بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

North Lebanon Automotive Systems

ANNUAL REPORT 2023

Electrical Tuk-tuk with solar system and Lithium Batteries including BMS Design

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Abdullah Mourad

Editor: Samir Mourad

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Preface

This report contains details of our implementation of the 2023 NLAS project. The presented project is 4 Wheel E-TRACTUK Electric Tractor based on Tuk-Tuk chassis.

1 Introduction

We have several positive aspects of this project:

1. Mechanically: The tuk-tuk with solar cells has good driving power and is easy to maintain. They were able to achieve more durability after new mechanical modifications. After changing to 4 Wheel tuktuk we have more safety and grip.
2. Electrically: Simply charge the battery and check the battery acid level and it works without motor, heat and noise.
3. Health: Without any pollution, which provides a clean environment.
4. Practically: The transportation is comfortable with more features for your comfort. You have more space for the driver than a traditional tuk-tuk. The way it rotates makes it easier to control as well.

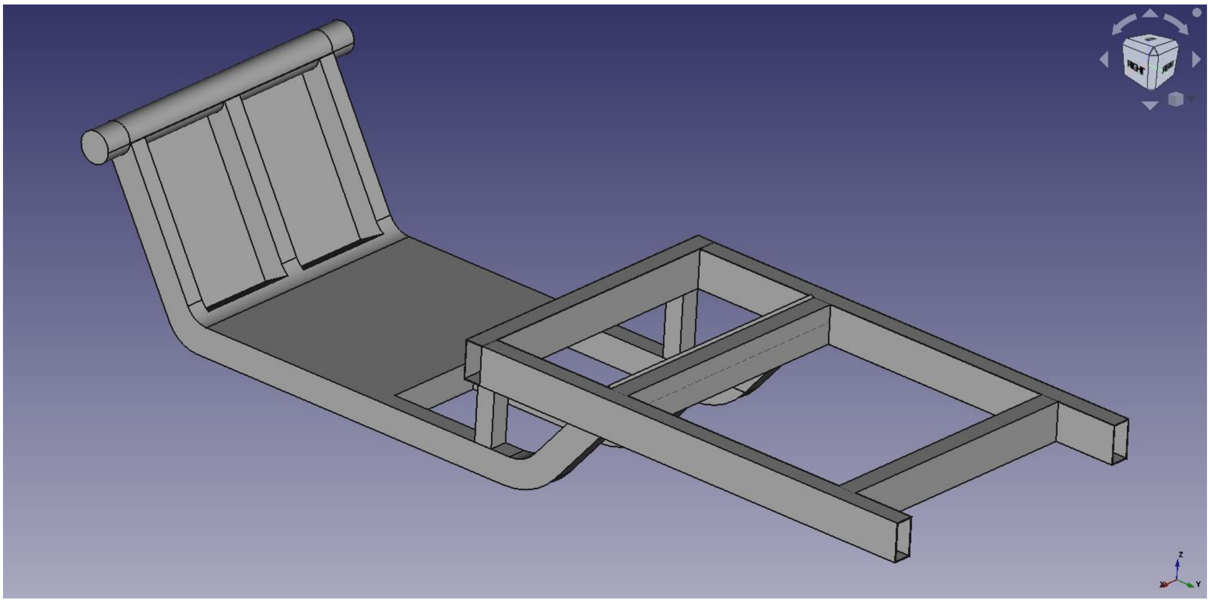
2 System Design

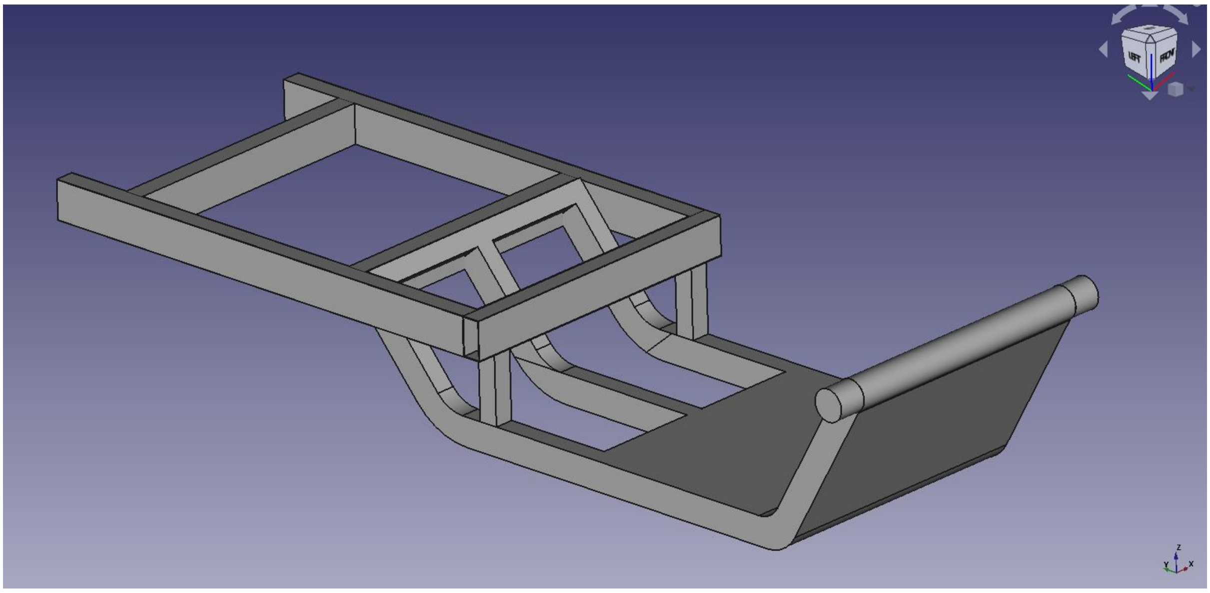
We radically modified the design on the front side, after conducting several experiments on the previous version of Tuk-tuk. We found a problem with balance when driving, and after checking we discovered that it was due to the front wheel. So, we replaced the old one-wheel budget, with a two-wheel budget ATV, with some modifications to fit the Tuk-Tuk chassis.

3 E-Tuktuk Mechanical Design

3.1 Chassis

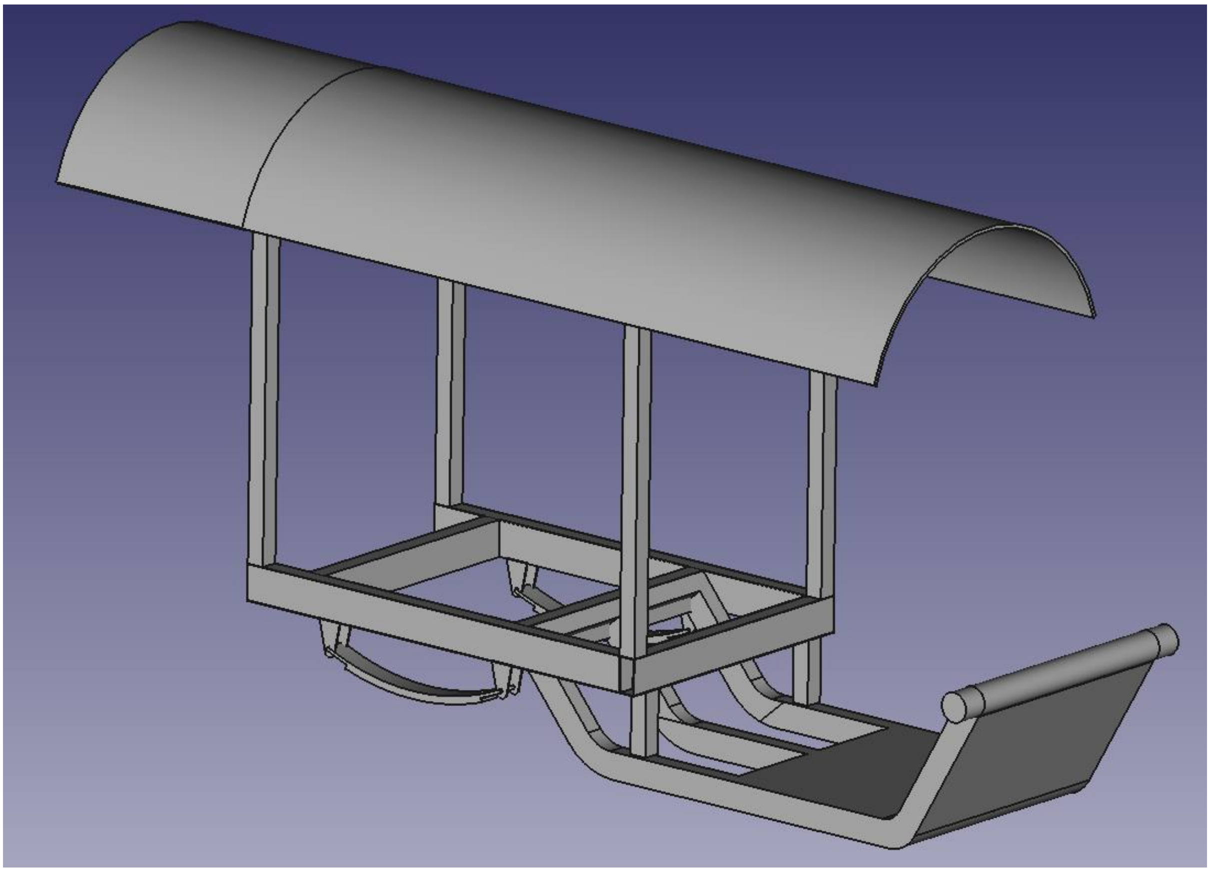
3.1.1 E-TukTuk FreeCAD Drawing





Tbd: Chassis 2D drawings

17-11-2022:



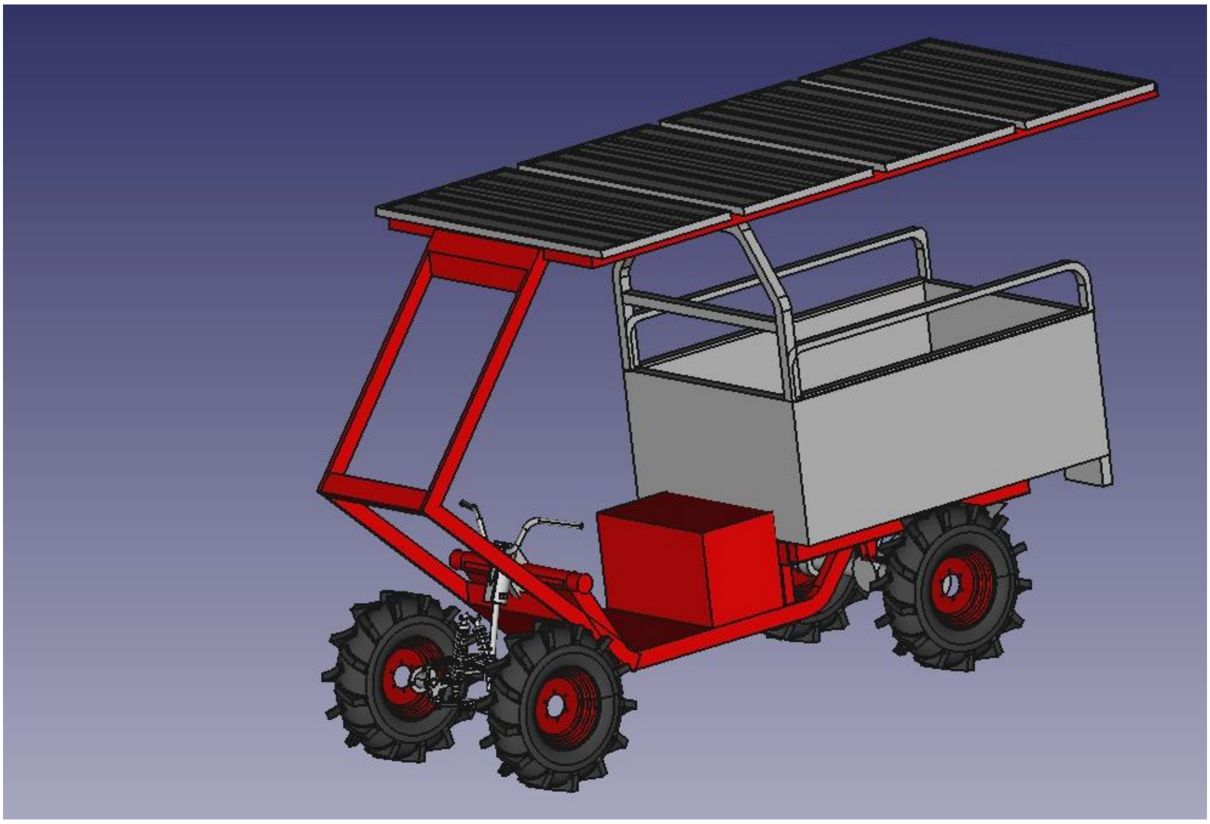
E-TukTuk FreeCAD Drawing
E-TukTuk FreeCAD 24-10-22

17-11-22
E-TukTuk.FCStd

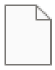
3.1.2 Mechanical Realization

3.2 Chassis design (Oct 2023)

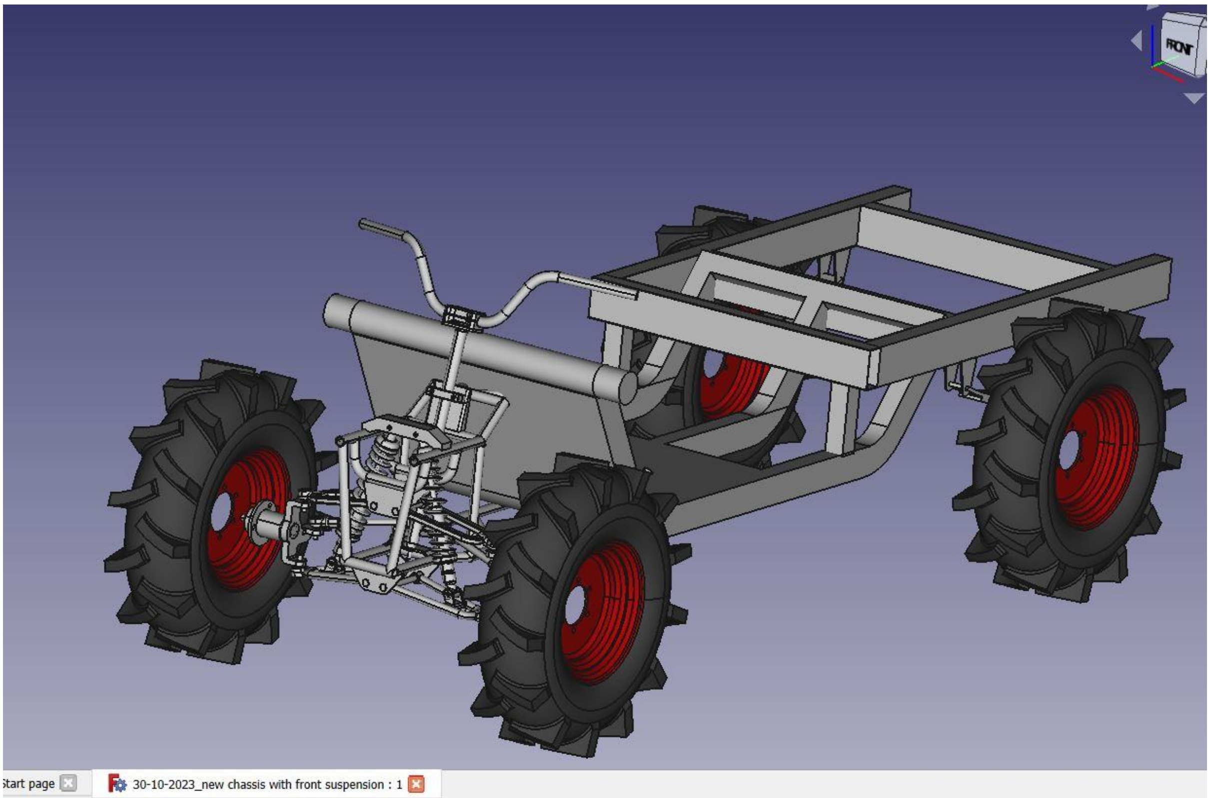
3.2.1 chassis design(oct2023)

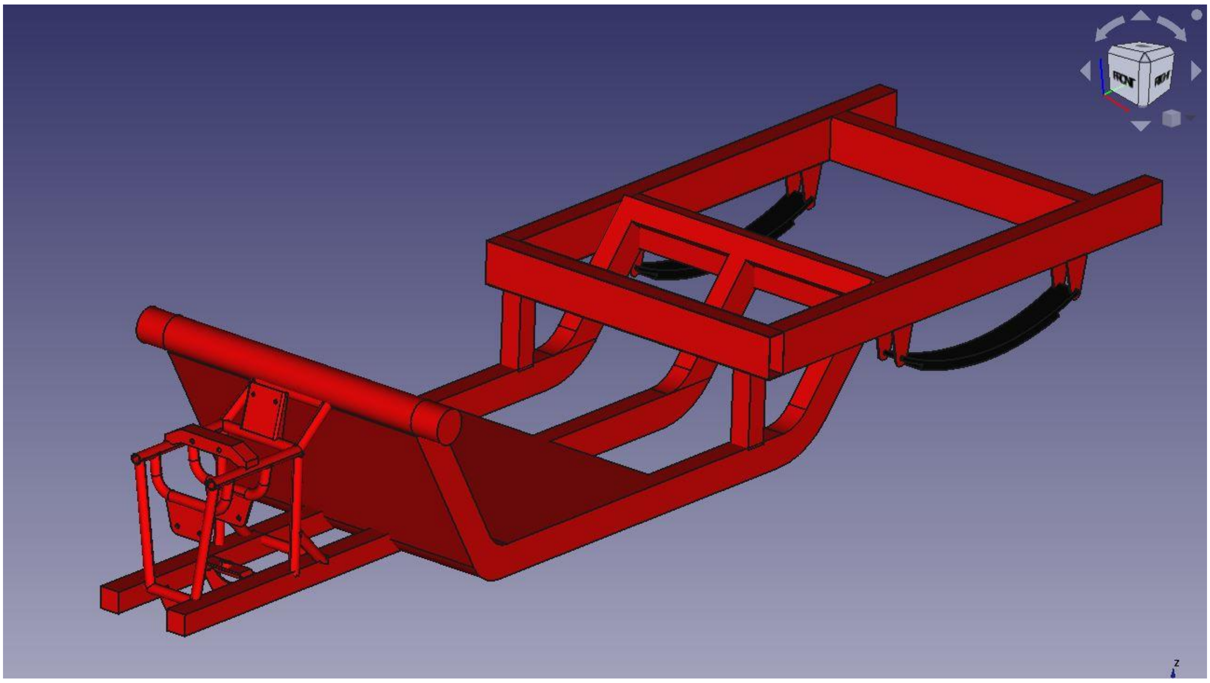


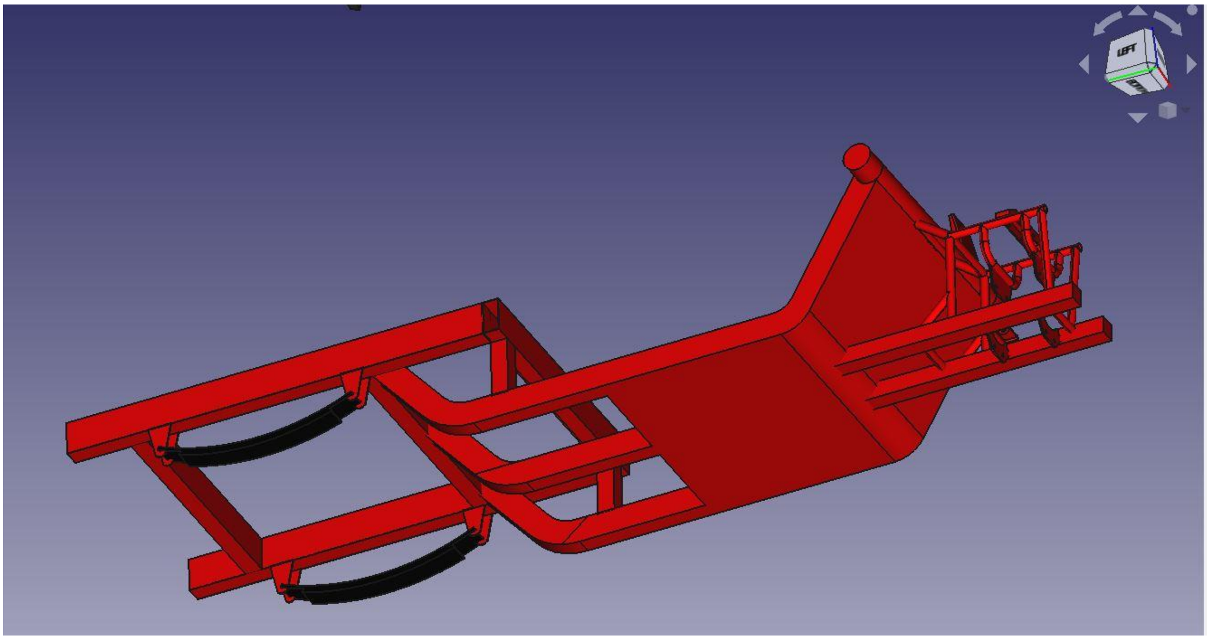
[FreeCAD design of new chassis (21.10.23)]:

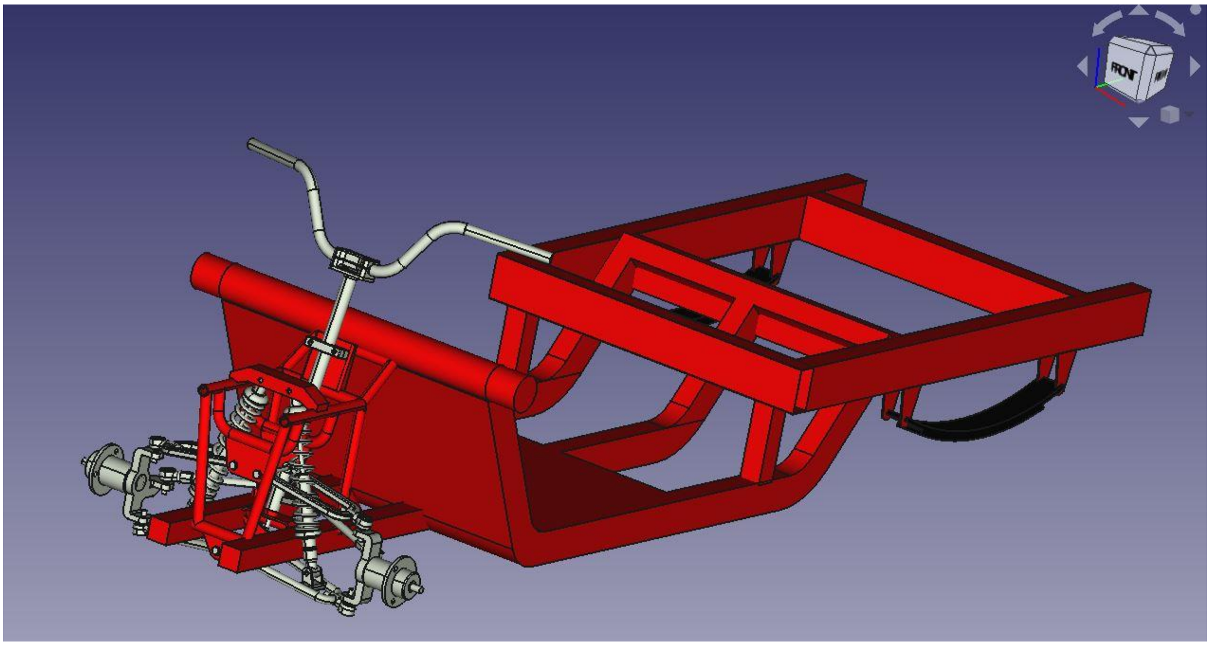


21-10-23
E_TukTuk.FCStd


30-10-2023_new chassis with front suspension : 1







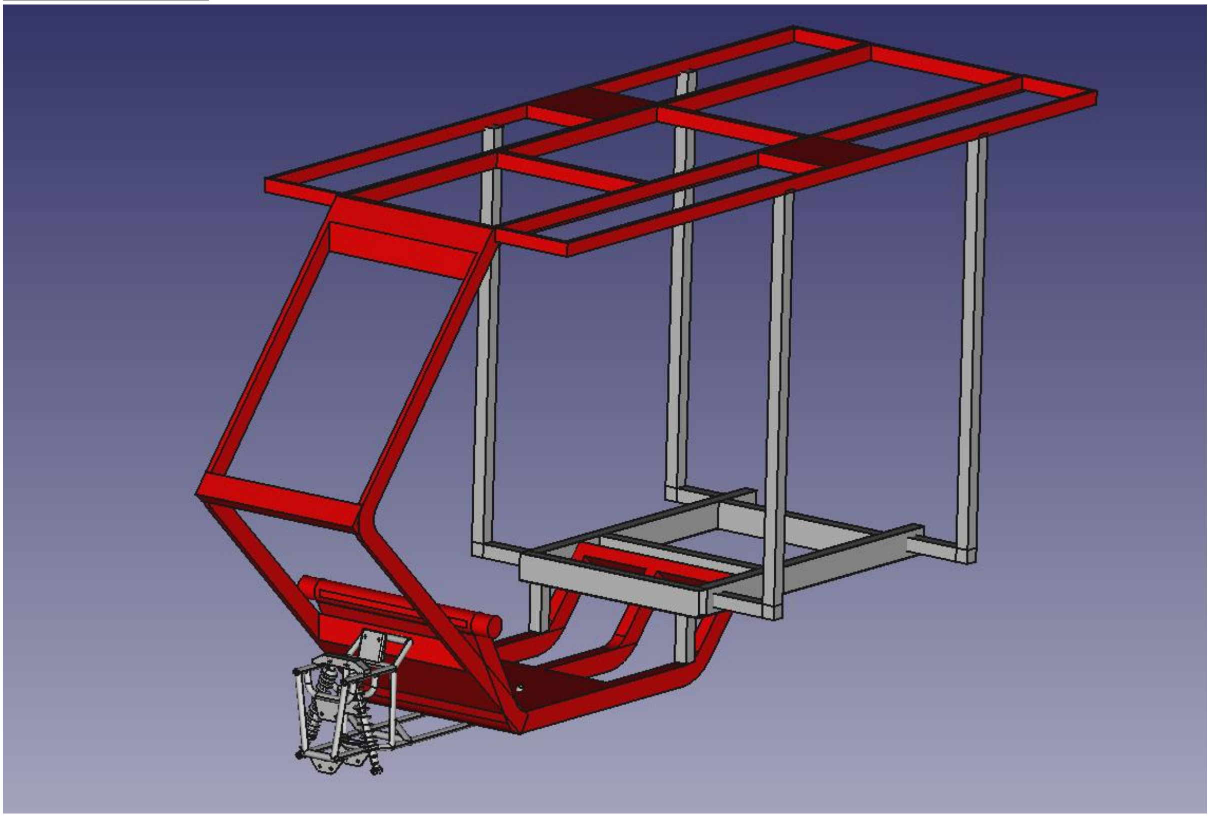
3.2.1.1 FreeCAD design 7-11-2023_new chassis with front suspension:

