Solar Cell Tech Report

1. Manufacturer's name and contact information

Maxeon Solar Technologies
+1 669 3215888

2. Stock number, type, or description

Type: MAXEON™ GEN III SOLAR CELLS.
Description: These are high-performance solar electric technology cells designed and manufactured by SunPower, known for producing 25-35% more power compared to conventional cells.

3. Manufacturer's quote for cell area (cm^2)

Cell Area: Approximately **153 cm^2**.

4. Manufacturer's quote for performance

The performance of the **Maxeon Gen III Cell** at Standard Test Conditions (STC)

Characteristic	NE3 Cells	ME3 Cells
Efficiency (%)	Min 24.4	24.00 - 24.4
Power (Wp)	Min 3.78	3.72 - 3.78
Vmpp (V)	0.621 - 0.630	0.616 - 0.626
Impp (A)	6.05 - 6.11	6.01 - 6.09
Voc (V)	0.728 - 0.735	0.724 - 0.734
Isc (A)	6.39 - 6.43	6.37 - 6.42
Grade	High Aesthetic, prime cells	High Aesthetic, prime cells

Wafer	Monocrystalline silicon	Monocrystalline silicon
Design	All back contact	All back contact
Front	Uniform, black antireflection coating	Uniform, black antireflection coating
Back	Tin-coated, copper metal grids	Tin-coated, copper metal grids
Cell Area (cm^2)	Approx 155	Approx 155
Cell Weight (g)	Approx 6.6	Approx 6.6
Cell Thickness	150 micron +/- 30 micron	150 micron +/- 30 micron

5. Cell area (cm^2)

39,995.9cm^2, 3.99m^2

6. A detailed layout map of the vehicle, showing all cell types/sizes and locations, as well as calculations of total area

6.1 Total Area Calculation

One cell = 12.5cm * 12.5cm = **156.25**
4x1 = 156.25 * 4 = 625
4x2 = 156.25 * 8 = 1250
4x3 = 156.25 * 12 = 1875
3x1 = 156.25 * 3 = 468.25
3x3 = 156.24 * 9 = 1406.25
2x1 = 156.25 * 2 = 312.5
Total Area = 625 * 2 + 1250 * 2 + 1875 * 13 + 468.25 * 9 + 1406.25 * 5 + 312.5 * 2
= **39,995.9**

6.2 Cell Physical Characteristics

Wafer: Monocrystalline silicon
Design: All back contact
Front: Uniform, back antireflection coating
Back: Tin-coated, copper metal grid

Cell Area: Approximately 153 cm^2
Cell Weight: Approximately 6.5 grams
Cell Thickness: 150um +/- 30um

6.3 Cell Size

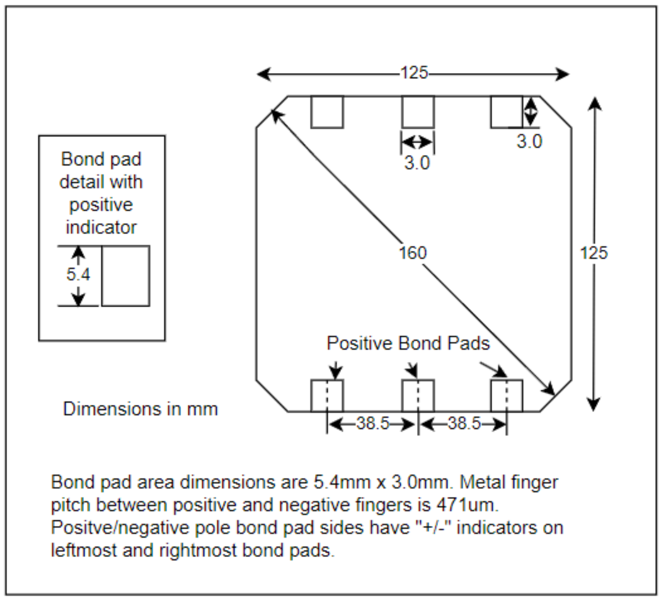


Fig 1. Cell dimensions

6.4 Detailed layout map of the vehicle

The solar cells will be laid out in four different zones. Blue-colored cells are Me3 cells and Red-colored cells are Ne3 cells. There are 256 cells in total. Our vehicle will use Ne3 cells are primary cells and Me3 cells as back up cells.

