to secure the shaft on the threaded side.
 9. Place the motor bracket with the motor attached next to the piece of tubing on the arm and bolt it to the arm. Using washers on each side of the nut and bolt.
 10. Finally, add the chain on to the sprockets attached to the motor and the wheel.

Safety Information

Due to the motor being mounted on the rear suspension, precaution must be taken when working it. The positive and negative wires running to the motor attach at the top and could accidentally be touched and shock the individual. Also, extra support needs to be added to the base plate due to bowing in the wood frame.

References

FAMU-FSU 2011-2012 Solar Car Website:

http://eng.fsu.edu/me/senior_design/2012/team20/