7-11-2023_new
chassis with front sus

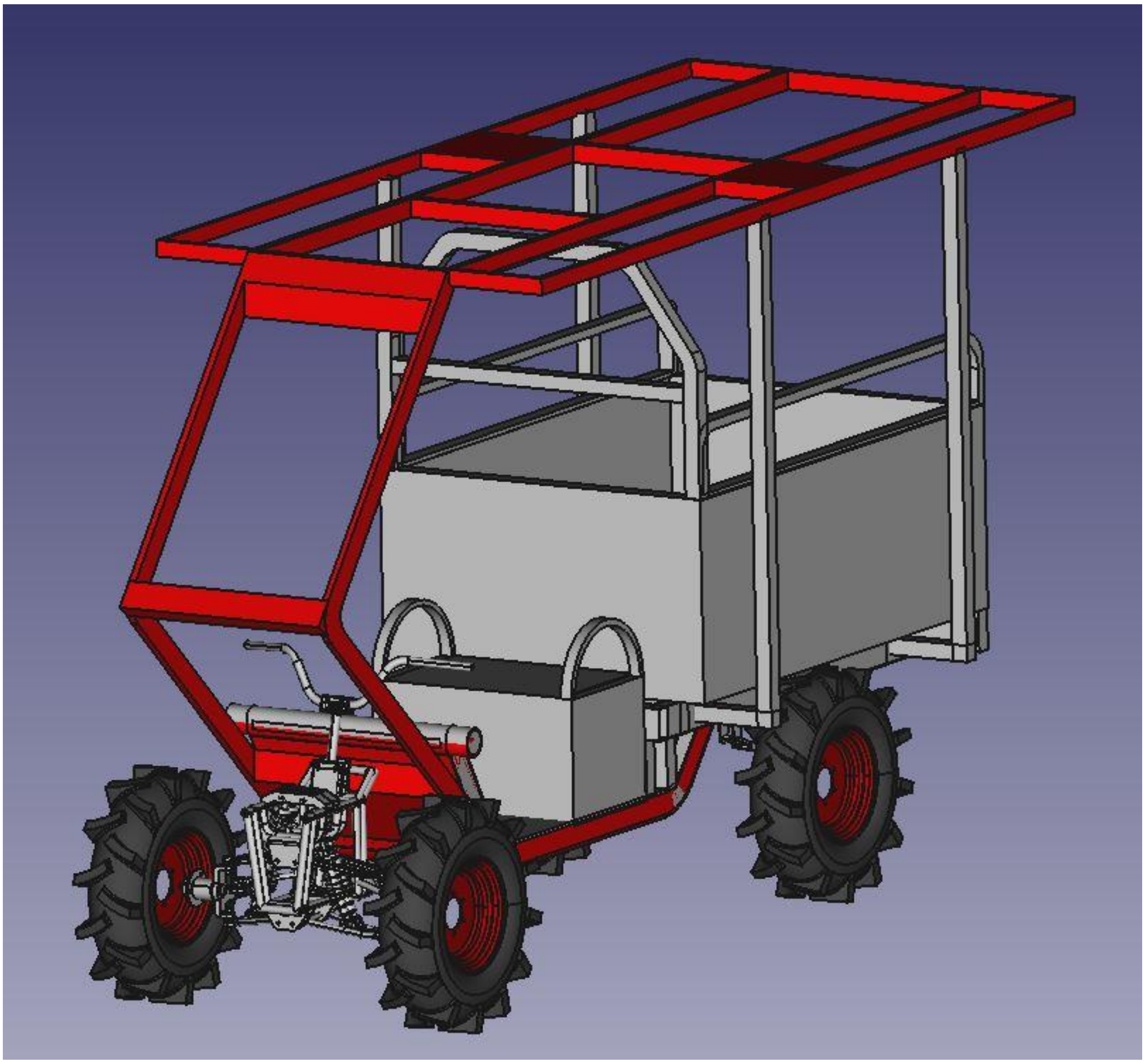
3.2.1.2 FreeCAD design for solar panels stand:

31-10-2023_solar panels stand new :

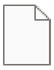
31-10-2023_solar panels stand new.FCS



3.2.2 Assembly of new chassis and solar panels stand (Version Oct 2023)



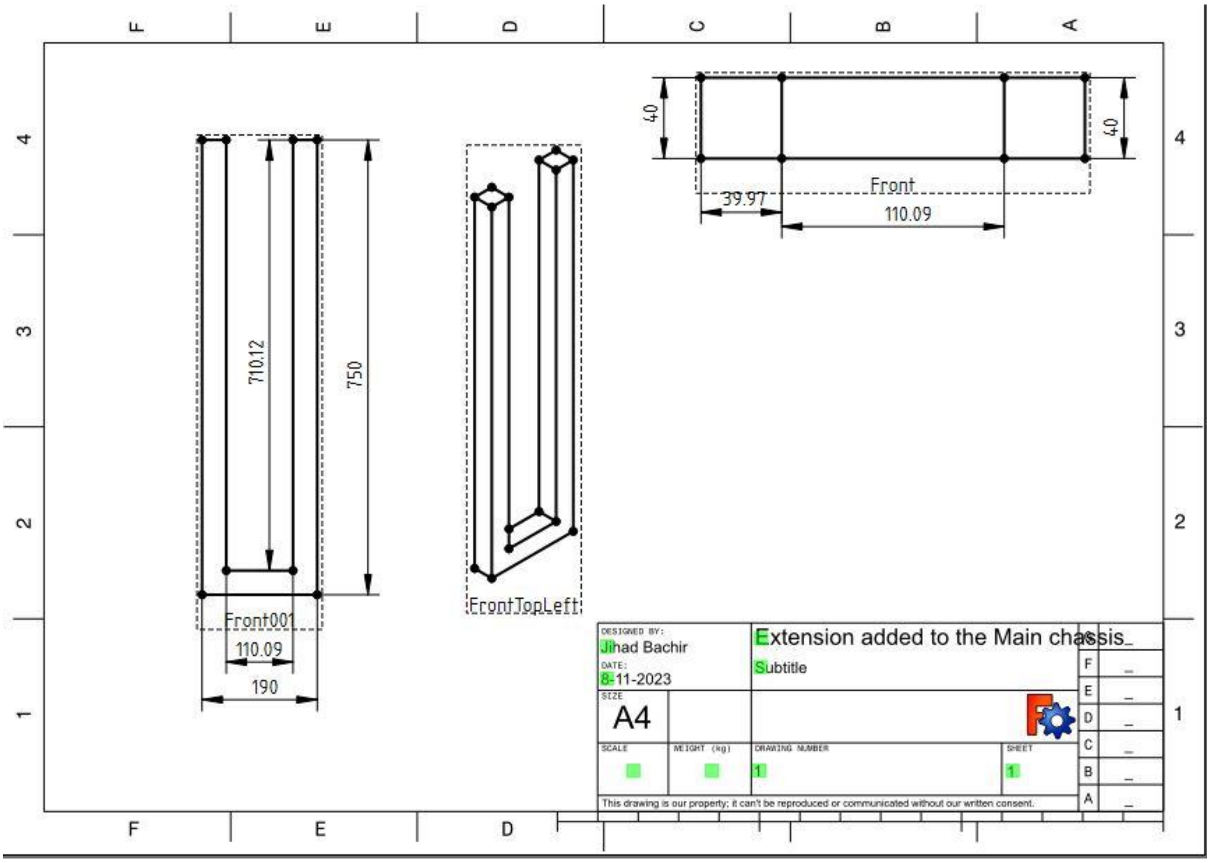
31-10-2023_new assembly chassis with front suspension and solar panels:



31-10-2023_new
assembly chassis with

3.2.2.1 2D Parts Drawings:

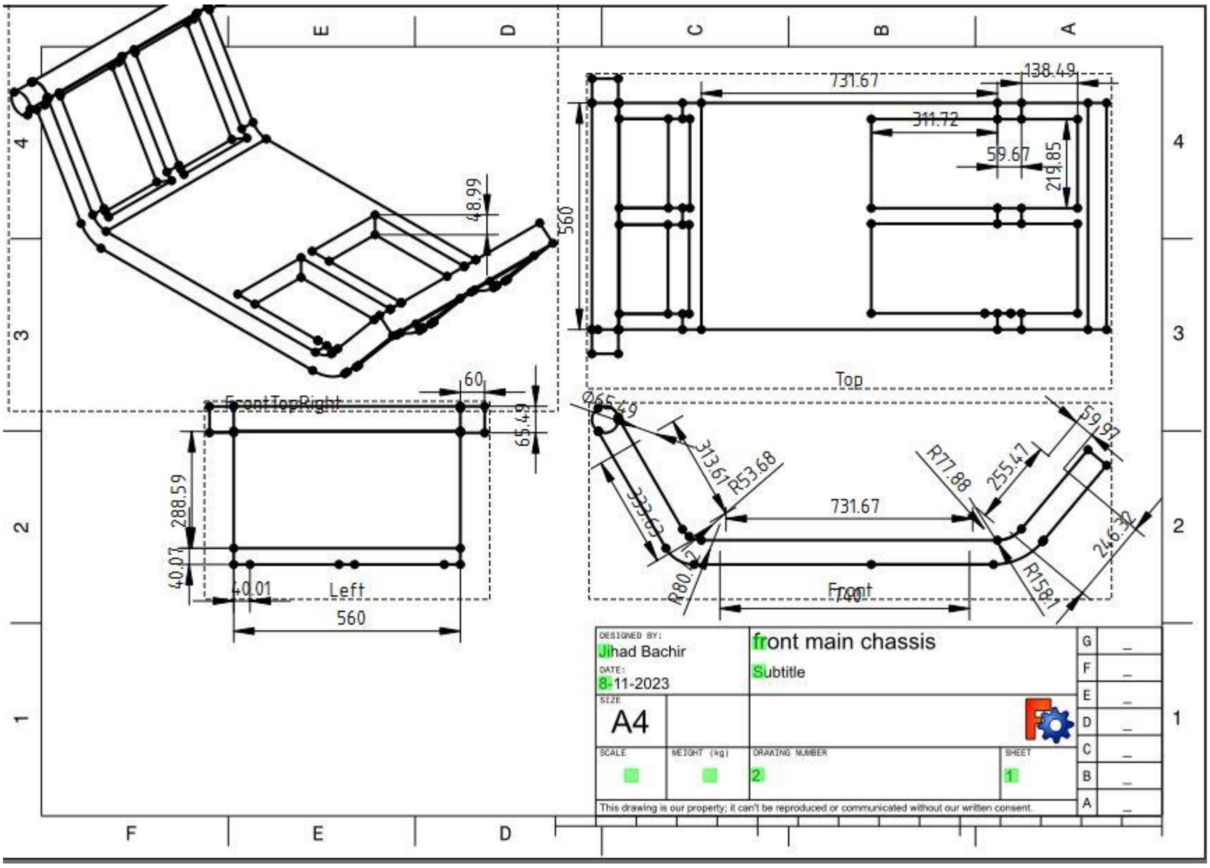
Extension link from front suspension to main chassis



FreeCAD 2d and 3d drawing of the extension link between front suspension and main chassis :

8-11-2023_extension link from front susper

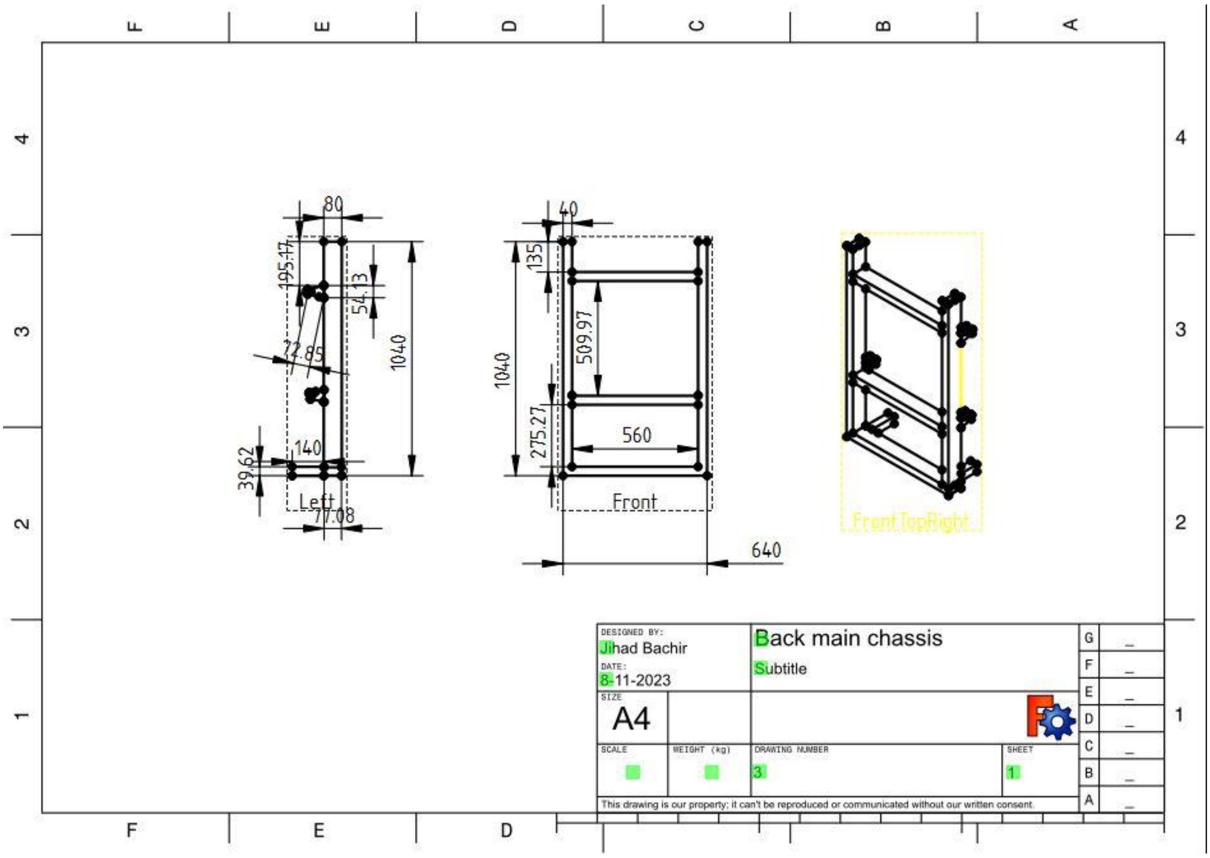
2- Front main chassis:



[2D and 3D drawing and techdraw for the front main chassis design]:

8-11-2023_front main chassis 3d and 2d.FCS

Back main chassis:



[2d and 3d drawing of the back part of the main chassis](#):

8-11-2023_Back main chassis 3d and 2d.FCS

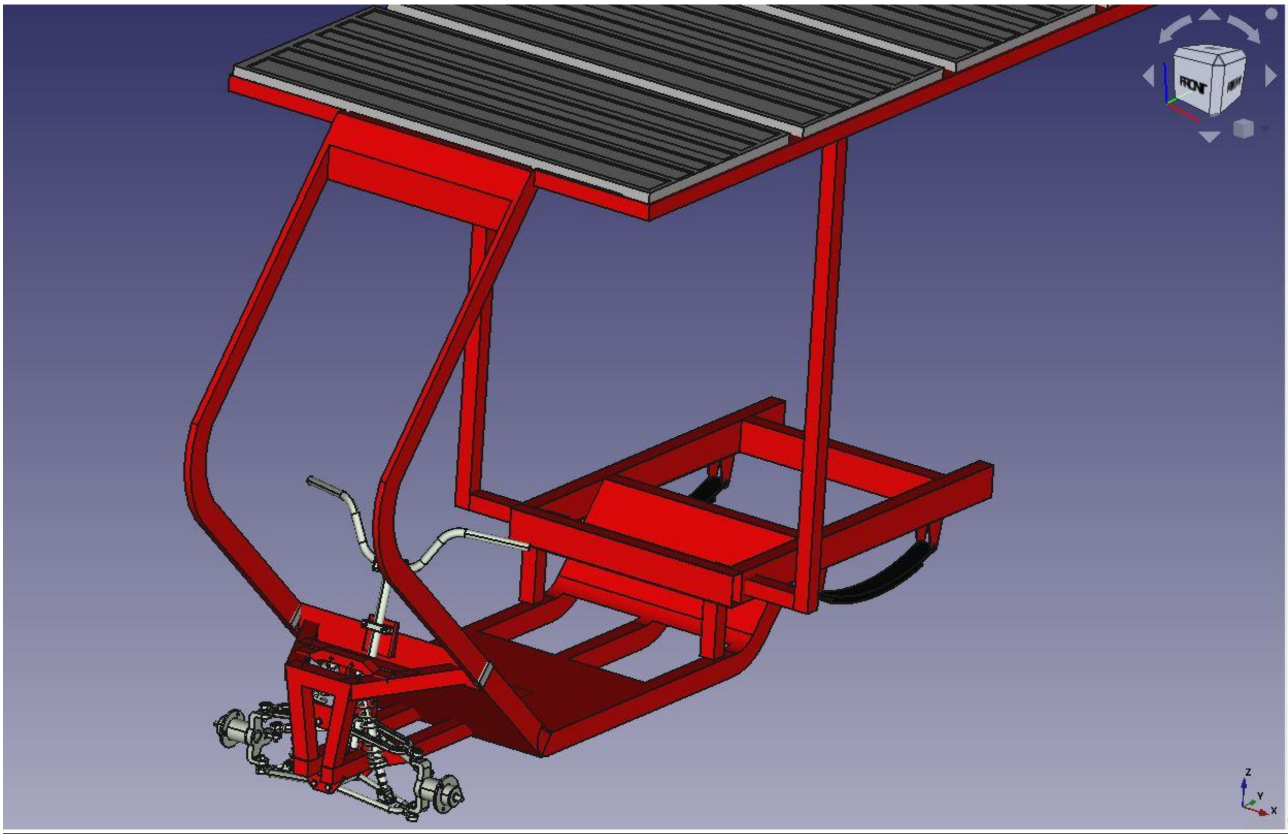
3.2.2.2 Excel sheet for all vehicle components

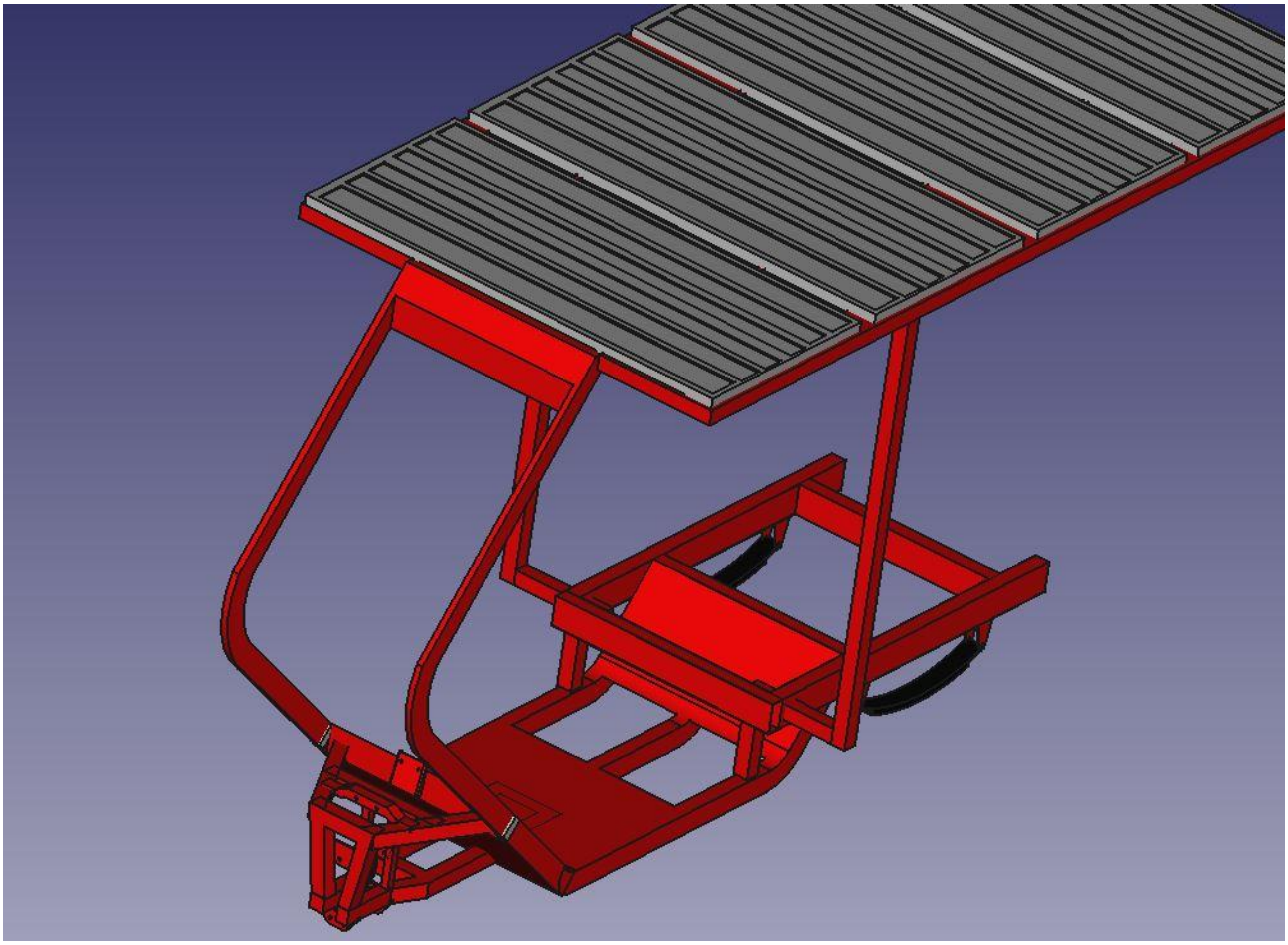
Excel einfügen

[31-10-2023_vehicle components list](#)

3.2.3 Chassis Version 7 Nov 2023

The new chassis and solar panel stand costs 500$ including material and labor work fees