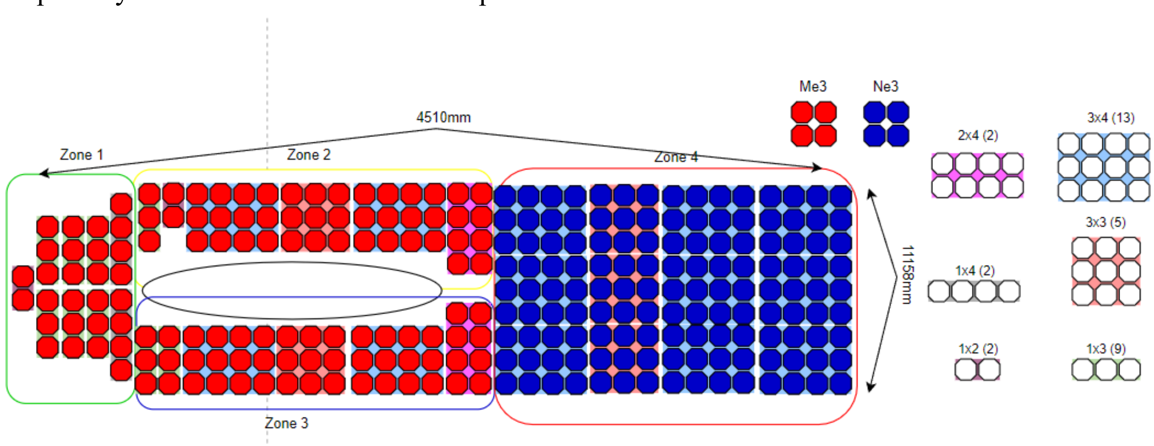


Fig 2. Solar cell layout map with array sizes, types, and locations.

Zone 1								
Module	Qty	Encap Dim (mm)	EC1	EC2	Front/Backsheet dim (mm)	BS	FS	LC Dim (mm)
4x1	2	510x130			550x150			513x131
3x1	6	383x130			420x150			387x131
2x1	1	256x130			300x150			260x131
Zone 2								
Module	Qty	Encap Dim (mm)	EC1	EC2	Front/Backsheet dim (mm)	BS	FS	LC Dim (mm)
4x3	2	510x383			550x420			513x386
4x2	1	510x256			550x300			513x260
3x3	1	383x383			420x420			387x387
3x1	1	383x130			420x150			387x131
2x1	1	256x130			300x150			260x131
Zone 3								
Module	Qty	Encap Dim (mm)	EC1	EC2	Front/Backsheet dim (mm)	BS	FS	LC Dim (mm)
4x3	2	510x383			550x420			513x386
4x2	1	510x256			550x300			513x260
3x3	1	383x383			420x420			387x387
3x1	2	383x130			420x150			387x131
Zone 4								
Module	Qty	Encap Dim (mm)	EC1	EC2	Front/Backsheet dim (mm)	BS	FS	LC Dim (mm)
4x3	9	510x383			550x420			513x386
3x3	3	383x383			420x420			387x387