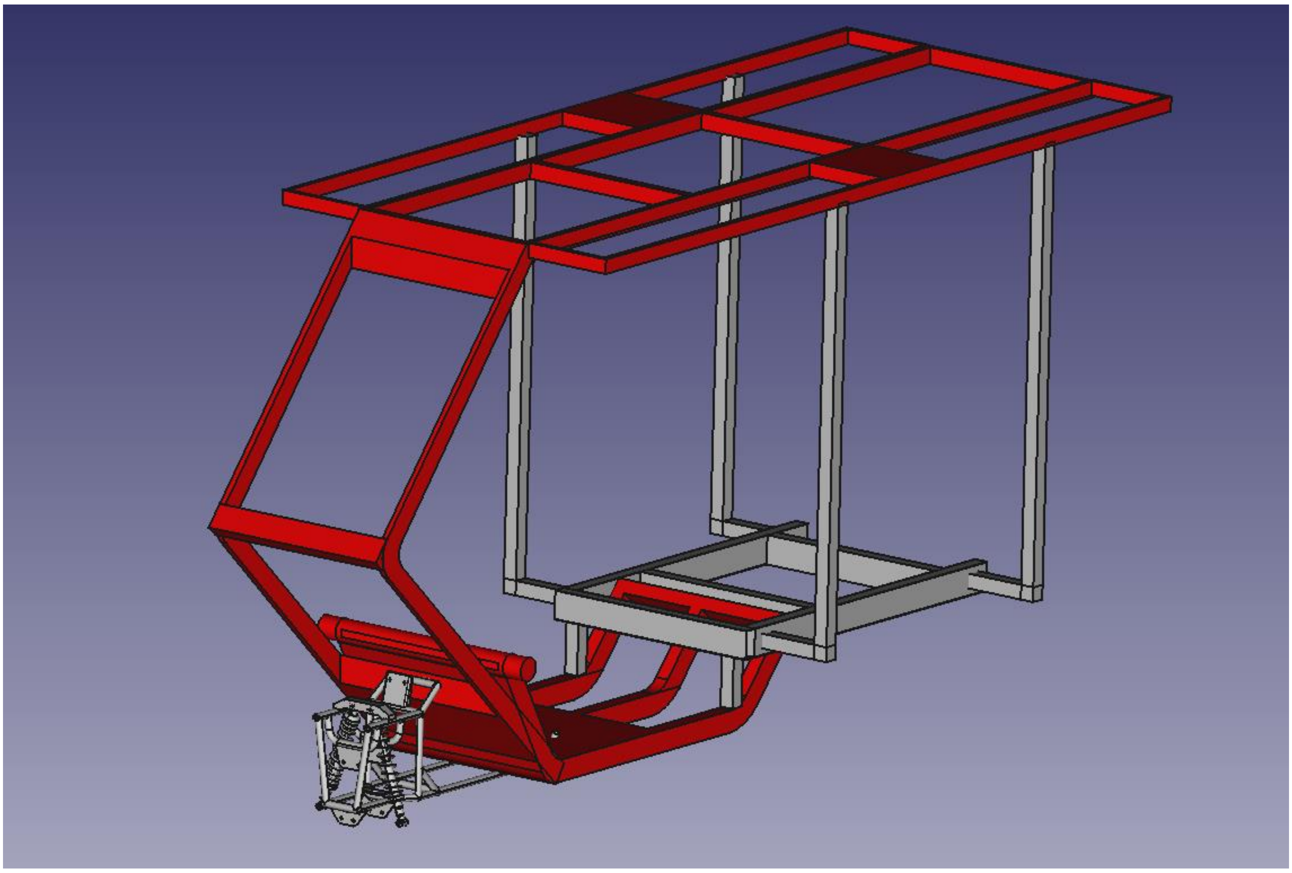




FreeCAD design 3-1-24_NEW tuktuk chassis with solar panel stand

FreeCAD design for solar panels stand:

31-10-2023_solar panels stand new



3.3 Front axis

3.3.1 FreeCAD Drawing

3D tbd

2D tbd

3.3.2 Mechanical Realization

tbd

3.4 Front Wheels

3.4.1 FreeCAD Drawing

3D tbd

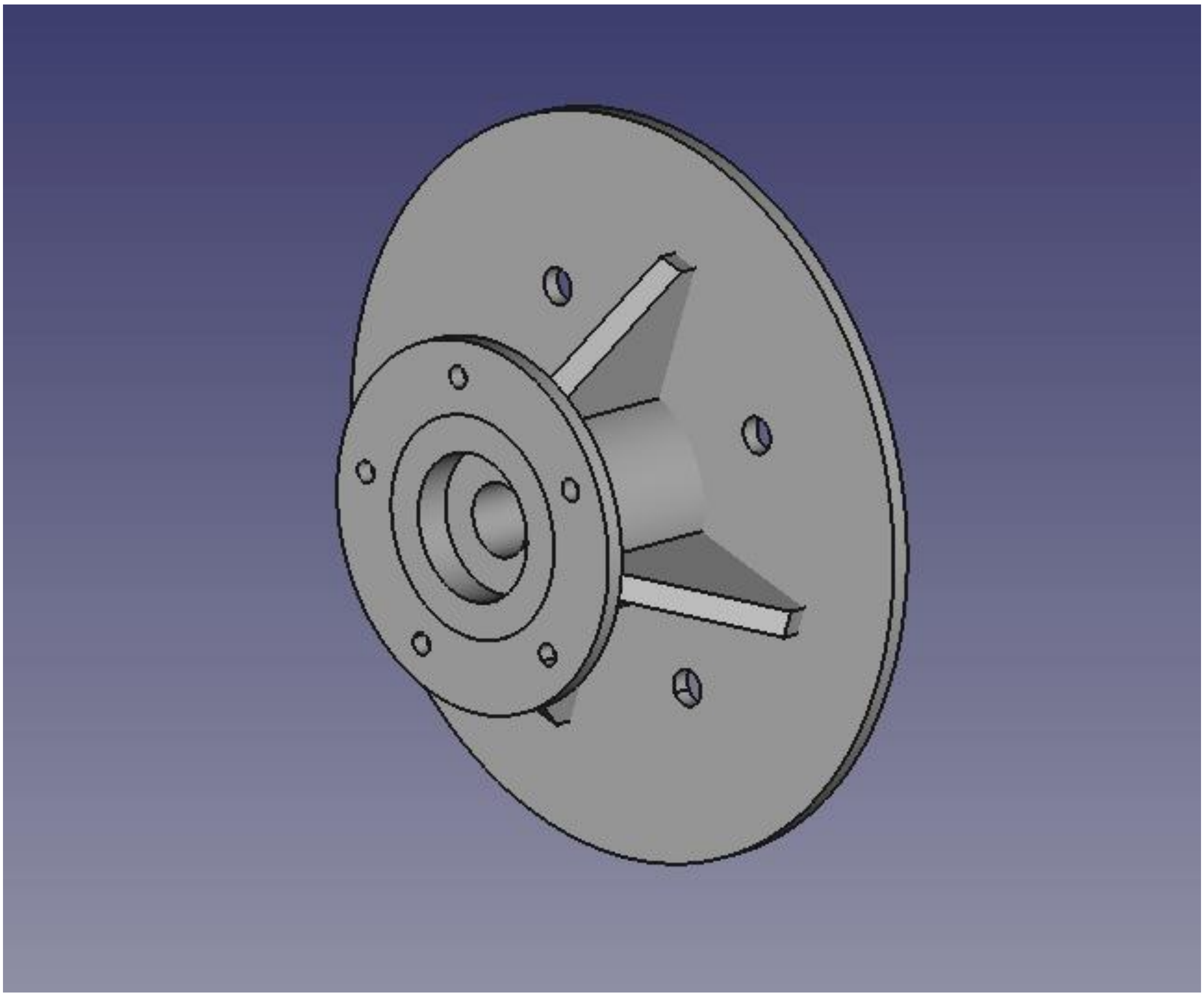
2D tbd

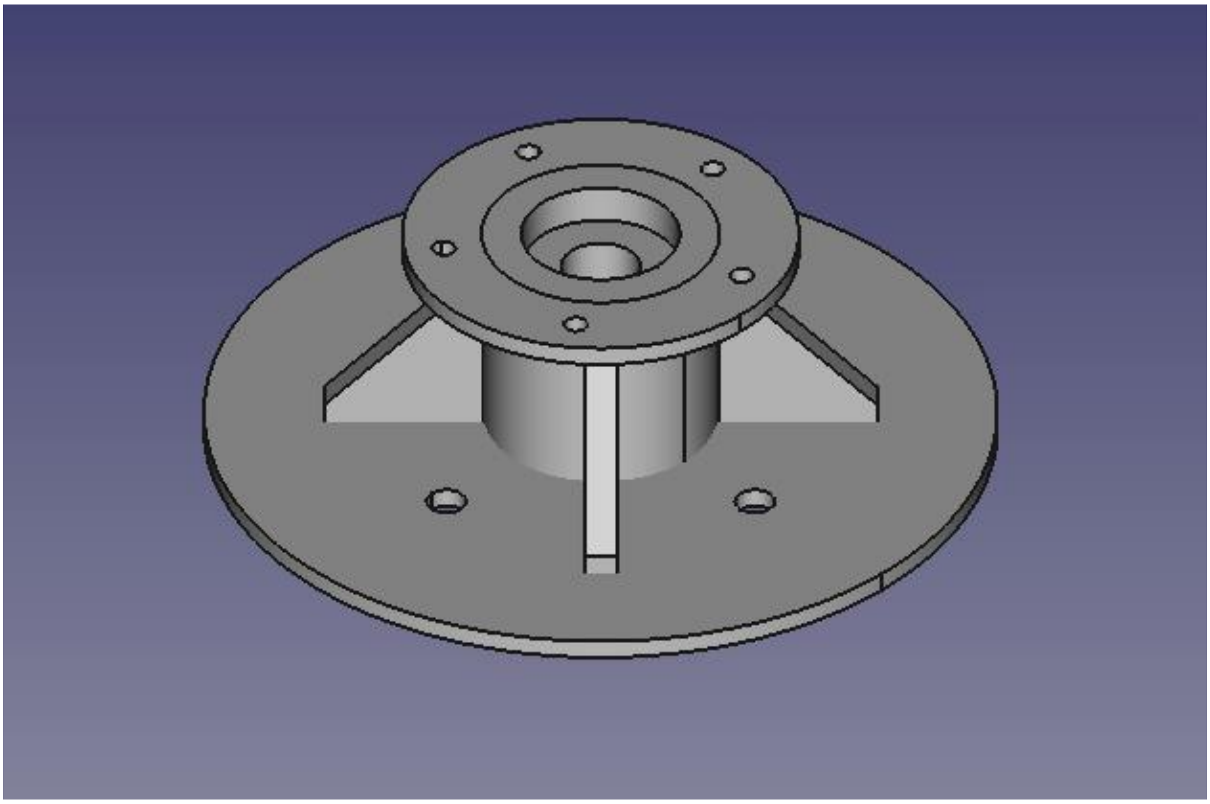
3.4.2 Mechanical Realization

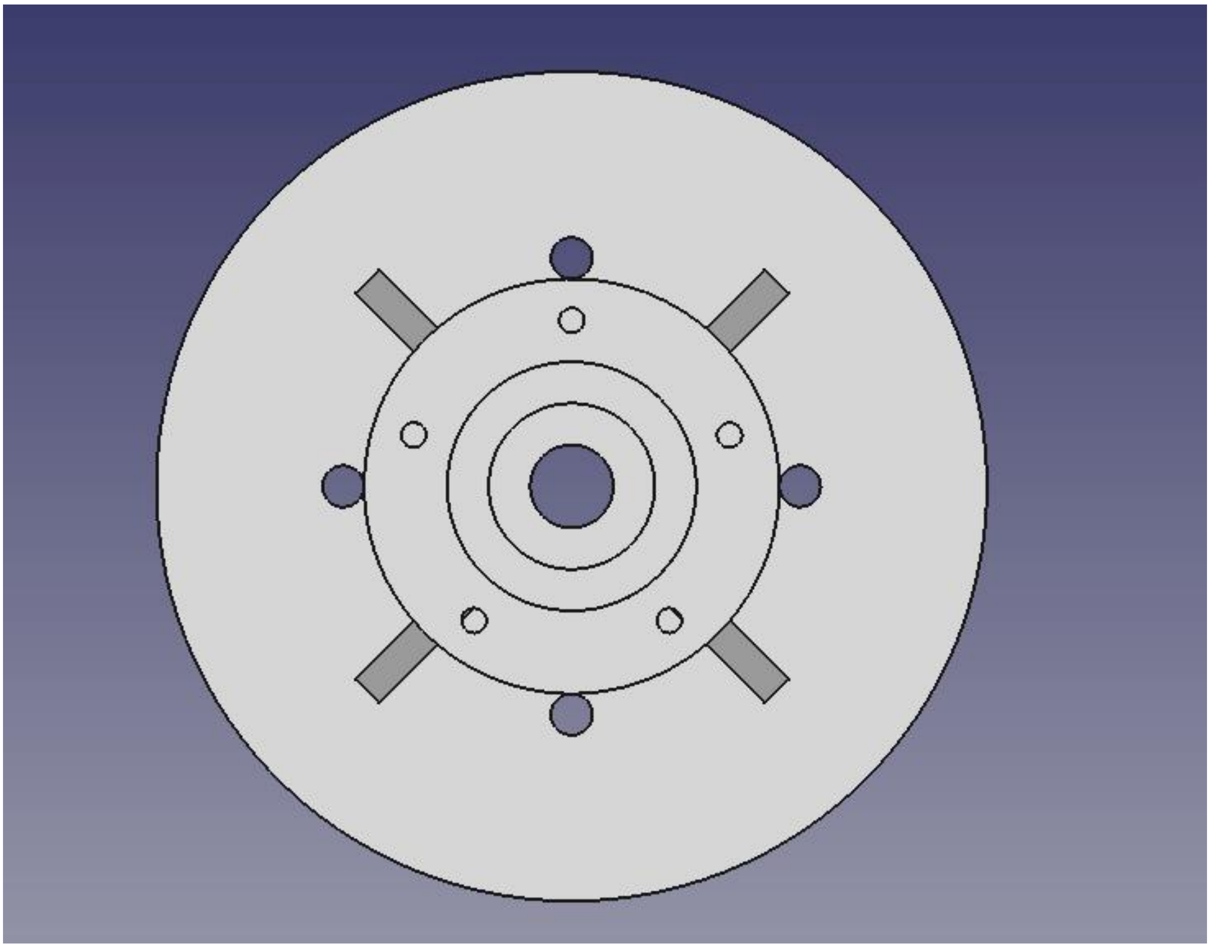
tbd

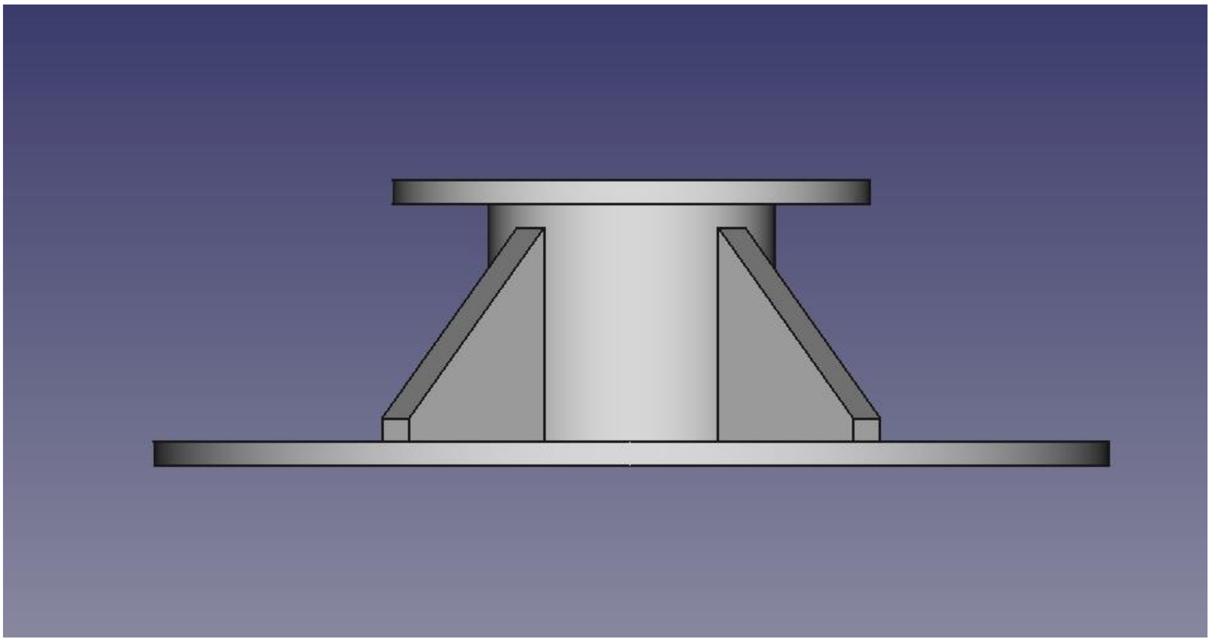
3.4.3 Front wheel rim disc

3.4.3.1 design:

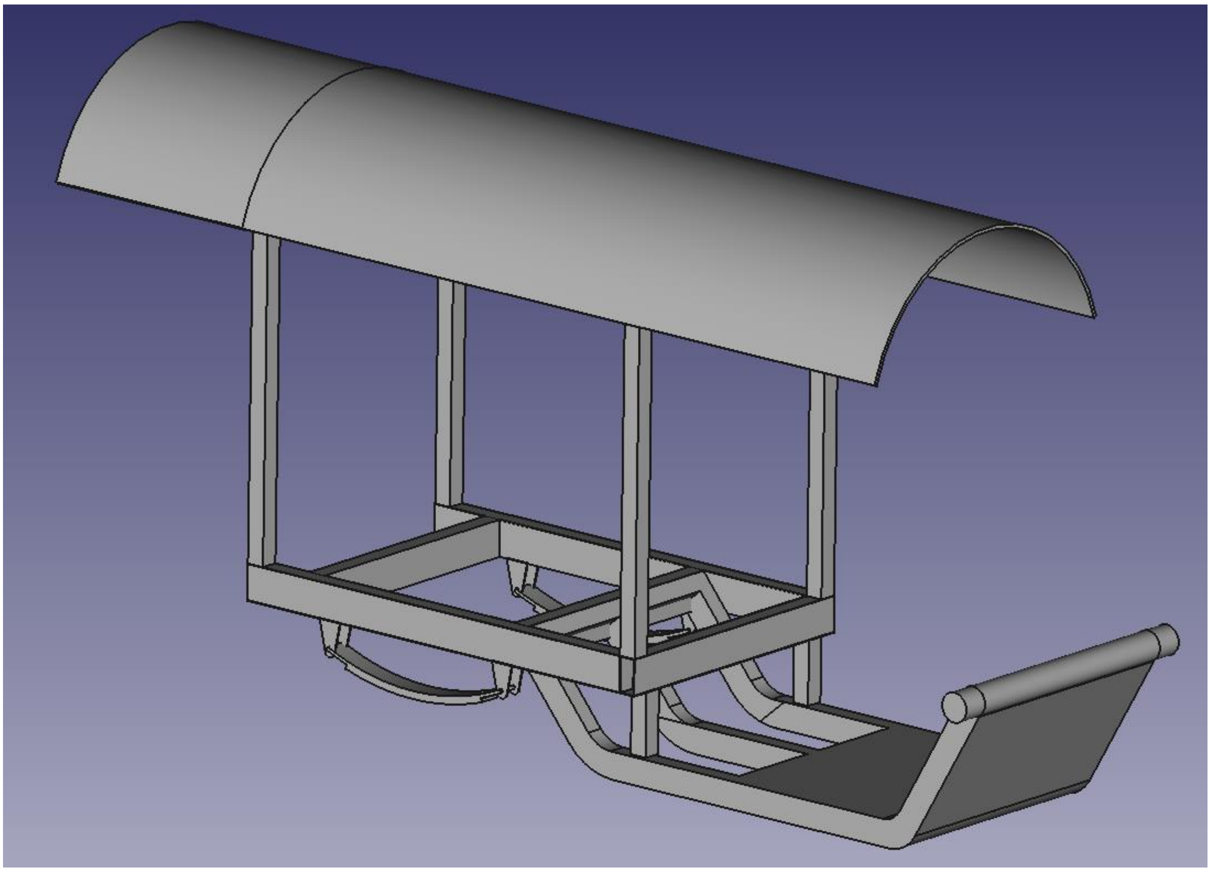




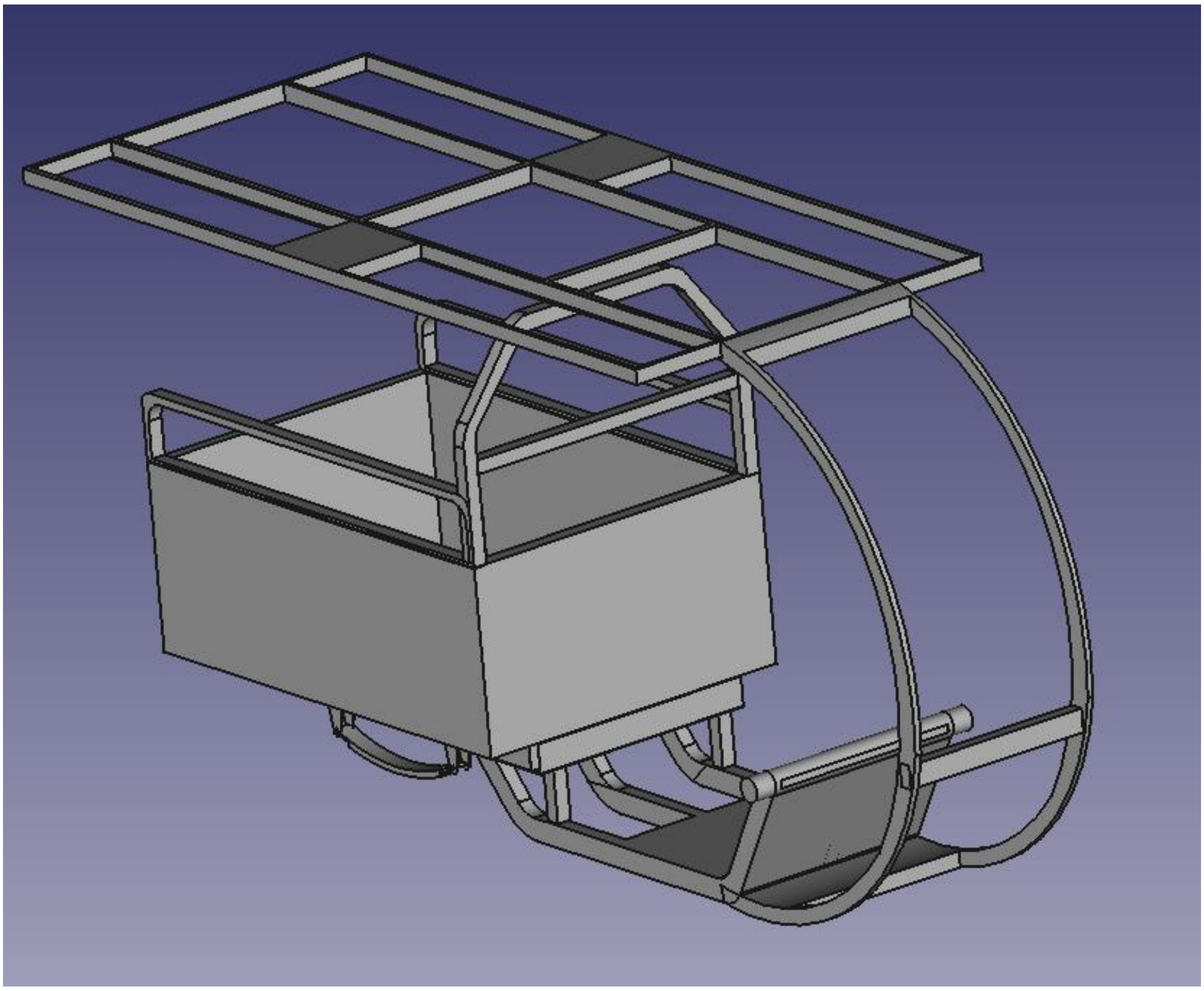


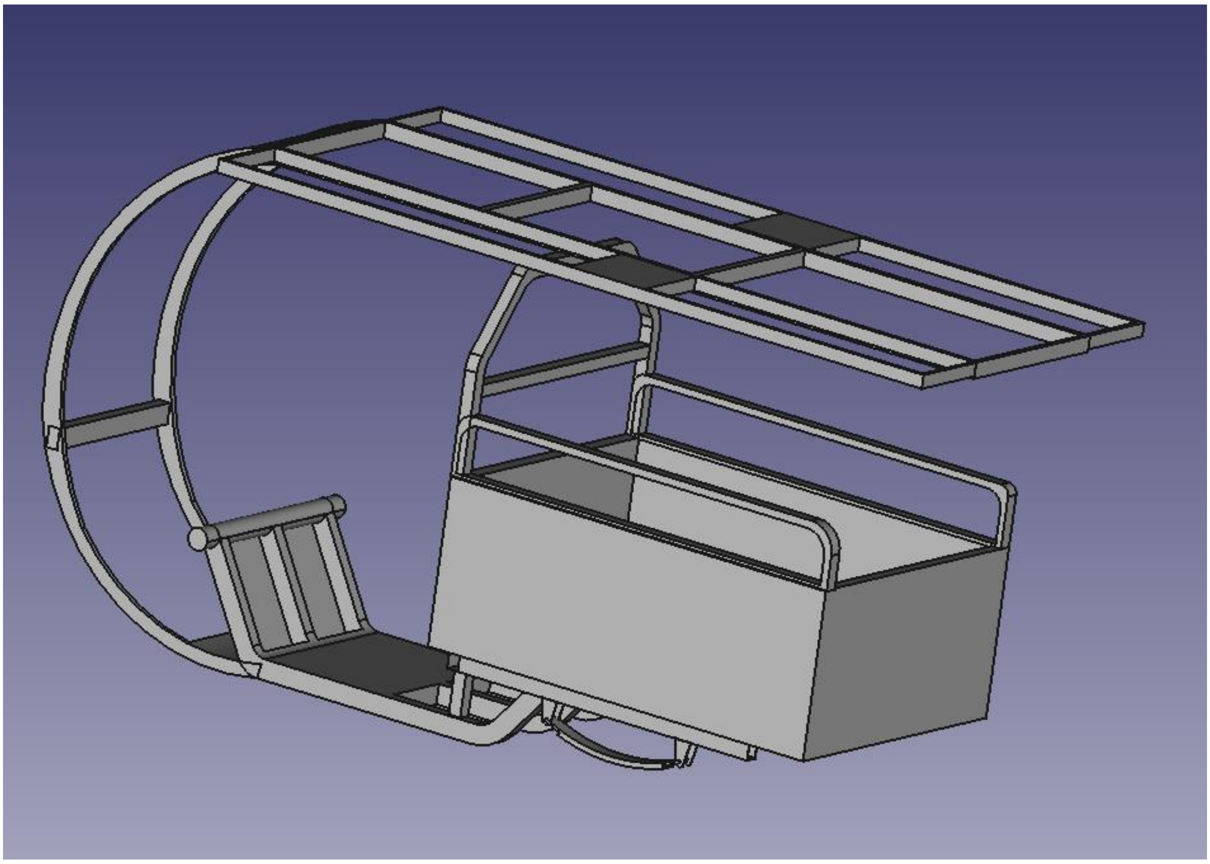


17-22-2022 drawing:

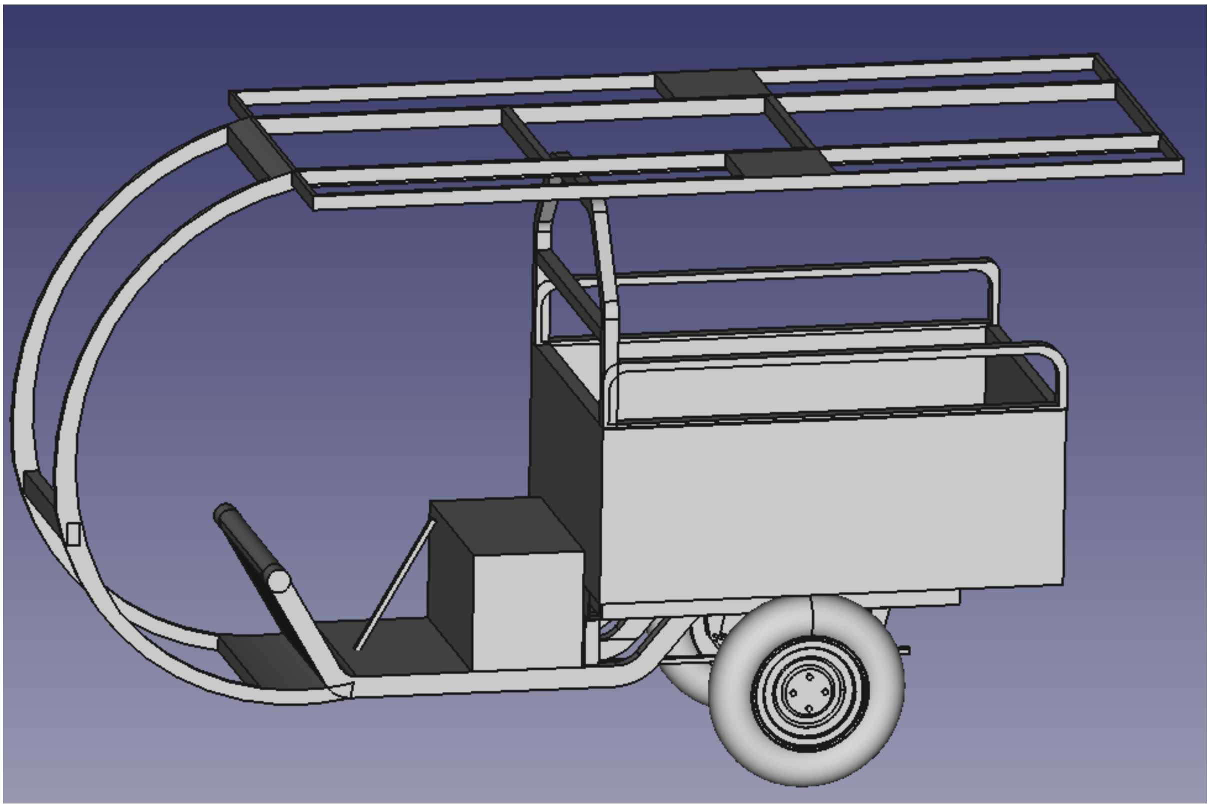


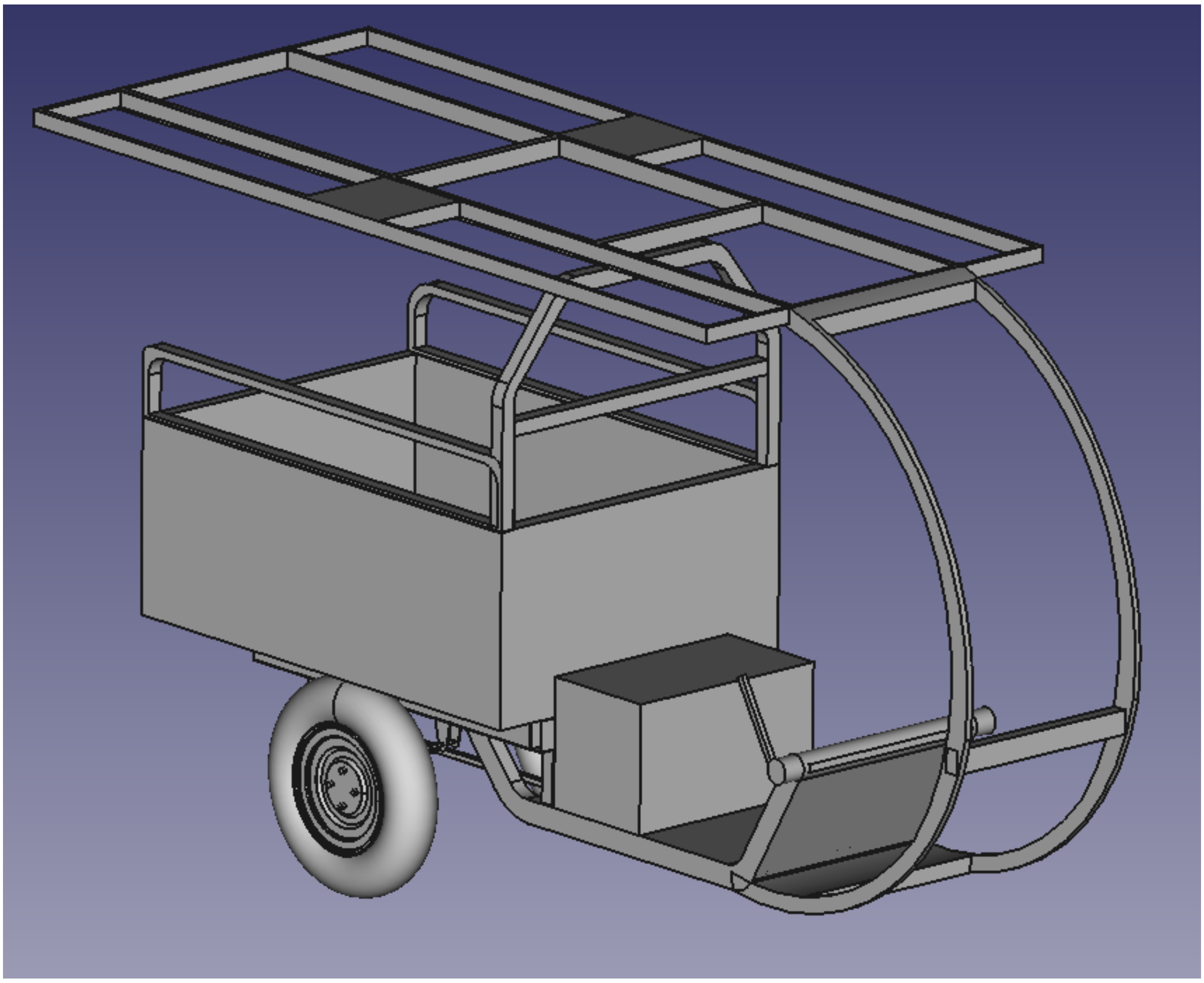
28-11-22 E_TukTuk with solar panel stand:



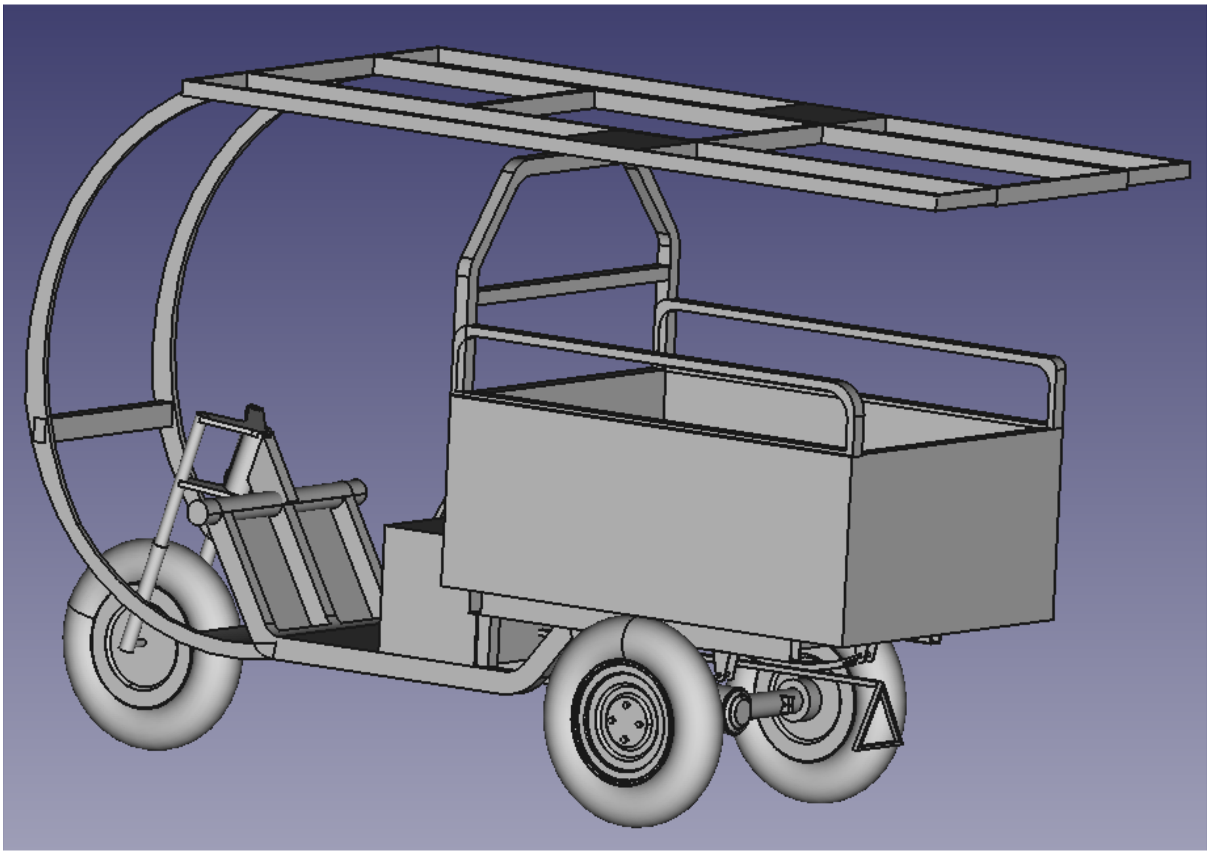


30-11-22 E_TukTuk with solar panel stand and hitch handle:

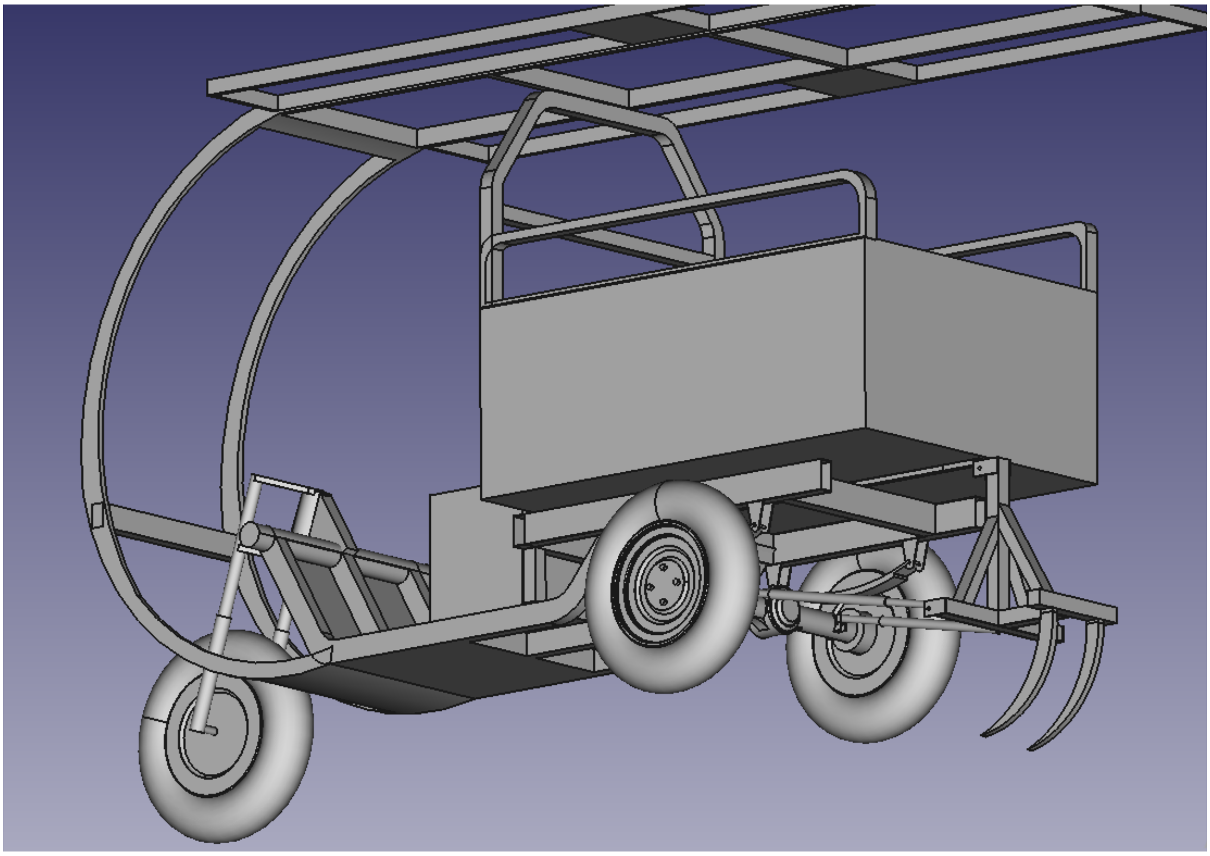


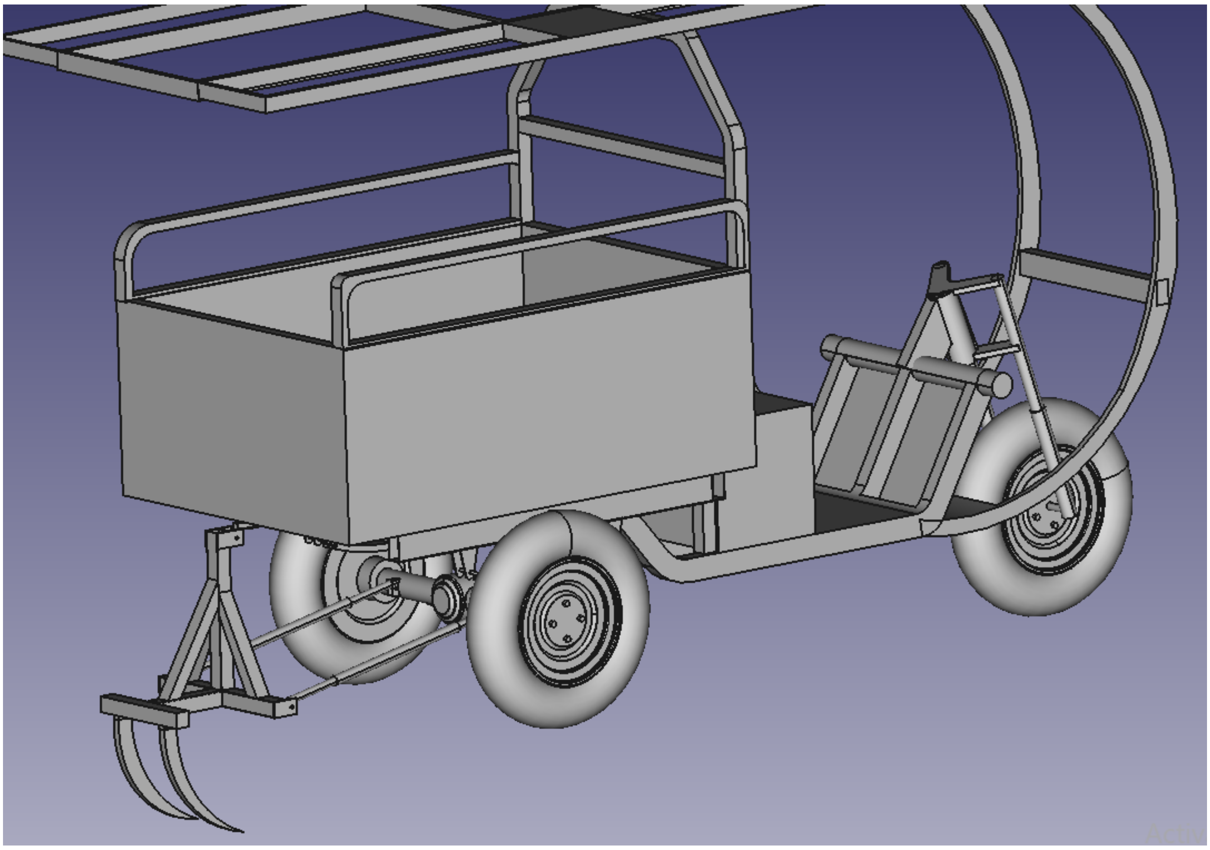


5-12-22 E_TukTuk:

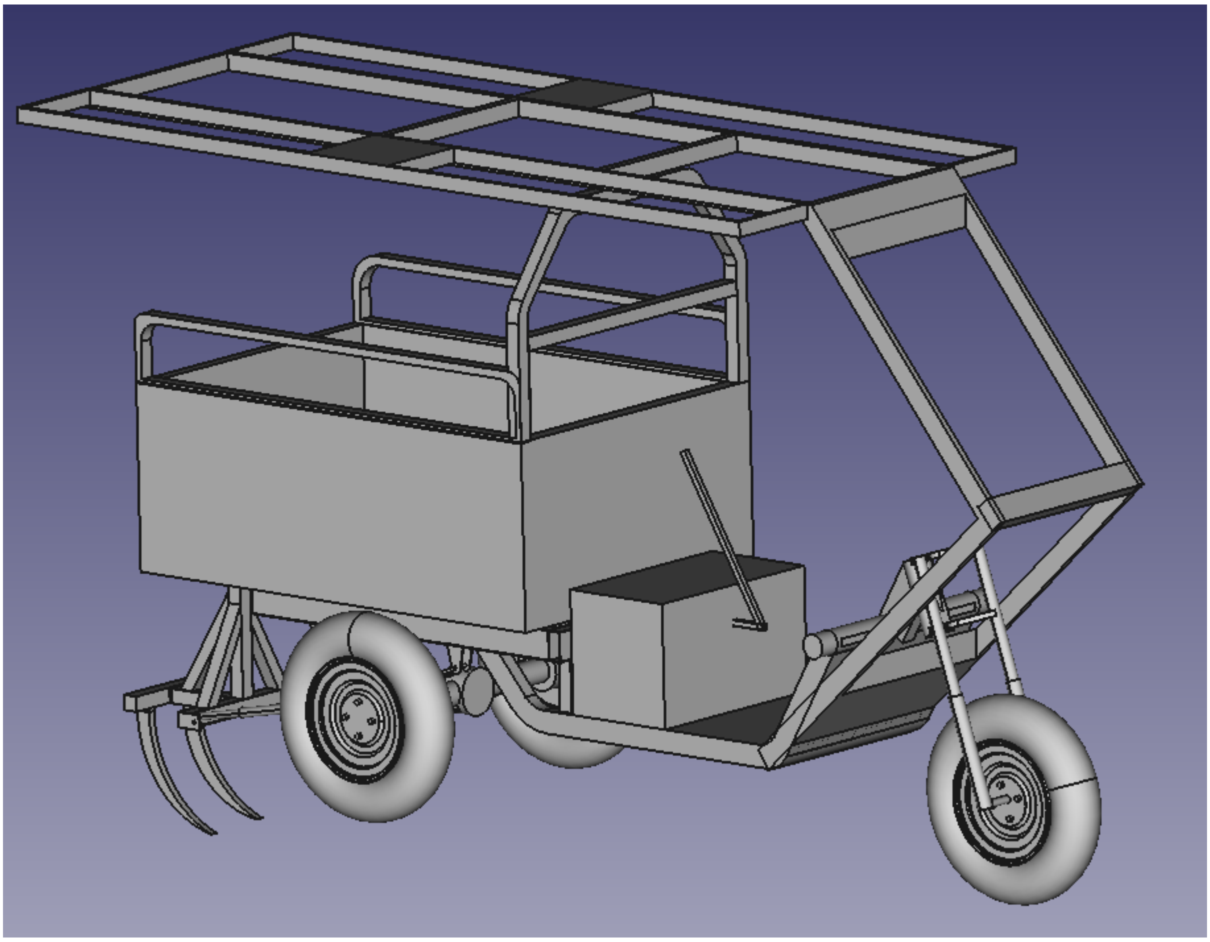


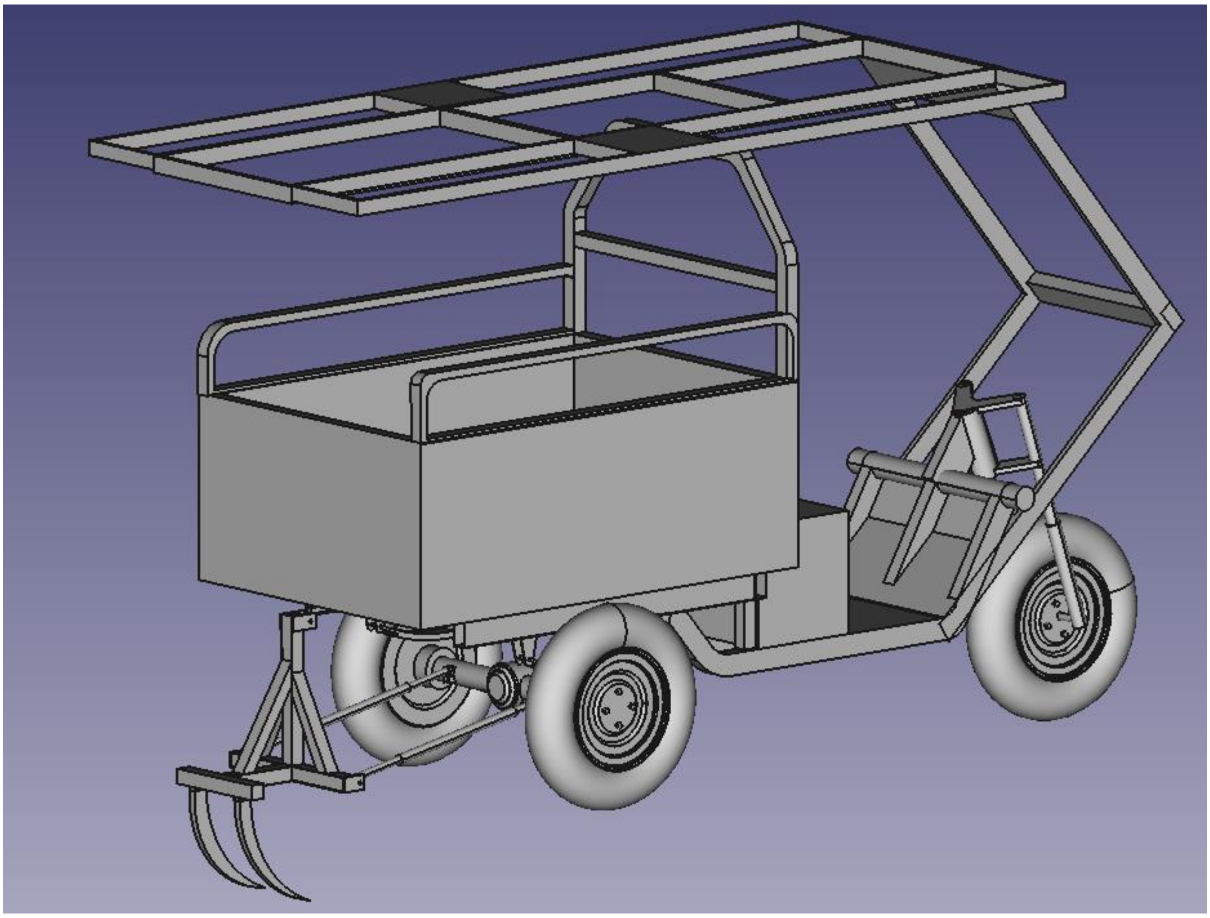
17-12-22 :

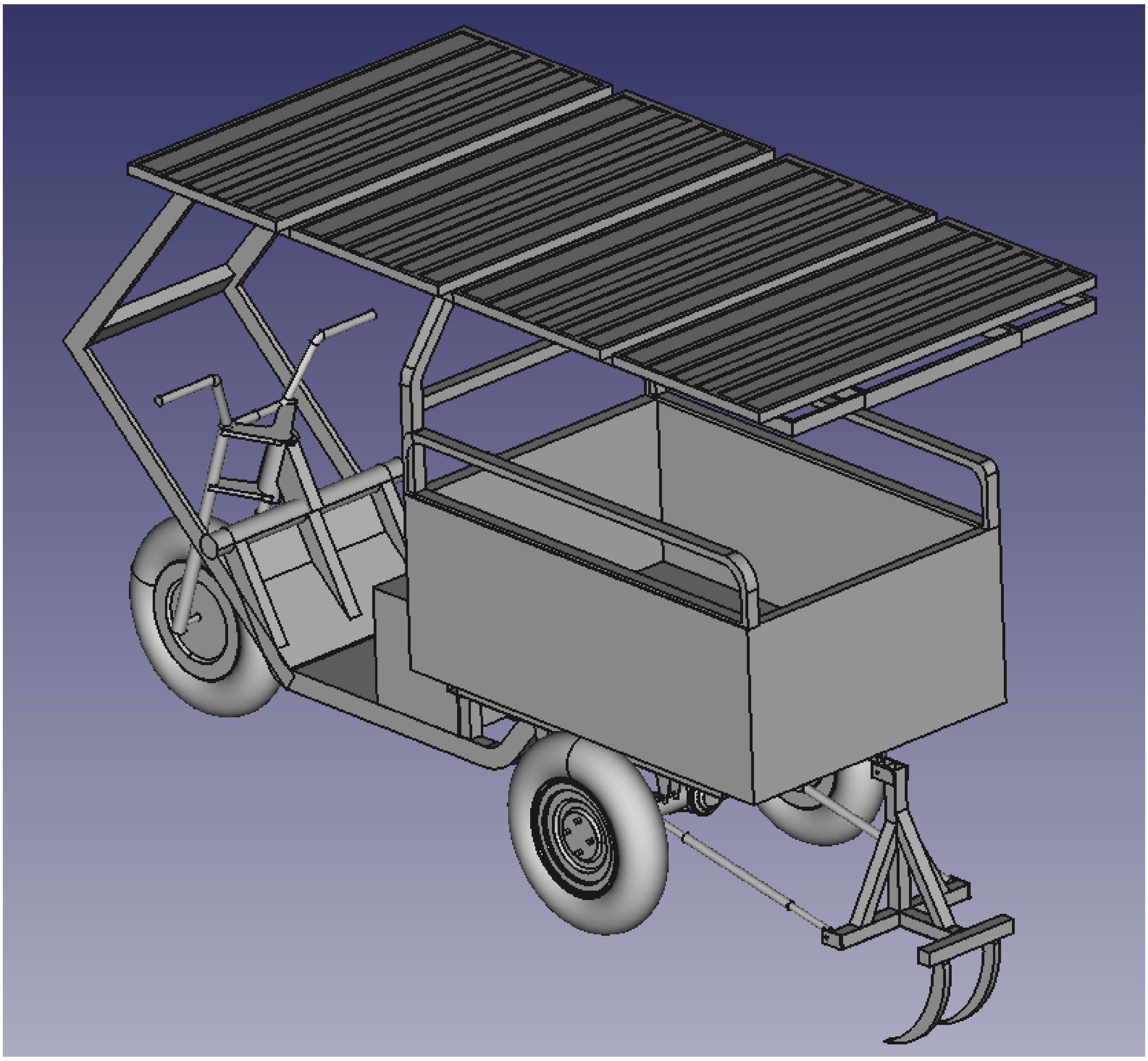


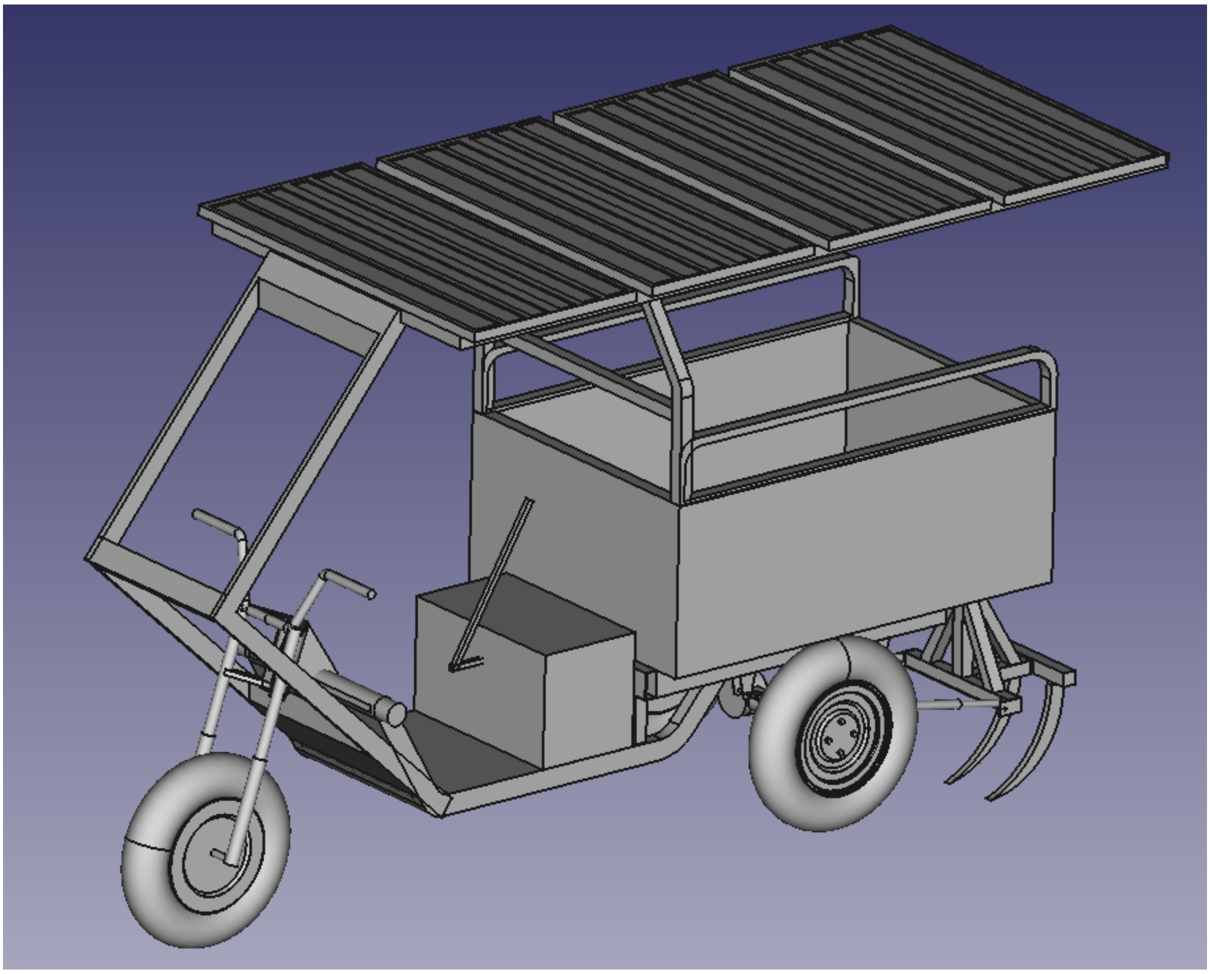


19-12-22 E_TukTuk with solar panel stand:









28-11-22 E_TukTuk with solar panel stand: [5-12-22 E_TukTuk]

19-12-22 E_TukTuk
with solar panel stand

17-12-2022 New Solar Panels stand [17-12-2022 E-tukTuk]

19-12-22 E_TukTuk
with solar panel stand

Hitch Design [19-12-22 New Hitch design]

19-12-22 E_TukTuk
with solar panel stand

3.4.3.2 Realization

3.5 Rear Wheels

3.5.1 FreeCAD Drawing

3D tbd

2D tbd

3.5.2 Mechanical Realization

tbd

3.6 Excel sheet for all vehicle components:

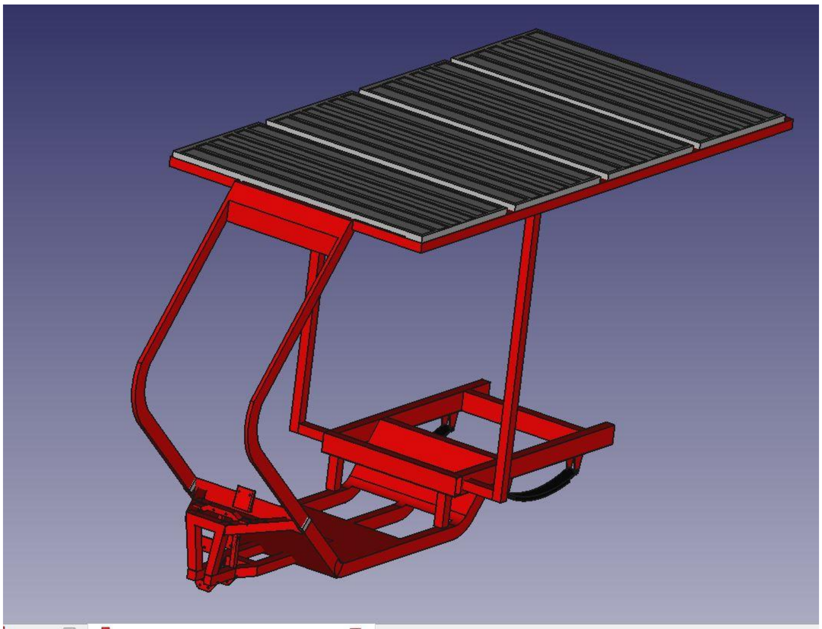
31-10-2023_vehicle components list:

31-10-2023_vehicle components list.xlsx

4 Enhancement Report (Oct-Dec 2023)

Task	Deliverables
Design new chassis	CAD design
Design & enhance the vehicle roof with the solar panel	CAD design
Find a manufactory for the chassis and solar roof	Quotations and contacts
Specify all vehicle components list	Excel sheet
Find provider for each component	Quotations and contacts
Fully check the battery requirement and solar charging	Electrical study
Start preparing for the license agreement	Official Lebanese answers
Documentation (Always UpToDate)	Word file and Website
Weekly meeting	Online/onsite weekly meeting

<u>The assembled design of the chassis and solar panel roof design</u>:

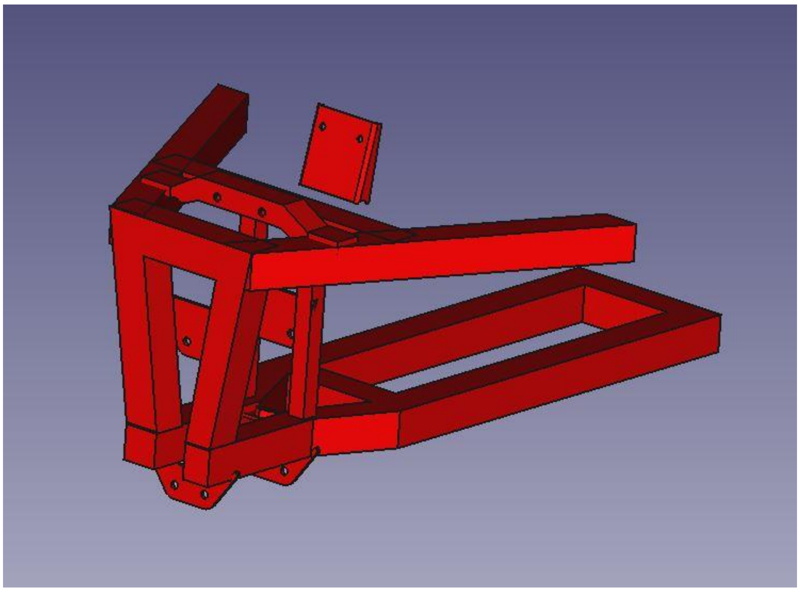


4.1 New chassis design

4.1.1 Chassis CAD file:

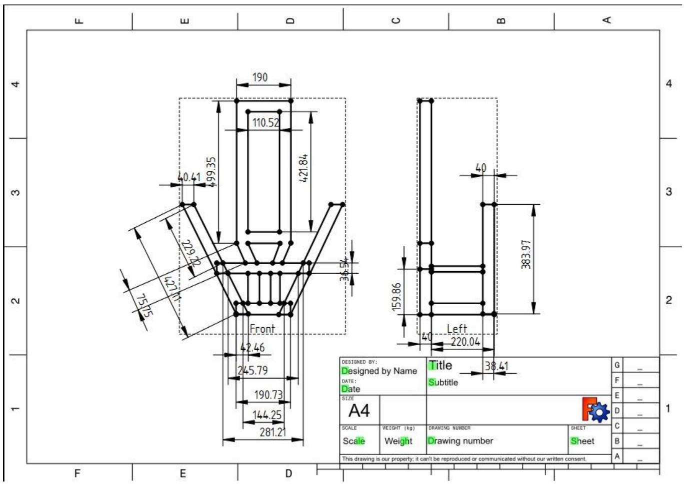
main front
suspension 2d.FCStd

4.1.2 Chassis design screenshot:

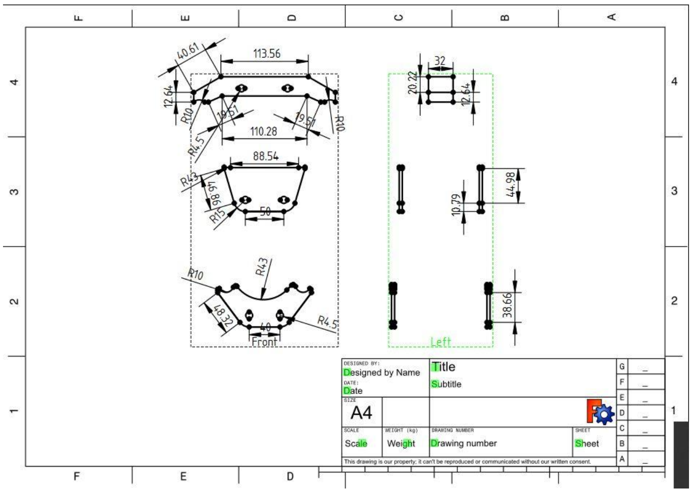


4.1.3 Needed 2D detailed designs:

main front
suspension 2d.FCStd



accessories.FCStd1

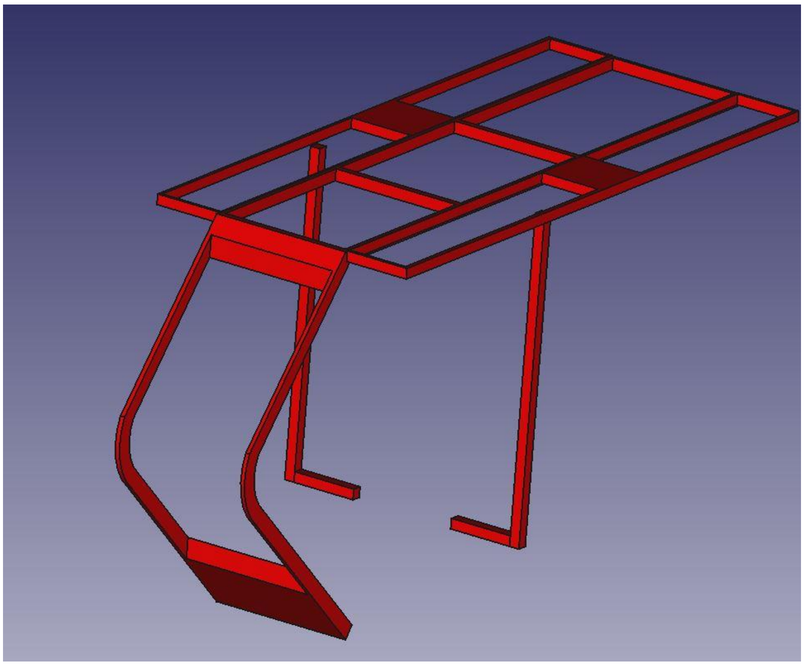


4.2 New roof design

4.2.1 roof CAD file

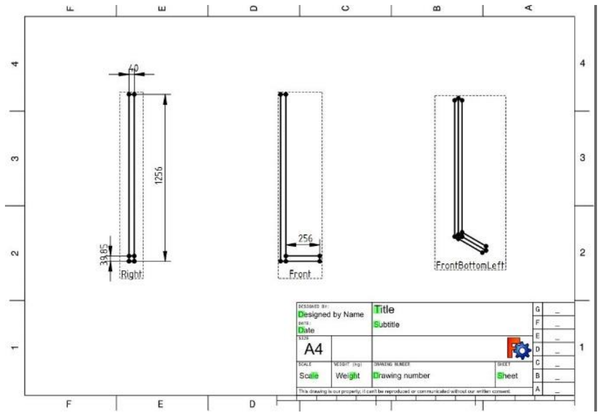
solar panels stand
and panels new versic

4.2.2 roof design screenshot:

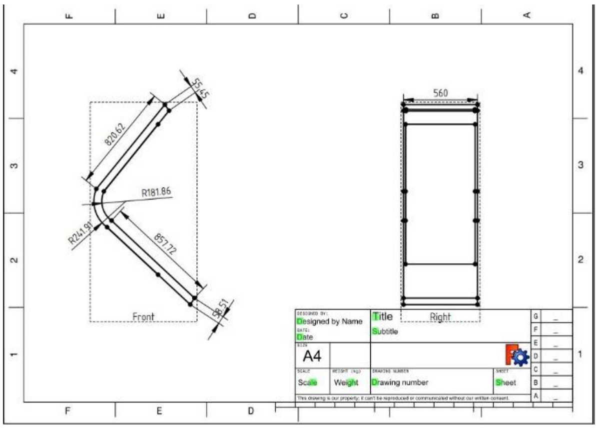


4.2.3 Needed 2D detailed designs:

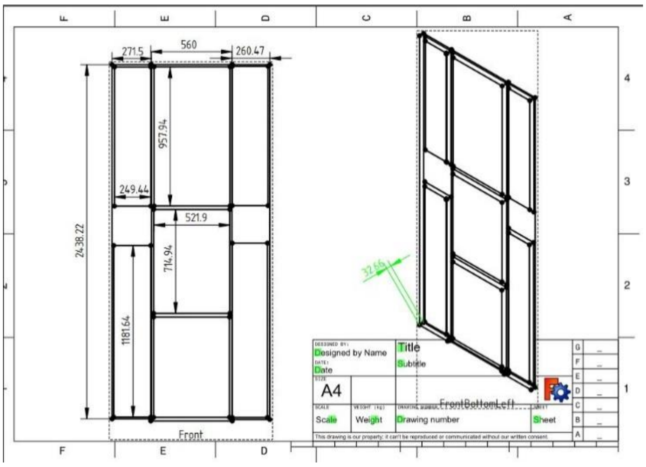
L shape.FCStd1



solar panel front side.FCStd



solar panel roof.FCStd1



4.3 Chassis and roof quotations (2 quotations min)

No official quotation sheet,

1- Abo Al Abeds quotation : 500$
2- Khaled Saleh CNC : 750$ if we order one peace, another price for a 5 plus chassis order.

4.4 Vehicle components list (with an image notes each component on the vehicle)

31-10-2023_vehicle components list.xlsx

4.5 Components quotations (2 quotations min)

Al halabi is the only local supplier of electric tuktuk parts with best prices and prices less then AliBaBa in the term of small orders

Invoice from al Halabi.pdf

Bicycle And E.Bike
Bicycle and Parts - Gen.Traid

TRIPOLI
North Lebanon

31/10/23 **تاريخ** **13393** **فاتورة رقم**

0000	زحل	المطلوب من السيد: تدريب

المجموع	السعر	العدد	الوحدة	الشرح
5.00	2.50	2	1	اشارات-تكتك-امامي-جنب
8.00	8.00	1	جوز	اشارات-تكتك-خلفي
7.00	3.50	2		اكس-عيار ديفرانسال-تكتك
9.00	3.00	3		اكس-فريم-تكتك
2.50	2.50	1		بوبين اشارة-60V-
18.00	1.50	12		بوغ-مقص-تكتك
10.00	10.00	1		تابلو-تكتك-60V-ديجيتال
18.00	18.00	1		تي-ملقط-تكتك
32.00	16.00	2		جنط-12"-تكتك-خلفي-فارغ
3.00	3.00	1		جوزة كونتاك-تكتك-
200.00	200.00	1		ديفرانسي-تكتك-كامل
7.00	7.00	1		رولمون-تكتك-ك
28.00	28.00	1		سرسيون تكتك-موديل جديد-كامل
5.00	5.00	1		سلك تكتك-GEAR-1M
2.50	2.50	1		سنسر-فريم-تكتك
2.50	2.50	1		علبة توصيل-6 برغي-
10.00	10.00	1		فقسات-تكتك-طلقم
8.00	4.00	2		قاعده-تثبيت-مقص
95.00	95.00	1		كف كهربا-BRSH-60/72V 1500W
10.00	10.00	1		كيدون-تكتك-حديد
7.00	7.00	1		مسكة تكتك-GEAR-
8.00	8.00	1		مسكة تكتك-فريم ايد-
6.00	6.00	1		مسكة سرعة-FR-3S
40.00	40.00	1	2	مقص-تكتك-جوز
120.00	120.00	1		موتير تكتك-72V 1500W-
661.50				المجموع :

رصيد حسابكم الكامل 0.00

4.6 Electrical study

Abdallah Kassem

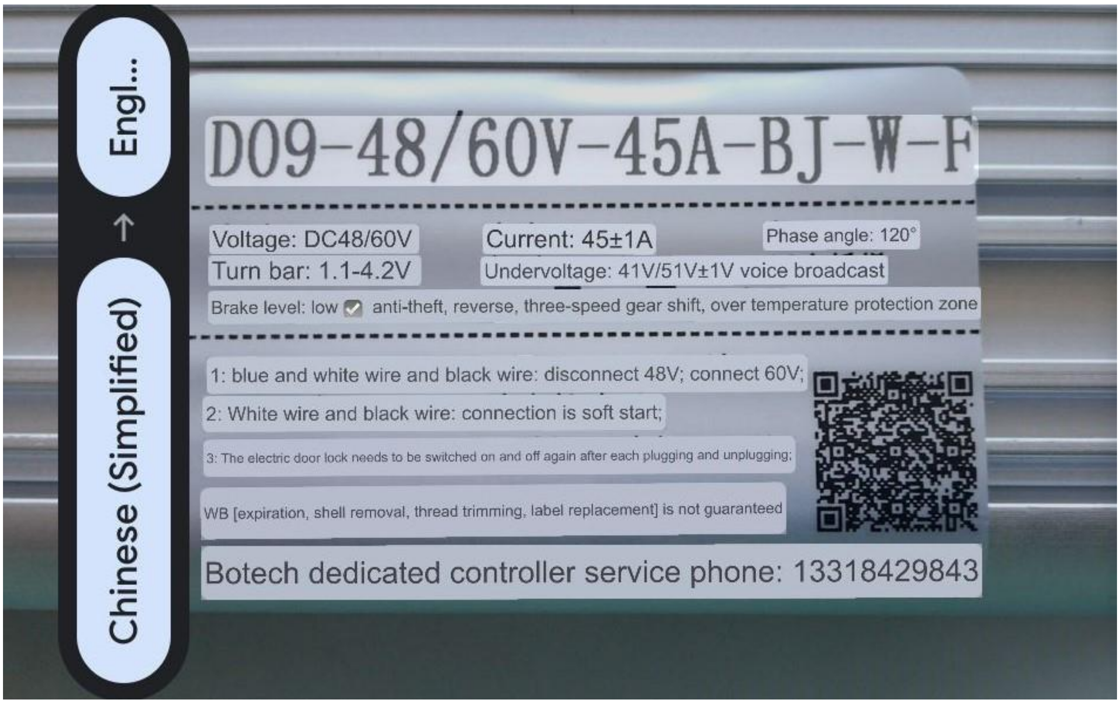
4.7 Official answers

محمد الصعيدي مخلص معاملات
+961 70 113 677

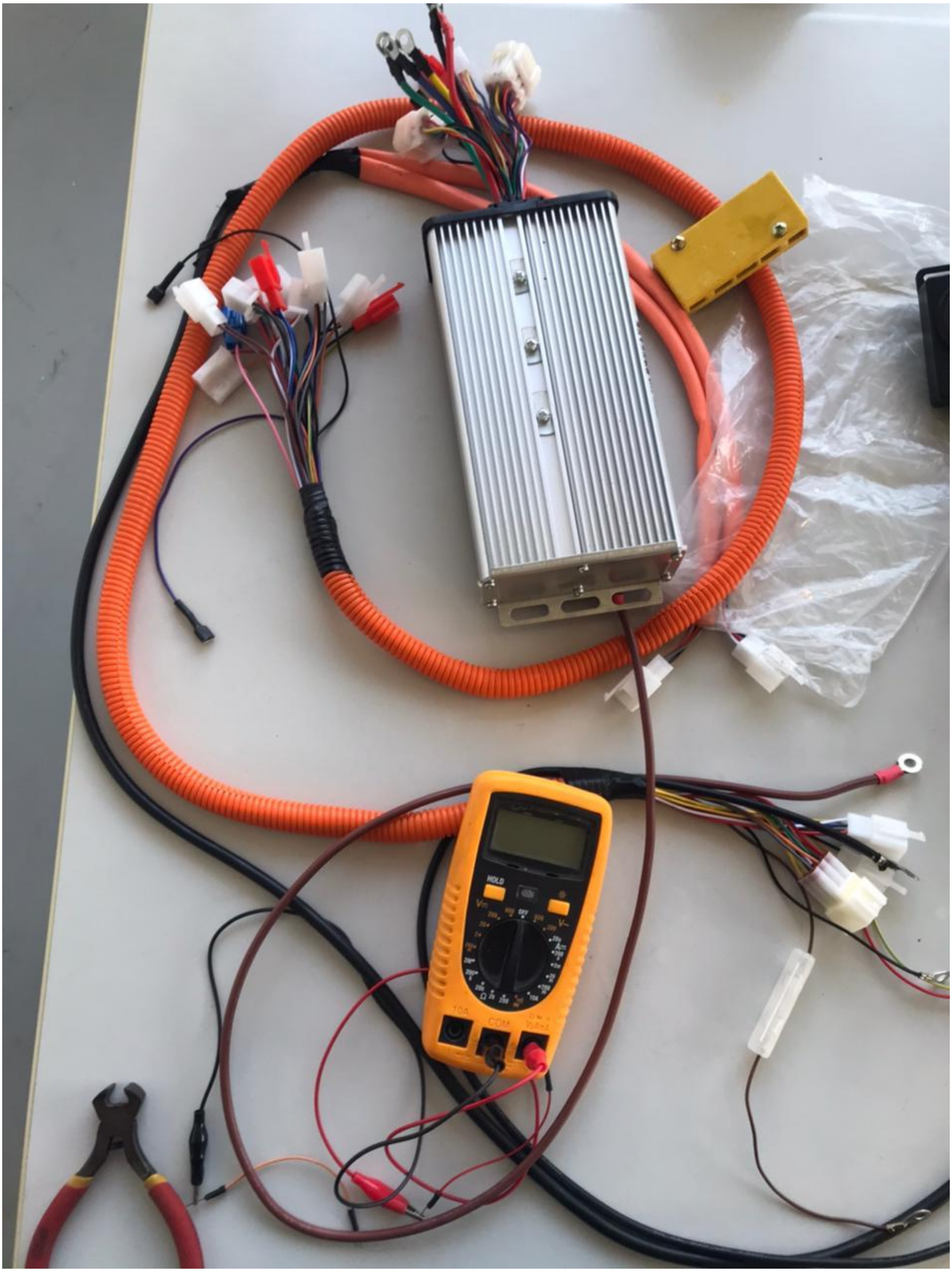
5 Electric/Electronic of E-Tuktuk[1]

5.1 Parts

5.1.1 Controller



[1] https://aecenar.com/index.php/companies/nl-automotive-systems-nlas/e-tuktuk/e-tuktuk-mechanical-realization

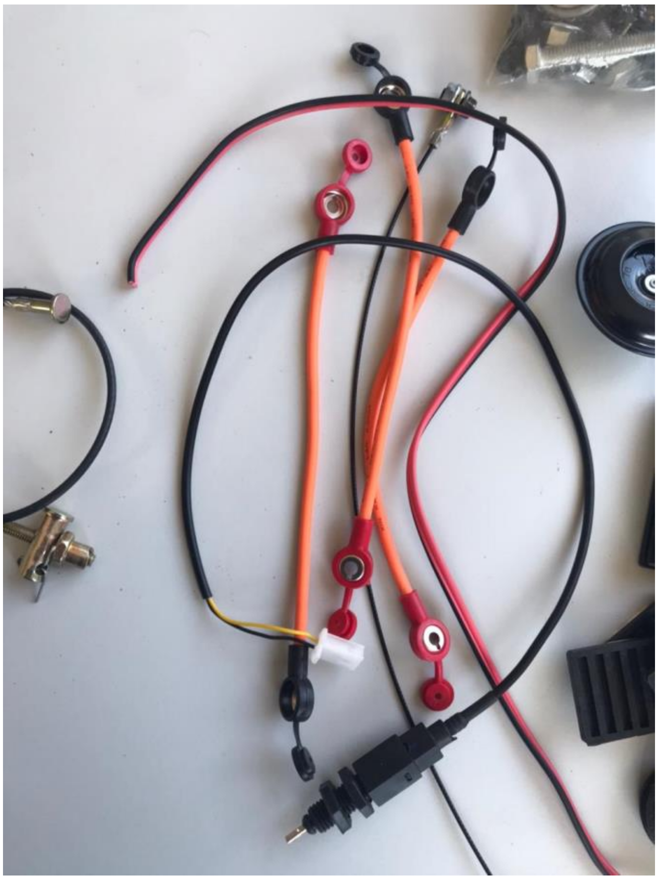

HOLD
OFF
10A
COM

5.1.2 1000w Electric Motor:

5.1.3 The Throttle Handlebar and lighting/Flasher controller:

5.1.4 Lighting and flashers

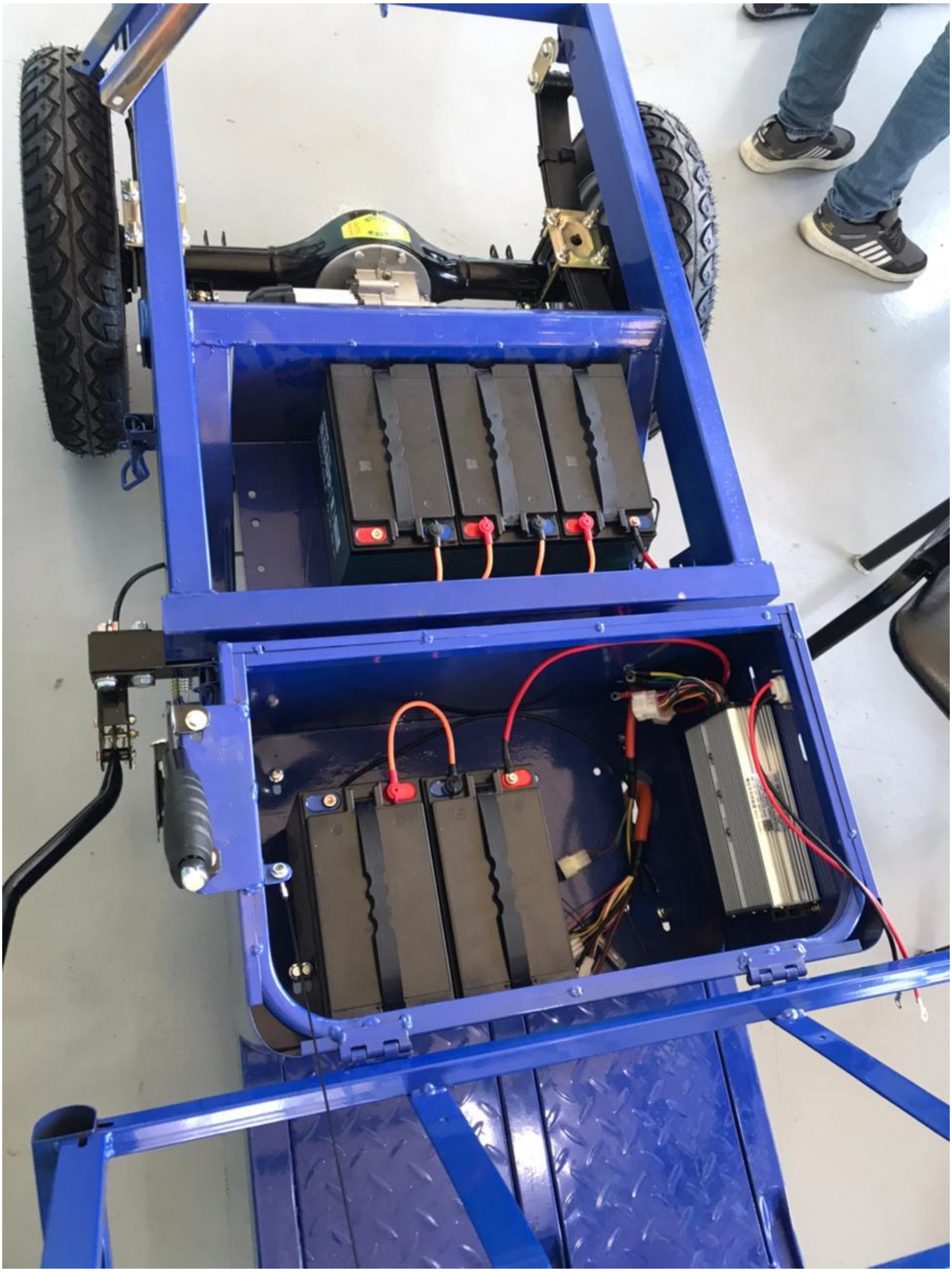
5.1.5 5 Batteries 12V , 45.2 Ah

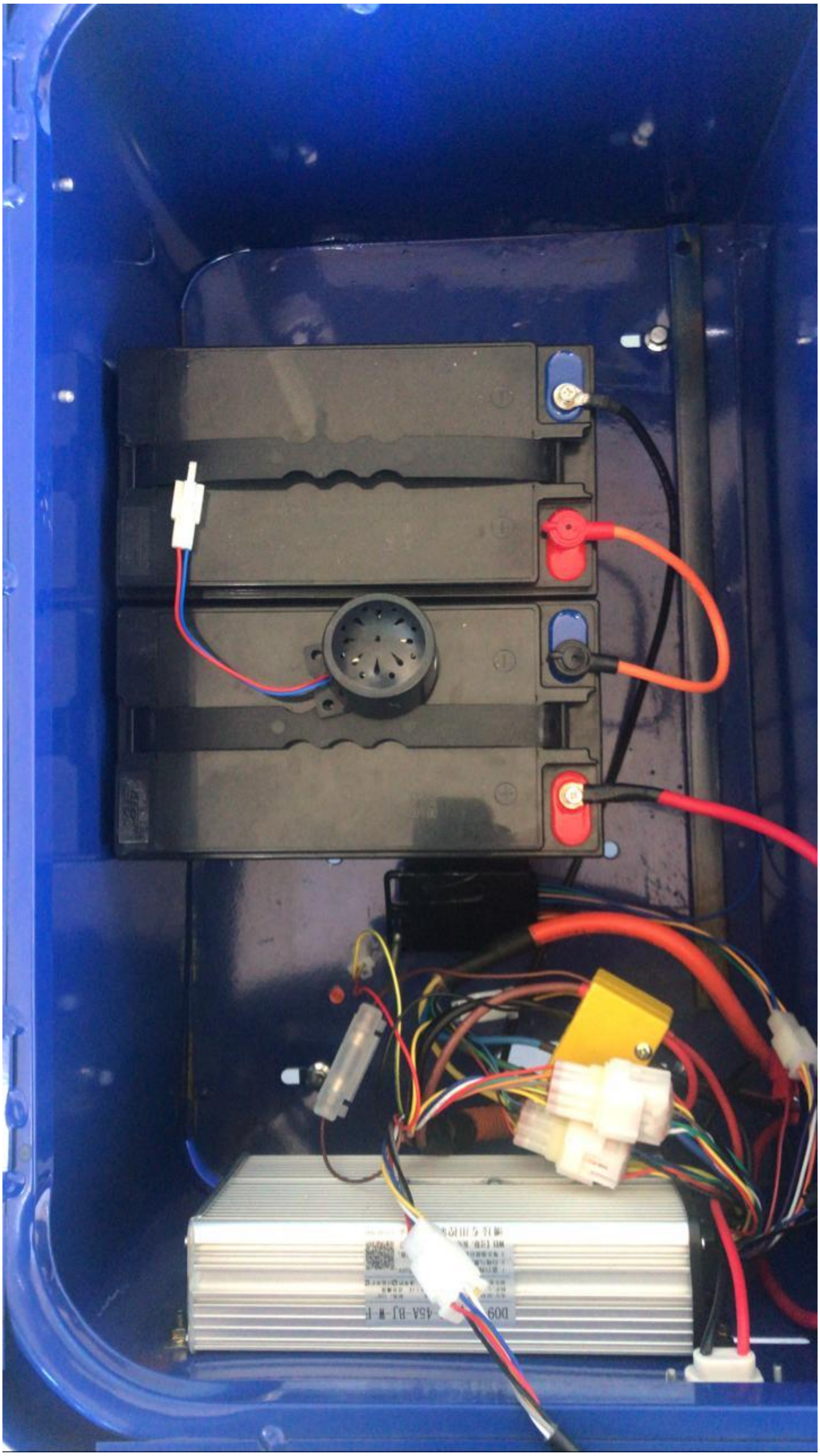


5.1.6 Batteries charger


电动车充电器
产品型号: 60V 45Ah
生产日期:
输入功率:≈360W
直流输出电压: 60-74.4V
直流输出电流: 5.5A±0.2A
输入电压: 220V～50Hz
执行标准: T/ TCDZ 0001-2019
注意事项
使用前应充分阅读使用说明书。
本充电器仅适用于铅酸电池充电。
用于户内使用，谨防雨淋。
禁止给不可再充电的电池充电。
严禁充电器放在电动车内或电动车上充电。
内有高压，非专业人员请勿打开。
如电源软线损坏，须由专业人员更换。
警告:

5.1.7 All electric parts installation with batteries and controller





6 Lithium-Ion Batteries Manufactoring Concept and Battery Management System (BMS) Design

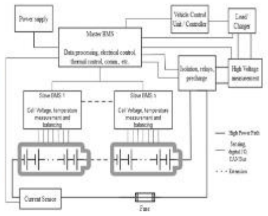
6.1 Overview

AECENAR
بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region

NLAS AUTOMOTIVE SYSTEMS

Lithium-Ion Battery Charger (18650)

Battery Management System(BMS)



1 **Theory of Operation** – Theoretical and mathematical aspects of Li-Ion battery charging

2 **Hardware** – Hardware design aspects of Li-Ion chargers

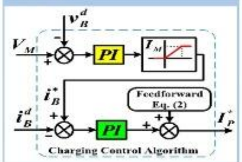
3 **Circuit Diagram** – Li-Ion charger circuit diagram

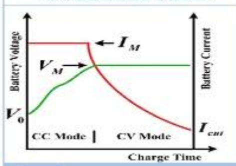
4 **PCB Layout** – PCB Layout for Li-Ion Charger

5 **User Interface** – Lithium-ion charger user interface

1.1 CC-CV Charging

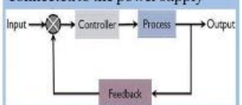
Li-Ion batteries are charged using the constant current charging (CC-CV) method at a constant current to reach a certain voltage Vmax = 4.2Vcell.





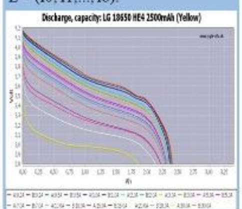
1.2 Control Loop

The "–" battery connected to the positive power supply (by MOSFET) The "-" battery connected to the power supply



1.3 State-of-Charge Estimation

The state of charge of the SOC is read through the battery voltage V and compared with the values stored in the lookup table L = (l0, l1,…, l8).



1.4 Safety

The charger implements many safety features, such as under-voltage, over-voltage, short circuit, and open circuit detection.

1.5 Trickle Charging

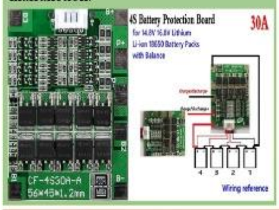
Once the end-of-charge (EOC) criteria are met, the charger cuts off the charging current, switches to idle mode, and continuously monitors the battery voltage.

2.1 Mechanical Design

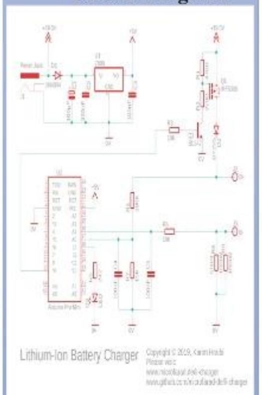
We used four LG 18650 HE4 Li-Ion cells and a battery protection board (or battery management system also known as BMS). Modern lithium-ion cells use much less space.

2.2 Battery Protection Board

It is necessary to use a dedicated battery protection board for each battery pack. This provides additional protection to prevent over-charging or over-discharging due to software or hardware malfunction.



3.1 Li-Ion Charger Circuit Diagram

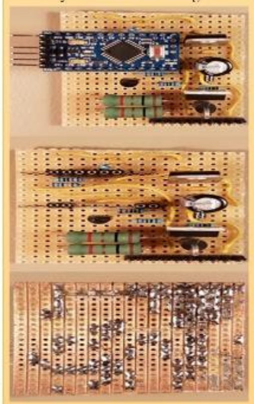


3.2 Different Number of Cells

The following values for R2, R4 and the power supply voltage need to be chosen in order to charge different numbers of Cells:

N_{cells}	Power Supply	R_2	R_4
1	5V-6V	220Ω	39KΩ
2	10V-15V	100Ω	82KΩ
3	14V-20V	220Ω	120KΩ
4	18.5V-20V	220Ω	180KΩ

All components are of the punch-hole type and are mounted on a PCB board. The Figure below shows the PCB layout of a Li-Ion charger.



The pin header located at the top right corner is used for connecting all the external wires. Following is the pinout assuming that pin 1 is at the top right corner and pin 10 is towards the middle of the board.

Pin	Purpose
1 *	LED +
2 *	LED -
3,4 ⏚	Power supply +
5,6 ⏚	Battery +
7,8 ⏚	Power supply -
9,10 ⏚	Battery -

5.1 LED Indicator

The charger status is displayed by turning on or flashing a single LED

Blinking Pattern	Meaning
On for half a second every 2 seconds	Ready, waiting for the battery to be connected
Solid on	Battery charging
On For 0.1 second every 2 seconds	Battery fully charged
Blinking fast (0.4 s period)	Error
Blinking very fast (0.2 s period)	Calibration mode

5.2 Command-Line Interface

This simple lithium-ion battery charger features a CLI that can be accessed via the Arduino's RS232.
Once turned on, the charger will display the current firmware version and present with a list of commands.
Some of these CLI commands must be supplied with arguments.

Command	Description
h	Help- show the list of available commands
.	Display the real-time parameters, including the charge duration T, charge capacity C, battery voltage V, charging current I, maximum charge duration T_{max}, maximum charge capacity C_{max}, maximum charging voltage V_{max}, maximum charging current I_{max}, PWM duty cycle, voltages V_1, V_2 and their raw ADC values $V_{1,raw}$ and $V_{2,raw}$
r	Show the list of calibration constants that are stored within EEPROM
t	Show the contents of the trace circular buffer
ncells <integer>	Set the total number of cells within the battery pack N_{cells}, the value provided as an argument will be validated and stored in EEPROM
cfull <integer>	Set the battery design capacity C_{full} in mAh, the value provided as an argument will be validated and stored in EEPROM
ichrg <integer>	Set the battery charging current I_{charge}, the value provided as an argument will be validated and stored in EEPROM
ifull <integer>	Set the end-of-charge current I_{full} in mA, the value provided as an argument will be validated and stored in EEPROM
lut <index> <voltage>	Configure the state-of-charge lookup table (LUT). This command takes and index i = 0, 1, 2, …, 8 and the reference voltage l_i in mV as arguments. Each time this command is called, a new reference voltage value l_i is populated into the LUT and stored into EEPROM, more on this in the following section
rshunt <integer>	Set the shunt resistor value R_{shunt} in mΩ, the value provided as an argument will be validated and stored in EEPROM
cal <start|stop|v1|v2> <mv>	The voltage calibration mode is entered by calling cal start and exited by calling cal stop. V_1 is calibrated using cal v_1 <mv>. V_2 is calibrated using cal v2 <mv>. <mv> is the measured voltage level in millivolts. Please refer to the next section for more details about the calibration procedure.

5.3 Calibration Procedure

This section provides an example on how to perform the first-time calibration of the Lithium-Ion battery charger using the CLI over the serial monitor.

5.3.1 Initial ranking

Initial configuration parameters must be loaded into the EEPROM by executing a command sequence.

ncells 4	lut 0 3200	lut 5 3710
cfull 2500	lut 1 3450	lut 6 3825
ichrg 1500	lut 2 3530	lut 7 3920
ifull 150	lut 3 3610	lut 8 4020
rshunt 500	lut 4 3650	

5.3.2 Voltage calibration

After performing the initial step please proceed to calibrate the ADC readings for voltages V1, V2:

1. Enter the Cal start command in the serial monitor.
2. Connect a constant voltage source between terminal B and ground.
3. Enter the command cal-v2 into the serial monitor
4. Connect a constant voltage source between terminal B+ and the ground of the power supply.
5. Enter the command cal v1 <value> into the serial monitor
6. Check the voltage calibration by applying a known voltage to both B+ and B-.
7. Repeat steps 2, 3,... and 6 until the voltage V readings are correct.
8. Enter the command cal stop in order to exit the voltage calibration mode.

5.3.3 Current calibration

Please proceed with calibrating the reading of the current I by following the steps below:

1. Connect a discharged lithium-ion battery in series using a digital ampere meter (set to the 10 A range) to terminals B+ and B-.
2. 2. The Charging message should appear and the current value should begin to increase gradually to approximately 1.5 A.
3. 3. Enter the command [.] and check the displayed value of I.
4. If output of the[.] command is higher than amper meter reading: Increase the Rshunt by 10 mΩ.
5. If output of the[.] command is lower than amper meter reading: decrease the Rshunt by 10 mΩ.
6. Repeat steps 3,4,5 until the current I readings are correct.

5.4 Trace Buffer

A lithium-ion battery charger records events that occur during the charging process in a circular buffer within the available EEPROM space. The contents of the trace buffer are dumped using the t command.

```
0: * 16760      6: i 1495       106: i 241
0: % 0          8: v 14137      108: v 16759
0: v 7820       8: i 1503       108: i 231
0: T 135        10: v 14206     110: v 16764
0: C 3263       (skipped...)    110: i 221
0: S 150        100: v 16767    112: v 16761
0: I 1500       100: i 638      112: i 150
2: v 13222      102: v 16764    113: F 1
2: i 1495       102: i 529      113: t 113
4: v 13719      104: v 16761    113: c 2508
4: i 1499       104: i 381      113: v 16767
6: v 13982      106: v 16754    113: i 139
```

Event	Description	Event	Description
*	Beginning of the charging cycle, indicates the maximum battery voltage V_{max} in V	i	Instantaneous battery current I in mA
%	Initial charge state %	F	Battery full, indicates the end-of-charge condition (1 = I_{full} reached, 2 = C_{max} reached, 3 = T_{max} reached)
T	Maximum permissible charging time T_{max} in minutes	t	Actual charging time T in minutes
C	Maximum permissible charging capacity C_{max} in mAh	c	Actual charged capacity C in mA
S	Safety charging in progress, I_{safe} is indicated in mA	E	Error (1 = over-volt, 2 = under-volt, 3 = open-circuit, 99 = CRC fail)
I	Normal charge in progress, indicates I_{charge} in mA		
v	Instantaneous battery voltage $V=V_1-V_2$ in mV		

Ahmad Dannawi @AECENAR/20-9-2023

6.2 Lithium Battery Prototype Manufactoring[2]

6.3 Lithium-Ion Battery Charger[3]

This is **Lithium-Ion battery charger** implemented on **Arduino**. Has more advanced features like:

- State of charge estimation.
- **EEPROM** logging.
- Command-Line interface.

It uses the **constant current constant voltage (CC-CV).**

The rationale behind this project was to upgrade the depleted battery pack and charger of an old cordless drill from **Nickel-Cadmium (Ni-Cd)** to **Lithium-Ion (Li-Ion)** technology.

Warning: Lithium-ion batteries are dangerous devices. Overcharging, short circuiting, or misuse of lithium-ion batteries may result in fire and/or violent explosion. It is necessary to equip each lithium-ion battery with its own dedicated battery protection board (or battery management system also known as BMS).

6.3.1 Theory of Operation

The following subsections cover the theoretical and mathematical aspects of charging a **Li-Ion battery**.

6.3.1.1 CC-CV Charging

Li-Ion batteries must be charged using the **Constant Current Constant Voltage (CC-CV)** charging method. This method consists of charging the battery at a constant current $\mathbf{I_{charge}}$ until a certain voltage threshold $\mathbf{V_{max}=4.2V_{cell}}$ is reached, then gradually reducing the charging such that the constant cell voltage $\mathbf{V_{max}}$ is not exceeded. Charging is terminated once the current reaches a certain minimum threshold $\mathbf{I_{full}}$ of typically **50-150 mA**.

Additional End of Charge (EOC) standards have been implemented for safety reasons. These include time-based and capacity-based **EOC** detection. When the battery is connected, the charger measures the voltage at its terminals. The **SOC** value is used to calculate the remaining capacity $\mathbf{C_{max}}$ and charging duration $\mathbf{T_{max}}$. Charging is terminated if any of these values are reached.

---

[2] https://aecenar.com/index.php/downloads/send/7-association-for-alternative-energy-research-vaef/263-lithiumbat-spec

[3] From Build a Lithium-Ion Battery Charger on Arduino | µF (microfarad.de) (https://www.microfarad.de/li-charger/)

6.3.1.2 Control Loop

The battery **"+"** terminal is connected to the positive power supply through a power **MOSFET** (field-effect transistor). The battery **"-"** terminal is connected to the power supply ground through a low-value **shunt resistor R_{shunt}.**

The charging current is regulated by **pulse width modulation (PWM)**, where the **MOSFET** is periodically turned on and off by the **Arduino** at a frequency of **31,250 kHz**. The charging current is controlled by gradually adjusting the **PWM** duty cycle which is the ratio between the **ON** and **OFF** duration of the **MOSFET**.

V_1 is the voltage measured at the **"+"** terminal of the battery and **V_2** is the voltage measured at the **"-"** terminal of the battery. Both voltages are measured relative to the power supply ground and are used to calculate the **voltage V** across the battery pack and the charging **current I** as follows:

$$\mathbf{V(Volt) = V1 - V2}$$

$$\boldsymbol{I(Ampere) = \frac{V2}{R_{\mathbf{shunt}}}}$$

Two separate **ADC** channels on the **Arduino** are used for measuring the above voltages. The **Arduino** continuously monitors **V** and **I** and adjusts the **PWM** duty cycle in order to achieve the desired constant current or constant voltage regulation.

6.3.1.3 State-of-Charge Estimation

The **state of charge SOC** is estimated by reading the battery **voltage V** and comparing it to a series of values stored in a lookup table **L = (l0, l1, l2, l3, l4, l5, l6, l7, l8).** The threshold voltages are derived from the particular discharge curve shown below for the **LG 18650 HE4** cells used in this project. ***(Source:* https://lygte-info.dk/review/batteries2012/LG%2018650%20HE4%202500mAh%20%28Yellow%29%20UK.html*).***

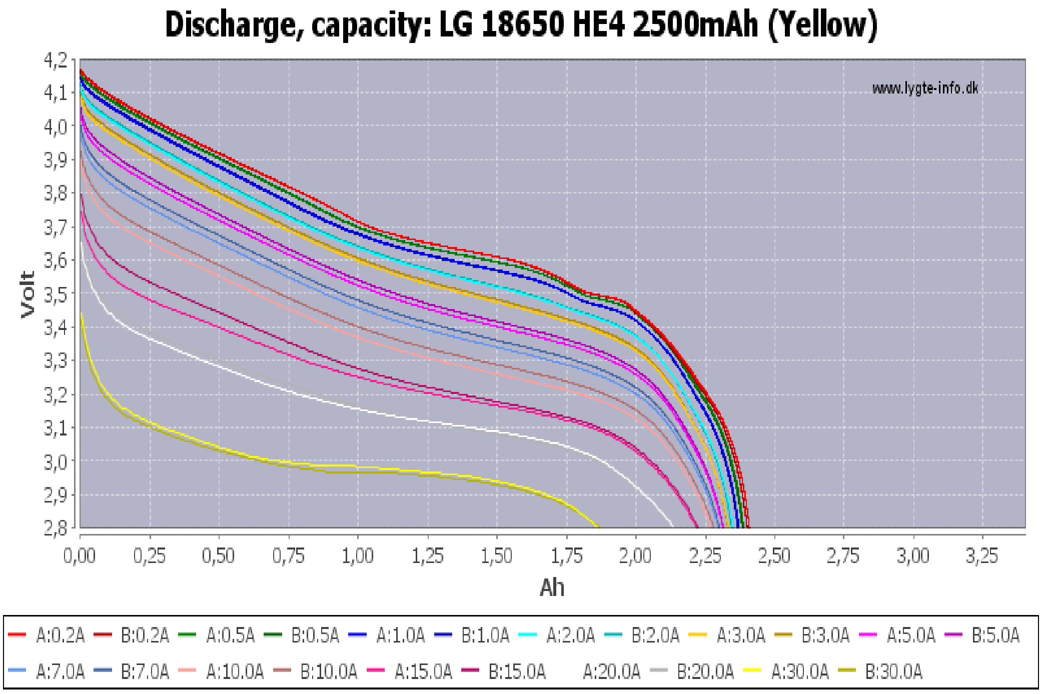


Figure 1: Statistic of Discharge, capacity (LG-18650-HE4-2500mAh)

The red discharge curve corresponding to **0.2A** discharge current has been used, whereas the values of **L** were assigned such that:

- **l_0= V~2.25Ah**
- **l_1= V~2.00Ah**
- **l_2= V~1.75Ah**

  .

  .
- **l_8= V~0.25Ah**

SOC is calculated as follows:

- V< **l_0: SOC= 0%**
- **l_0<V< l_1: SOC= 10%**
- **l_1<V< l_2: SOC= 20%**

  .

  .
- **l_8<V: SOC= 90%**

The remaining capacity **C_{max}** and charge duration **T_{max}** are derived as follows:

$$\boldsymbol{C_{\text{max}}\,(\text{mAh}) = C_{\text{full}} \times (100 - \text{SOC}) \times 1.3}$$

$$\boldsymbol{T_{max} = 3600 \times \frac{C_{\text{full}}}{I_{\text{charge}}} \times (90 - \text{SOC}) + 45.6}$$

Where **C** full is the design capacity of the battery and **C** is the nominal charging current. Note that **C_{max}** is increased by **30%** and **T_{max}** is increased by **45 min** in order to account for resistance losses and inaccuracy of **SOC** estimation.

6.3.1.4 Safety

The charger implements several safety features. These include:

- **Undervoltage.**
- **Overvoltage.**
- **Short circuit.**
- **Open circuit detection**.

The typical voltage range where a **Li-Ion battery** can safely operate is between $V_{\mathbf{min}} = \mathbf{SI}(2.5)V_{\mathbf{cell}}$ and $V_{\mathbf{max}} = \mathbf{SI}(4.2)V_{\mathbf{cell}}$. Operating outside this range is likely to cause permanent damage to the **Li-Ion** cells and may even result in a catastrophic failure such as an explosion or fire. In addition, the battery pack is protected by a battery protection board (or battery management system also known as **BMS**). The **BMS** measures the voltages of individual battery cells as well as the charging and discharging current flowing through the battery. The **BMS** uses a **solid-state switch** to disconnect the battery once the voltage or current values become outside the specified limits. For the most part, the **BMS** is completely transparent and does not interfere with the charging process, except for the case where the **BMS** disconnects the depleted battery in order to prevent **over-discharge**. In this case, the voltage of the depleted battery is still present across the **BMS** terminals through a high value resistor placed in series with the battery. This high value resistor causes a much lower voltage value to be measured at the charger terminals. Consequently, the charger must ignore the $\mathbf{V_{min}}$ lower limit and start charging at a much lower value of as low as $V_{\mathbf{start}} = \mathbf{SI}(0.5)V_{\mathbf{cell}}$. When served with a depleted battery, the charger will start charging at a low safety current $I_{\mathbf{safe}} = \frac{I_{\mathbf{charge}}}{\mathbf{10}}$ until the battery voltage reaches $V_{\mathbf{safe}} = \mathbf{SI}(2.8)V_{\mathbf{cell}}$, after which full charging current $\mathbf{I_{charge}}$ will be applied. Once the voltage reaches this threshold, it is no longer allowed to drop below $\mathbf{V_{min}}$. A voltage lower than $\mathbf{V_{min}}$ may cause an **"under voltage fault"** which may be caused by either a short circuit or open circuit of the battery. Open circuit is also detected if the charging current stays equal to zero while the **PWM** duty cycle increases beyond a specific threshold. This condition would raise an ***"open circuit error"***. Overvoltage is detected whenever the battery pack voltage momentarily exceeds $V_{\mathbf{surge}} = \mathbf{SI}(4.25)V_{\mathbf{cell}}$. Exceeding this value would raise an **"overvolt error".**

6.3.1.5 Trickle Charging

Once the **end-of-charge (EOC)** criteria has been met, the charger would **cut-off** the charging current and switch to an idle mode where it will continuously monitor the battery voltage. Once the voltage drops below a specific threshold of $V_{\mathbf{trickel/start}} = \mathbf{SI}(4.10)V_{\mathbf{cell}}$, a new charging cycle will be initiated using the following parameters:

$$\mathbf{V_{max}}\,(V_{\mathbf{cell}}) = V_{\mathbf{trickel\_max}} = (4.15)V_{\mathbf{cell}}$$

$$C_{max}(\mathbf{mAh}) = C_{full} \times \mathbf{0.3} + \mathbf{C}$$

$$T_{max}(s) = \mathbf{20} \times \mathbf{60} + \mathbf{T}$$

Where $\mathbf{C_{full}}$ is the battery design capacity. **C** and **T** are the accumulated charge capacity and charge time since the battery has been connected, including the initial charge and all of the subsequent trickle charge cycles. Given the above formulas, the trickle charge cycle uses a reduced $\mathbf{V_{max}}$ and allows for charging up to a maximum of **3%** of the battery design capacity during a maximum duration of **20 minutes**.

6.3.2 Hardware

The following **sub-sections** describe the hardware design aspects of the **Li-Ion charger.**

6.3.2.1 Mechanical Design

We used **four LG 18650 HE4 Li-Ion cells** and a battery protection board (or **battery management system** also known as **BMS**). Modern **lithium-ion cells** use much less space.

6.3.2.2 Battery Protection Board

It is necessary to use a dedicated battery protection plate for each battery pack. This provides an extra layer of protection to prevent **over charging** or **over discharging** due to software or hardware malfunction. In **figure 2** below, it shows the **4S/30A (4S means 4 cells in series)** battery protection board (or **BMS**).

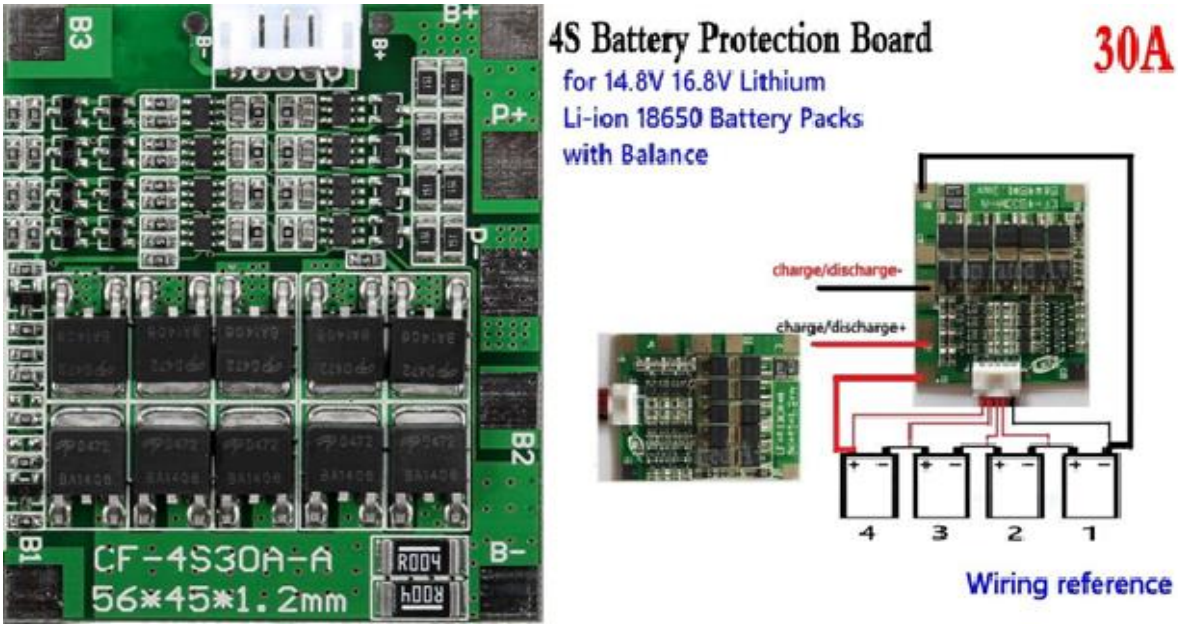


Figure 2: 4S Battery Protection Board

In **figure 2** can see the wiring diagram for connection the **4 Li-Ion cells** with the **BMS**.

This particular **BMS** includes the cell balancer feature. If the voltage of one or more cells becomes higher than the rest of the pack, the **BMS** would actively discharge those cells to ensure that all the cells of the battery pack share the exact same voltage.

6.3.2.3 Circuit Diagram

In **figure 3** below, it shows the **Li-Ion charger circuit diagram**.

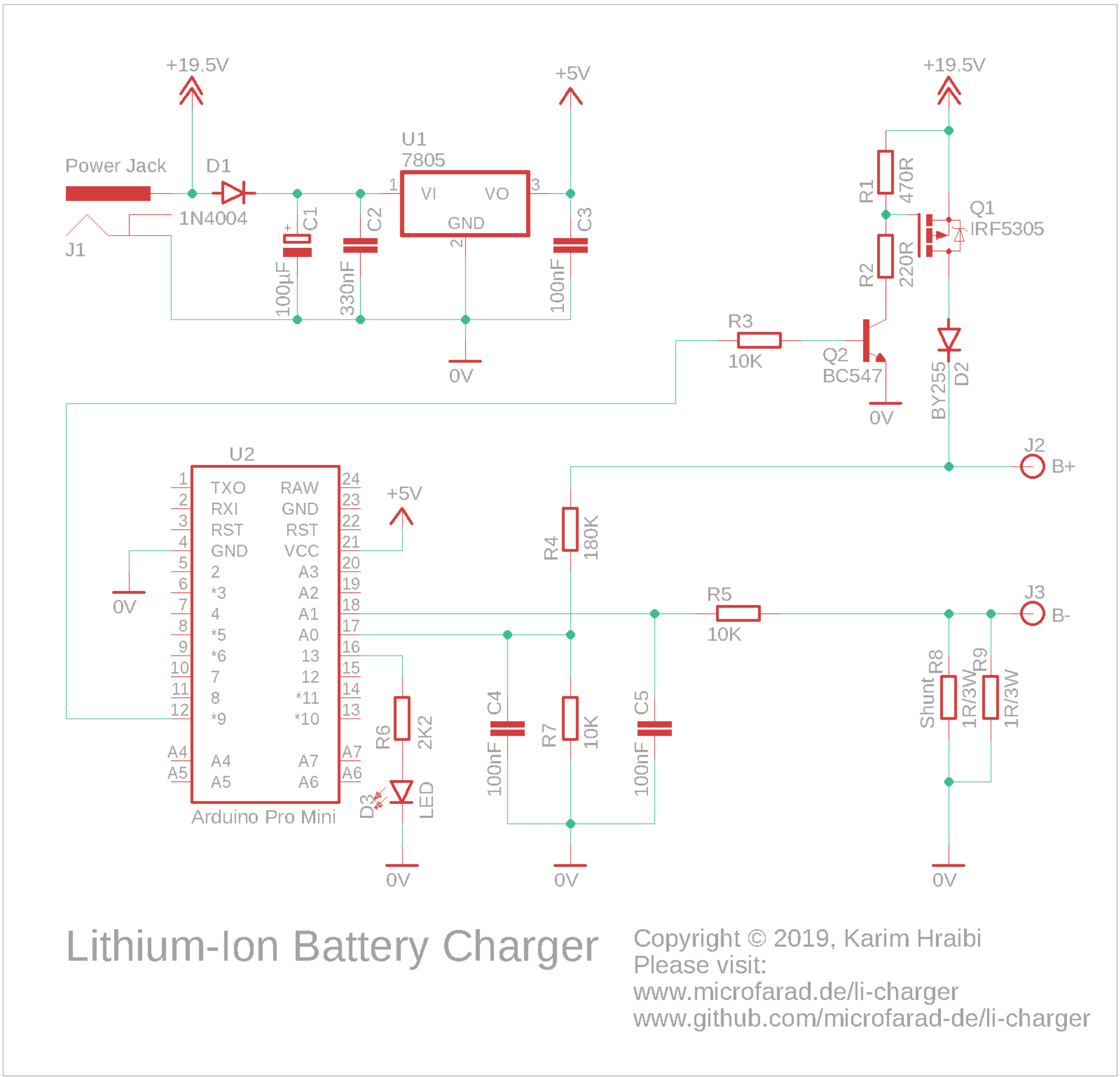


Figure 3: Li-Ion charger circuit diagram

In **figure 3** above schematic, the **19.5 V** of the power supply are stepped-down to **5 V** by the **7805-voltage regulator** U1. The **5 V** is used for powering the **Arduino board**.

The **Arduino Pro Mini** compatible board **U2** hosts an **AT-mega 328P** microcontroller running at **16 MHz** clock frequency and is used as the main processing unit for the device.

The **Lithium-Ion battery** is connected across the **B+** and **B-** terminals. The battery charging current is regulated by switching **P-Channel MOSFET (field-effect transistor) Q1** via **pulse-width modulation (PWM).**

The **PWM-enabled digital output pin 9** on the **Arduino** generates a **PWM** signal which drives the gate of the **MOSFET Q1** through the **NPN transistor Q2**. The **voltage divider** formed by **R1** and **R2** ensures that the **gate-source voltage** of the **MOSFET** stays within the specified limits.

A **current-sensing** shunt resistor connects the **B-** terminal with **ground**. It consists of **two 1 Ω / 3 W resistors R8** and **R9** connected in **parallel**. This results in a **total resistance** of **0.5 Ω**. At a **charging current** of $I_{charge} = 2A$, the voltage across the shunt will be exactly **1 V**; which is slightly below the **1.1 V** internal voltage reference of the **Arduino** thus corresponds to the full range of the **Arduino**'s **analog-to-digital converter (ADC).**

The **analog pin A_0** on the **Arduino** is used for measuring the **voltage V_1** between **B+** and **0 V**. and the **Analog pin A_1** is used for measuring **V_2** between **B-** and **0V**.

B+ is connected to **pin A_0** through a **voltage divider** consisting of **R_4** and **R_7**, the ratio has been chosen such that the **maximum battery** pack voltage of **16.8 V** would result in slightly less than the **Arduino**'s internal reference voltage of **1.1 V** at **A_0**. Please note that the value of **R_4** needs to be adapted to the number of cells in use. For example, using a **1 cell** setup would require reducing the value of **R_4** to **39 KΩ**.

B- is connected to **A_1** through a **current-limiting resistor R_5**; A **voltage divider** is not required for measuring **V_2** as its value stays below the **Arduino**'s **ADC** internal reference voltage.

Two 100 nF capacitors C_4 and **C_5** are used for blocking the **high-frequency** noise caused by the **PWM** from reaching the **analog inputs**, an essential measure for smooth ADC readings.

The **Diode D_1** protects the **7805** regulator from a reverse power supply polarity. The **diode D_2** protects the battery from a reverse polarity. it also prevents the battery from feeding power back into the **Arduino** in case the main power supply has been disconnected.

A **LED indicator D_3** and its dropper **resistor R_6** are connected to **Arduino**'s **digital pin13.**

Important: The battery terminals in the circuit diagram are labeled as B+ and B-. It is important to connect these terminals to the P+ and P- terminals of the Battery Management System (BMS) depicted in the figure 3. The BMS has its own set of B+ and B- terminals that must be connected directly to the battery terminals. It is crucial to avoid connecting the charger's B+ and B- terminals to the B+ and B- terminals of the BMS, as this would bypass the BMS and prevent it from safeguarding the battery against overcharging.

6.3.2.4 Different Number of Cells

The following values for **R_2**, **R_4** and the power supply voltage need to be chosen in order to charge different numbers of Cells:

N_{cells}	Power Supply	R_2	R_4
1	5V-6V	220Ω	39KΩ
2	10V-15V	100Ω	82KΩ
3	14V-20V	220Ω	120KΩ
4	18.5V-20V	220Ω	180KΩ

Table 1: N_{cell} with Power Supply, R_2, R_4

When charging **1 cell**, the following circuit modifications must be performed:

- Remove the **voltage regulator U_1** and **capacitor C_3** and power the **Arduino** directly from the output of **D_1.**
- Replace **Q_1** with a **IRLML2244 MOSFET**.
- Increase **R_1** to **10 KΩ.**

- Remove **Q_2** and **R_3.**
- Connect **R_2** directly to **Arduino digital pin 9**.
- Modify the code in **li-charger.ino** to invert the **PWM** signal by subtracting the **PWM** duty cycle from **255** within all instances of **analogWrite ()** using one of the following statements in the figure below:

```
analogWrite (MOSFET_PIN, 255 - G.dutyCycle);  // Replaces analogWrite (MOSFET_PIN, G.dutyCycle)
analogWrite (MOSFET_PIN, 255);                // Replaces analogWrite (MOSFET_PIN, 0)
```

Figure 4: code of analogWrite () in li-charger.ino

6.3.3 PCB Layout

All components are of the **punch-hole type** and are mounted on a **PCB board**. The **Figure 4** shows the **PCB layout** of a **Li-Ion charger**.

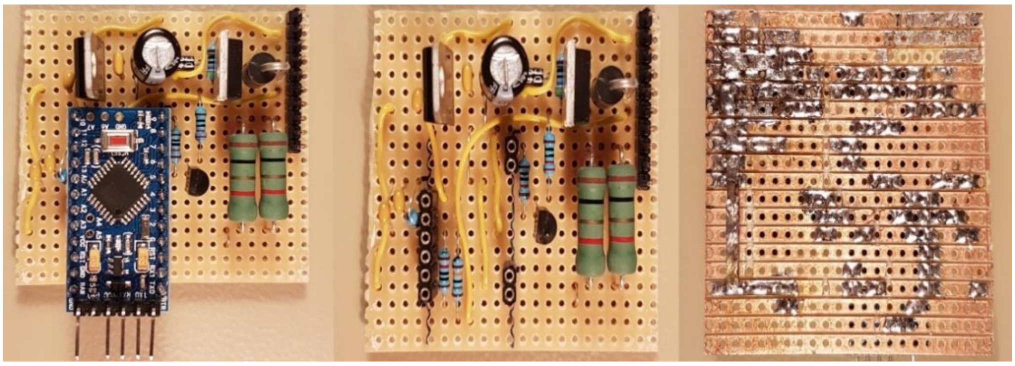


Figure 5:PCB layout of the Li-Ion charger

The **MOSFET Q_1 (TO-220 device in the top right corner)** and large **green-colored shunt resistors** will get pretty hot so adequate ventilation needs to be assured. The following measures has been taken to avoid overheating:

- The **shunt resistors R_8** and **R_9** are raised by around **5mm** from the **PCB** in order to assure adequate cooling.
- A series of holes has been drilled in the bottom of the enclosure in order to allow for a better air flow.
- The charging current **I_{charge}** has been limited to **1.5 A**.

The **electrolytic capacitor C_1** towards the top center of the board is in a **sub-optimal** position due to its location between two hot components, the **7805 regulator** and the **MOSFET**. High temperatures reduce the lifespan of **electrolytic capacitors** thus the must be kept away from heat sources.

The **pin header** located at the top right corner is used for connecting all the external wires. Following is the pinout assuming that **pin 1** is at the top right corner and **pin 10** is towards the middle of the board.

Pin	Purpose
1 *	**LED +**

2 *	LED -
3,4 ⸸	Power supply +
5,6 ⸸	Battery +
7,8 ⸸	Power supply -
9,10 ⸸	Battery -

Table 2: All pinhead work

* The LED dropper resistor is located on a separate PCB together with the LED itself.

⸸ Two pins are connected in parallel in order to increase their current capacity.

6.3.4 User Interface

The following sections describe the user interface of the **Lithium-Ion charger**. It consists of a **LED indicator** and **a Command-Line Interface (CLI).**

6.3.4.1 LED Indicator

The charger status is displayed by turning on or flashing a single **LED** as shown

in **Table 3.**

Blinking Pattern	Meaning
On for half a second every 2 seconds	Ready, waiting for the battery to be connected
Solid on	Battery charging
On For 0.1 second every 2 seconds	Battery fully charged
Blinking fast (0.4 s period)	Error
Blinking very fast (0.2 s period)	Calibration mode

Table 3: The meaning of what is displayed via the LED

6.3.4.2 Command-Line Interface

This **Lithium-Ion battery charger** features a **Command-Line Interface (CLI)** that can be accessed via the **Arduino**'s **RS232 serial port**. The easiest way to connect to the **CLI** is to open the serial monitor of the **Arduino IDE** while connected to the charger using a **FTDI USB** to **Serial converter**. Please ensure that the **Baud rate** is set to **115200**.

Once up and running, the charger will display a welcome message on the serial monitor, show the current firmware version and present with the list of available commands shown in the following list.

Some of these **CLI commands** need to be provided with arguments. Thus, one needs to enter the command followed by **one** or **two** arguments separated by a **white space**. SSS

Command	Description
h	Help- show the list of available commands
.	Display the real-time parameters, including the charge duration T, charge capacity C, battery voltage V, charging current I, maximum charge duration T_{max}, maximum charge capacity C_{max}, maximum charging voltage V_{max}, maximum charging current I_{max}, PWM duty cycle, voltages V_1, V_2 and their raw ADC values $V_{1, raw}$ and $V_{2, raw}$
r	Show the list of calibration constants that are stored within EEPROM
t	Show the contents of the trace circular buffer
ncells <integer>	Set the total number of cells within the battery pack N_{cells}, the value provided as an argument will be validated and stored in EEPROM
cfull <integer>	Set the battery design capacity C_{full} in mAh, the value provided as an argument will be validated and stored in EEPROM
ichrg <integer>	Set the battery charging current I_{charge}, the value provided as an argument will be validated and stored in EEPROM
ifull <integer>	Set the end-of-charge current I_{full} in mA, the value provided as an argument will be validated and stored in EEPROM
iut <index>	Configure the state-of-charge lookup table (LUT). This command takes and index $\boldsymbol{i} = \mathbf{0, 1, 2, \ldots, 8}$ and the reference voltage l_i in mV as arguments. Each time this command is called, a new reference voltage value l_i is populated into the LUT and stored into

<voltage>	EEPROM, more on this in the following section
rshunt <integer>	Set the shunt resistor value R_{shunt} in mΩ, the value provided as an argument will be validated and stored in EEPROM
cal <start|stop|v1|v2> <mv>	The voltage calibration mode is entered by calling cal start and exited by calling cal stop. V_1 is calibrated using cal v_1 <mv>. V_2 is calibrated using cal v_2 <mv>. <mv> is the measured voltage level in millivolts. Please refer to the next section for more details about the calibration procedure.

Table 4: command followed by one or two arguments separated

6.3.4.3 Calibration Procedure

This section provides an example on how to perform the **first-time** calibration of the **Lithium-Ion battery charger** using the **CLI** over the serial monitor.

The calibration values are stored into the **Arduino**'s **electrically erasable programmable read-only memory (EEPROM).** A **cyclic redundancy check (CRC)** checksum is appended to the configuration parameters set and stored into **EEPROM** as well. All configuration parameters are validated and **out-of-range values** are automatically replaced with the corresponding failsafe values.

The current example assumes a system consisting of $\mathbf{N_{cells}= 4}$ connected in series having a design capacity of $\mathbf{C_{max}=}$ **2500mAh** charged using a current of $\mathbf{I_{charge}=}$ **1500mA**.

Important:

- **Do not connect the battery** during the calibration procedure unless instructed otherwise.
- Ensure that the voltage calibration procedure has been properly executed and verified prior to attempting to connect a **Lithium-Ion battery**. It is mandatory to connect a good quality battery protection board between the charger and battery. Failing to observe these precautions may lead to permanent damage or even explosion of the **Lithium-Ion cells**.

Initial ranking

A first step, the initial configuration parameters need to be loaded into **EEPROM** by executing the command sequence as shown in **figure 6** below:

ncells 4	**lut 0 3200**	**lut 5 3710**
cfull 2500	**lut 1 3450**	**lut 6 3825**
ichrg 1500	**lut 2 3530**	**lut 7 3920**
ifull 150	**lut 3 3610**	**lut 8 4020**
rshunt 500	**lut 4 3650**	

Figure 6: command sequence

A confirmation message will be printed on the serial monitor following each value entry.

Voltage calibration

Having performed the above initial step, please proceed for calibrating the **ADC** readings for the voltages **V_1, V_2** as shown below:

1. Enter the **Cal start** command in the serial monitor, this will activate calibration mode. The **Start Calibration** message should appear on the serial monitor.
2. Connect a constant voltage source of approximately **750 mV** between the **B-** terminal and the power supply **ground**, and measure its exact value using a digital multimeter. Note that **750 mV** corresponds to **1.5 A** flowing through the **shunt resistors R_8** and **R_9**.
3. Enter the command **cal v_2 <value>** into the serial monitor, where **<value>** is the value in **mV** of the voltage measured in the previous step. The value of the calibration constant **$V_{2,cal}$** will be displayed upon the successful calibration of **V_2**. If the calibration fails, the message Out of range will appear in the serial monitor.
4. Connect a **constant voltage source** of approximately **16800 mV (4200 mV per cell)** between the **B+** terminal and the **power supply ground**, and measure its exact voltage using a **digital multimeter**.
5. Enter the command **cal v_1 <value>** into the serial monitor, where **<value>** is the value in **mV** of the voltage measured in the previous step. The value of the calibration constant **$V_{1,cal}$** will be displayed upon the successful calibration of **V_1**. If the calibration fails, the message Out of range will appear in the serial monitor.
6. Verify the voltage calibration by applying a known voltage to each of **B+** and **B- (relative to 0 V)**, then enter the **[.](dot)** command and check the displayed values for **V_1** and **V_2** which must match the measured voltages at **B+** and **B-** as closely as possible.
7. Repeat **steps 2, 3, 4, 5 and 6** until the **voltage V** readings are correct.
8. Enter the command **cal stop** in order to exit the voltage **calibration mode**. The message **Calibration stop** should appear on the serial monitor.

Current calibration

Please proceed with calibrating the reading of the **current I** by following the steps below:

1. Connect a discharged **lithium-ion battery** in series using a **digital ampere meter (set to the 10 A range)** to terminals **B+** and **B-.**
2. The message Charging should appear in the serial monitor and the measured current value should start to gradually increase until it reaches a maximum of approximately **1.5 A.**
3. Enter the **[.] (dot)** command and check the displayed value for **I** which must match the measured current as closely as possible.
4. If the output of the **[.]** command is **higher** than the ampere meter reading: **Increase** the **R_{shunt}** value by **10 mΩ** by calling the **r_{shunt}** command.
5. If the output of the **[.]** command is **lower** than the ampere meter reading: **decrease** the **R_{shunt}** value by **10 mΩ** by calling the **r_{shunt}** command.
6. Repeat **steps 3, 4, and 5** until the **current I** readings are correct.

6.3.4.4 Trace Buffer

A **lithium-ion battery charger** records events that occur during the charging process in a circular buffer within the available **EEPROM** space. The contents of the trace buffer are dumped using the **t command**. Here is a sample trace log output for a complete shipping cycle as shown in **figure 7** below:

0: * 16760	6: i 1495	106: i 241
0: % 0	8: v 14137	108: v 16759
0: v 7820	8: i 1503	108: i 231
0: T 135	10: v 14206	110: v 16764
0: C 3263	(skipped...)	110: i 221
0: S 150	100: v 16767	112: v 16761
0: I 1500	100: i 638	112: i 150
2: v 13222	102: v 16764	113: F 1
2: i 1495	102: i 529	113: t 113
4: v 13719	104: v 16761	113: c 2508
4: i 1499	104: i 381	113: v 16767
6: v 13982	106: v 16754	113: i 139

Figure 7: t command

Trace messages have the format **<timestamp>: <event> <value>.** While the timestamp counts the minutes that have passed since the beginning of the charging process. The following table shows the available events and their descriptions:

Event	Description
*	**Beginning of the charging cycle, indicates the maximum battery voltage V_{max} in V**
%	**Initial charge state %**
T	**Maximum permissible charging time T_{max} in minutes**

C	Maximum permissible charging capacity C_{max} in mAh
S	**Safety charging in progress, I_{safe} is indicated in mA**
I	Normal charge in progress, indicates I_{charge} in mA
v	**Instantaneous battery voltage $V=V_1-V_2$ in mV**
i	Instantaneous battery current I in mA
F	**Battery full, indicates the end-of-charge condition (1 = I_{full} reached, 2 = C_{max} reached, 3 = T_{max} reached)**
t	Actual charging time T in minutes
c	**Actual charged capacity C in mA**
E	Error (1 = over-volt, 2 = under-volt, 3 = open-circuit, 99 = CRC fail)

Table 5: Available events and descriptions

6.3.5 Download:

Below you can find **GitHub download links** for the **Arduino firmware source code**, **Eagle schematic source files** and bill of material. All of the source code is distributed under the **GNU General Public License v3.0**.

Please note that the current implementation uses the watchdog timer functionality which requires the customized **Arduino** bootloader found under the **link** below. For more details, please follow the installation instructions found within the **README file** on **GitHub**.

Customized Arduino Bootloader

Lithium-Ion Charger Firmware

Eagle Schematic Source Files

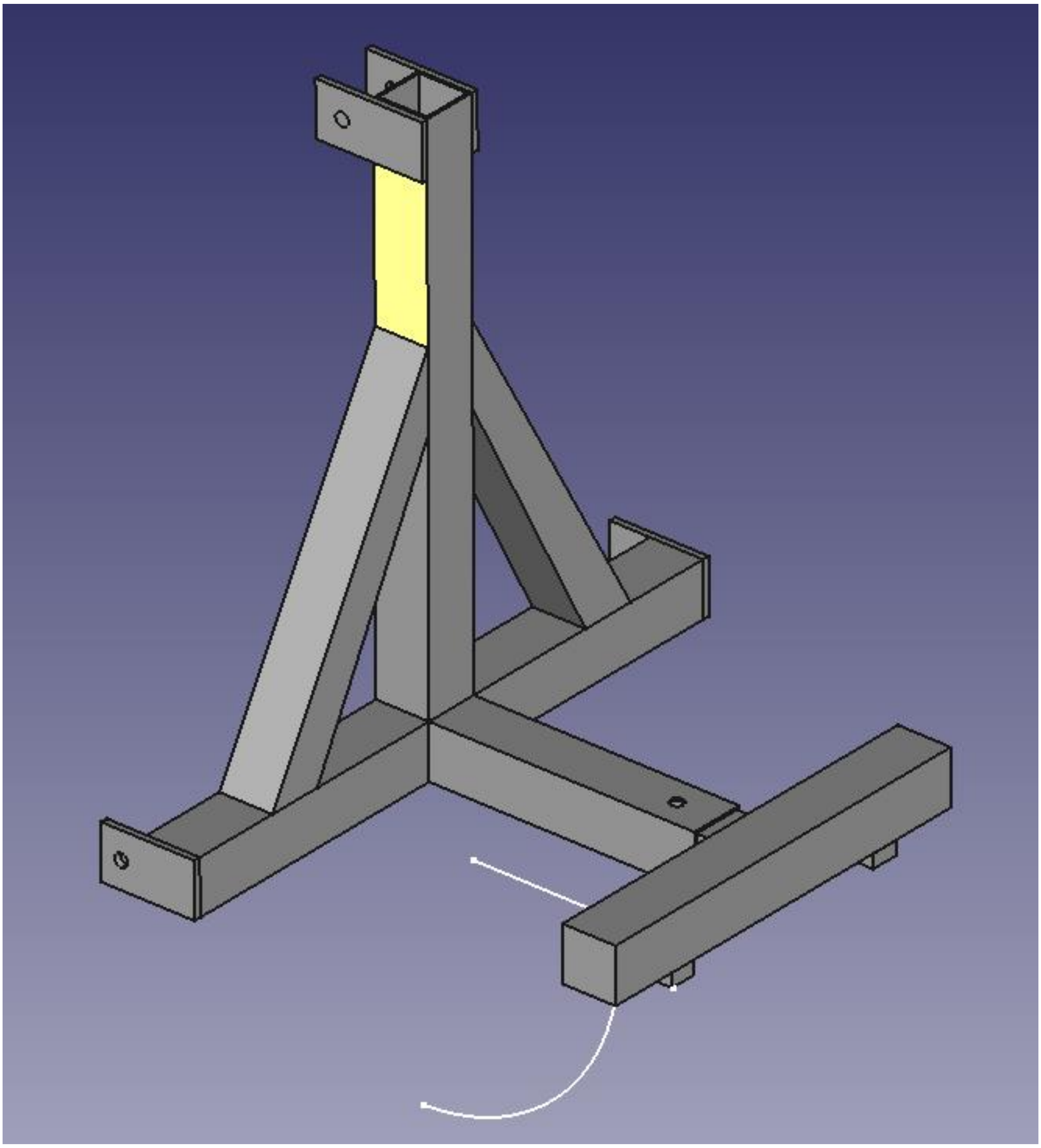
Bill of Material

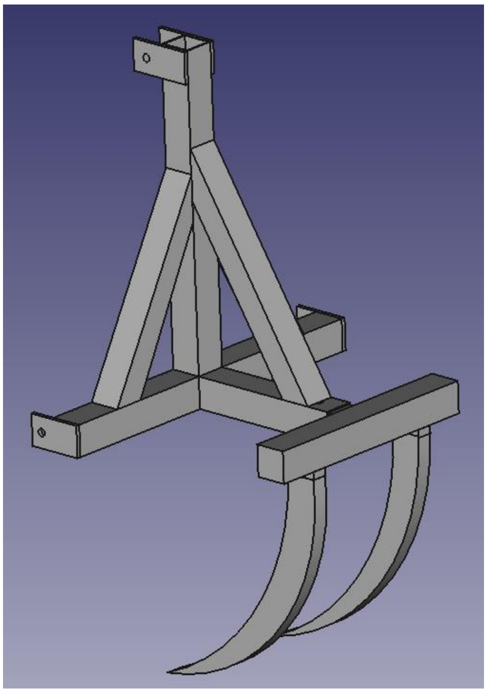
7 Agricultural Accessories

7.1 Mechanics of Agricultural Acessories

7.1.1 Hitch

7.1.1.1 FreeCad Design



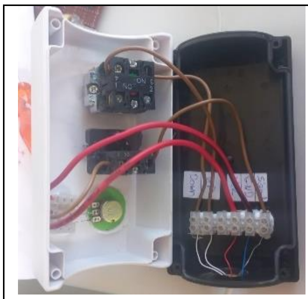
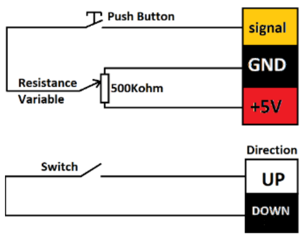


7.1.1.2 Mechanical Realization

7.1.1.3 Off-the-shelf device

7.2 E/E of Agricultural Acessories

7.2.1 Working on controlling the crane (25/6/2023)

8 Steps of work

8.1 Assemblage the Tuk-Tuk (10/1/2023)

8.2 Installing a new structure for solar panels (25/1/2023)

After modifying it from the shape of the blue Tuk-Tuk's structure.

8.3 Small Adjustments (1/2/2023)

Raise the box level by 4 cm.

Changing the type of tire rubber

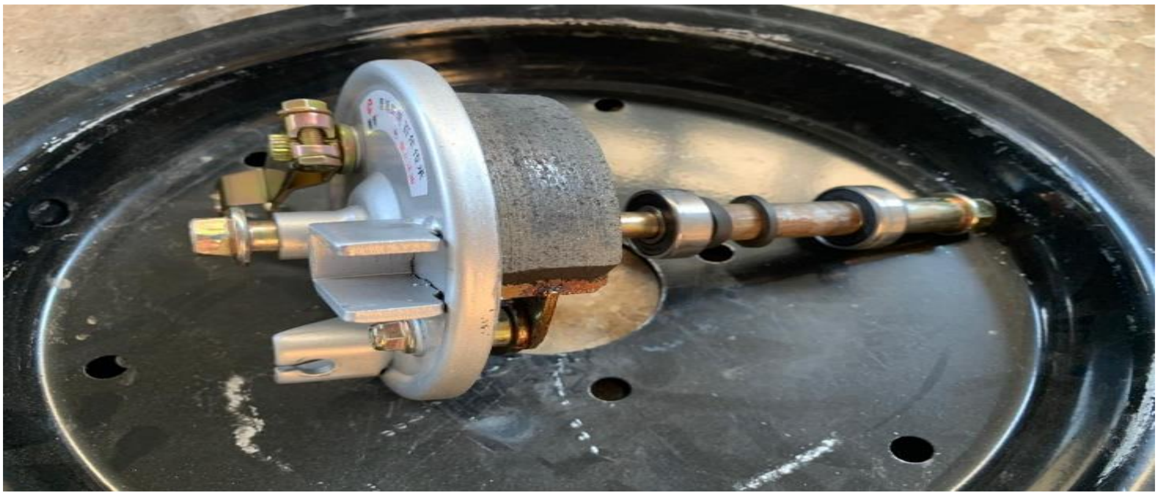
	
Figure 1: Before	Figure 2: After

8.4 Modified basic mechanics: (8/2/2023)

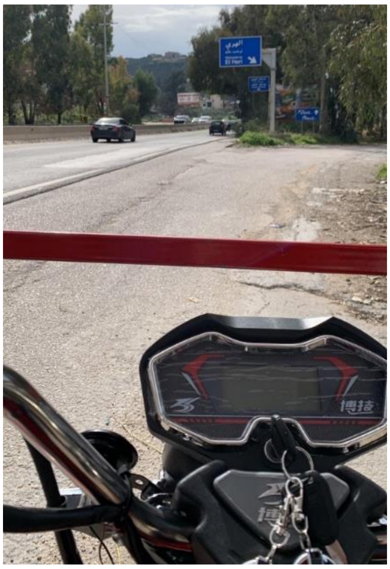
8.4.1 Add 2 springs to the front wheel

8.4.2 Adjust the springs.

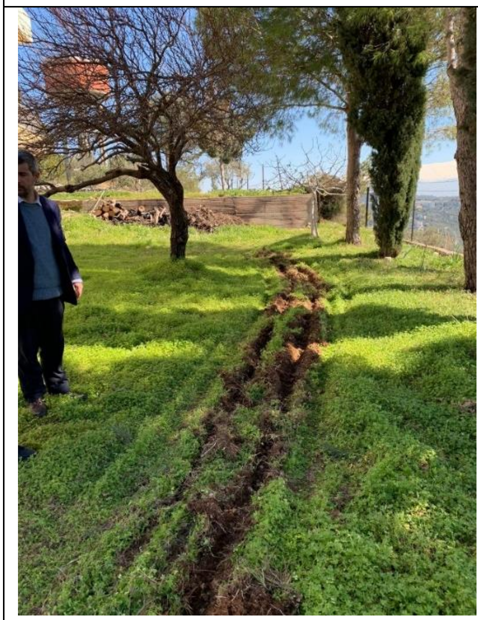
8.4.3 Changing the brake system (From the wire to the disc and the oil)



8.5 Transfer the red tuk-tuk to Ras Nhache (25/2/2023)

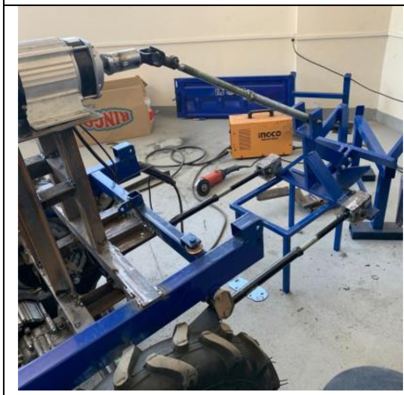


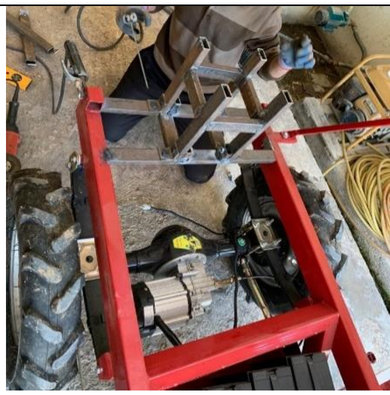
8.6 Trying the little blue dibble on the red tuk-tuk (12/3/2023)



8.7 Work on the crane of the dibble for red and blue tuk-tuk's (25/3/2023)

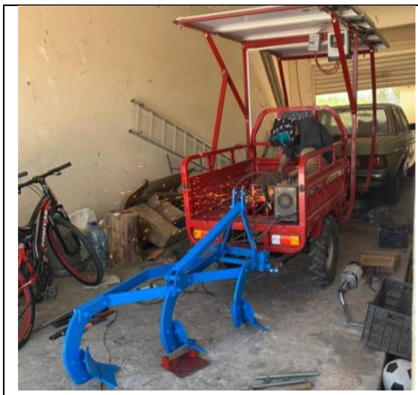




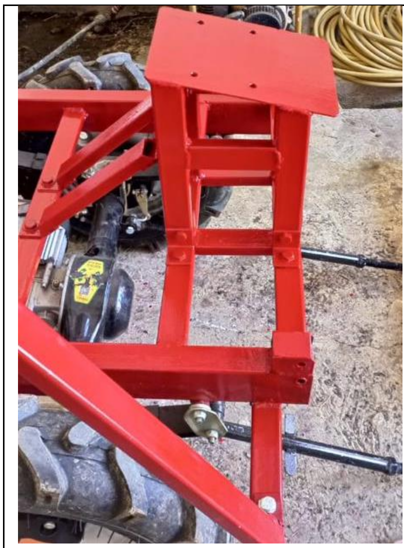

8.8 Installing the big red Dibble on the blue Tuk-tuk. (15/4/2023)

8.9 Installing the big red Dibble on the red Tuk-tuk. With modification to the crane base (17/4/2023)



8.10 Testing the big Dibble (23/5/2023)

8.11 Adjusting the crane base on the red tuktuk (30/5/202)



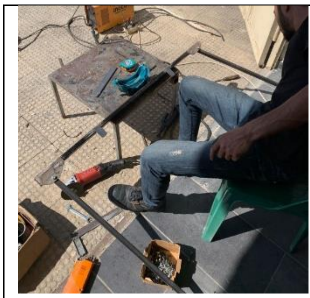
8.12 Paint the Tuk-tuk red (1/6/2023)

8.13 Testing the Tuk-tuk (6/6/2023)

8.14 Receiving the store next to the center and transporting the Tuk-tuk to it from Ras Nhach.(10/6/2023)

8.15 Design and installation of an irrigation system on a red Tuk-tuk. With some modifications from the old system in the blue Tuk-tuk (22/6/2023)

8.16 Grass shredder installation. (3/7/2023)

8.17 Installing a 12V water pump on the red Tuk-tuk (7/7/2023)

8.18 Irrigation test (10/7/2023)

8.19 20- Installing two front tires instead of one tire on the red tuk-tuk. (16/8/2023)

8.20 Testing and Marketing the red Tuk-tuk (20/8/2023)

8.21 The new Tuktuk's front budget is painted red (31/8/2023)

8.22 Used the red tuk-tuk by AECENAR team(Power plan) (20/8/2023 to present)

TBD : 3D and 2D designs fort he following parts :

Motor
The heart and soul of your vehicle is the internal electrical motor

Transmission
The transmission is a gearbox filled with gears and gear trains that makes effective use of the motor's torque to change the gears and power the vehicle.

Battery
The battery delivers the electricity needed to run your vehicle's electrical components. Without a battery, your car won't work.

Charger
Part of the electrical system, the charger charges the battery.

Front Axle
Part of the suspension system, the front axle is where the front wheel hubs are attached.

Front Steering and Suspension
Helps improve the ride and handling of the vehicle. Though systems vary in makeup, they typically include shocks/struts, ball joints, tie rod ends, rack and pinion steering system and idler/pitman arms.

Brakes
Found on all four wheels, your brakes are one of the most important safety

systems on your vehicle. Disc brakes can be found on the front and back wheels and feature brake pads and calipers. Drum brakes with brake shoes and wheel cylinders may be found on the back wheels of some vehicles.

Rear Axle

Key part of the suspension system to which the rear wheels are mounted.

Rear Suspension

As with the front suspension, the rear suspension contributes to the handling and ride quality of the vehicle. Systems can vary, but they usually are made up of shocks, **coil springs**, **ball joints**, **control arms** and CV joints

Text

Reference

NLAS ANNUAL REPORT 2022