Fig 3. Array types, quantity and dimensions in each zones

Electrical PVDR

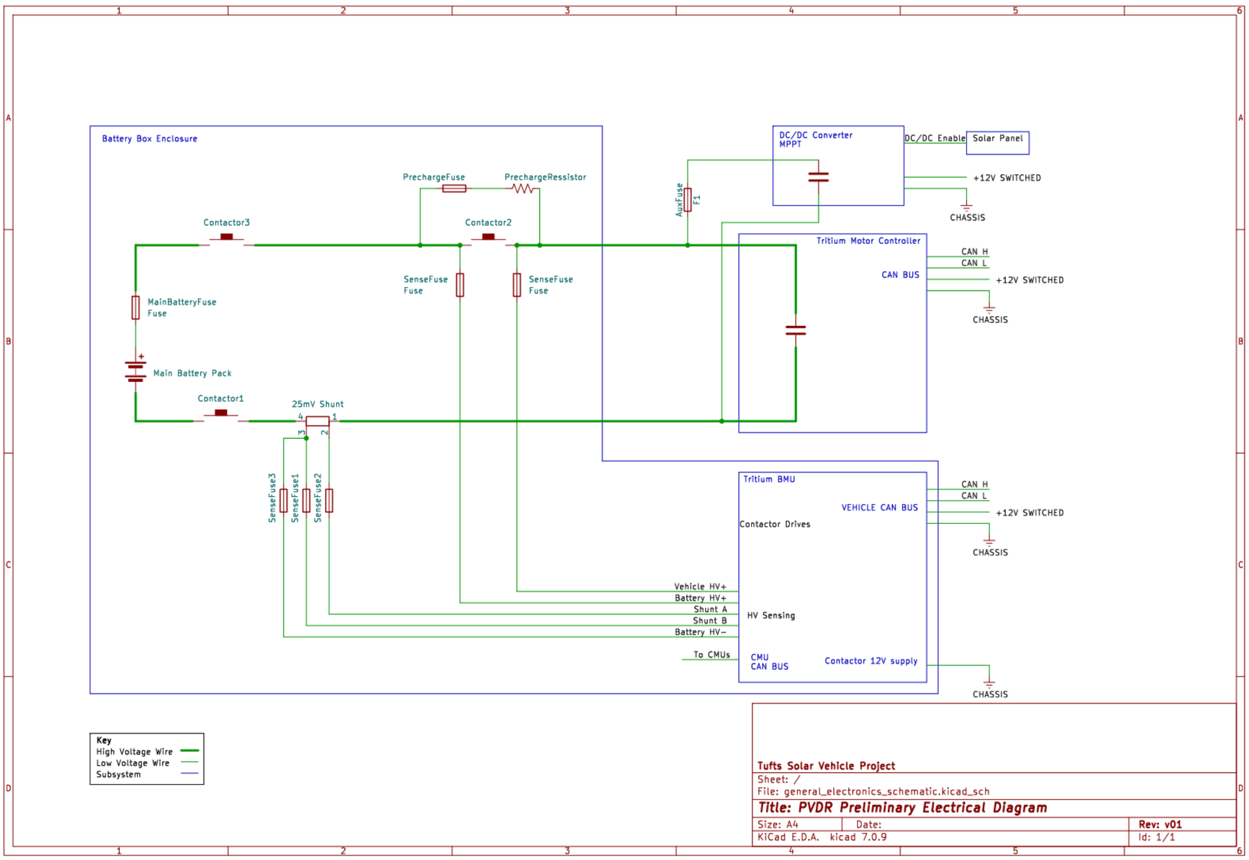
1. Overview

The main components of the electrical system are the solar panel, battery, and motor. Energy flows from the solar panel to an MPPT and into the battery box enclosure where the battery management unit will handle energy going into the battery and serve as a battery protection system as well. This protection extends to other sources of energy such as through regen.

2. Contact Information

Senri Nakamura : 781-539-3225, Senri.Nakamura@tufts.edu

3. Preliminary Electrical Diagram



5. Battery Types

BUTTON TOP 21700 9.8A 5000MAH BATTERY (SAMSUNG 50E2 INSIDE)
https://www.18650batterystore.com/products/samsung-50e

6. Battery testing plans with critical dates

Battery testing can be split into two components: Cell characterization and battery protection system testing.

Main Battery: Li-Ion battery

Configuration: 32S9P

Test Equipment

SM8124 battery impedance meter
Digital Multi-Meter (DMM): Used to measure voltages, small current, and temperature.

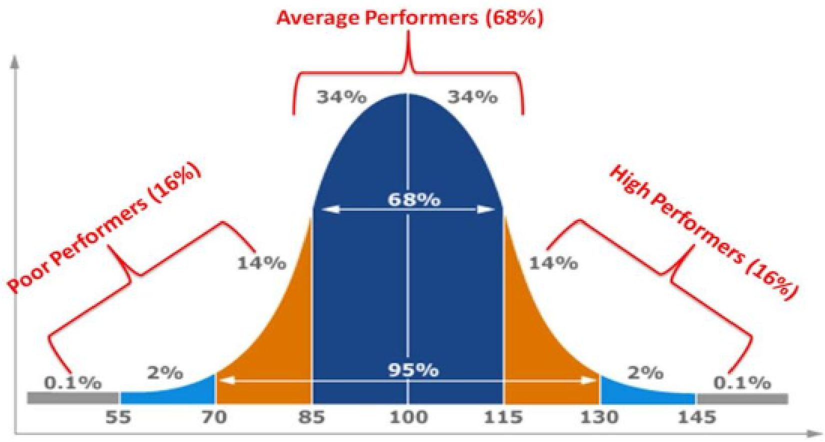
- **Power Supply & Voltage reference:** Used to produce a floating potential of 0 to the Maximum String Voltage. Lithium battery packs will be tested at the module or cell voltage level. This will allow testing of OV, UV, and OC(shunt or analog sensor).
- **Thin film heating element w/ PS:** Used to produce temperature rise in proximity to BPS thermal sensor to trigger OT condition.
- **Wire loop and current source:** In the case of digital current sensor, it may be necessary for teams to supply a spare sensor that can bypass the actual and be used to produce a trigger condition with a reference current loop.

Supplemental Battery: Types of supplemental battery has not been decided other than the fact that it won't be a lithium battery due to the regulation. However, OV test will be conducted.

Cell Characterization
Cell impedance (AC)
Samsung 50E2 21700 3.6V
Initial AC impedance from data sheet: <35mΩ

Methods:
Using the impedance meter mentioned above, we will measure AC impedance of each cell. To measure impedance, each probe of the meter will be in contact with one of the terminals of the battery. The impedance measurement obtained will be compared to the internal impedance specified in the data sheet. After measuring each cell, it will be labeled with its internal impedance and assigned an arbitrary name for tracking purposes. These values will then be recorded in a Google Sheet, which will serve as a centralized database. In MATLAB, this data will be utilized to generate a cell characterization curve. From the obtained AC impedance values, average performers will be picked, which are 68% of the total number of cells tested.

Number of battery cells in the battery pack: 32 cells in series, 9 in parallel = 32s * 9p = 288 cells.



Total number of cells tested: 288 / 0.68 = 424 cells.

****Date of testing:** Specific critical dates for testing have not been decided. In the current phase of our planning process, there are several variables that contribute to uncertainty regarding the scheduling of testing activities. The team is currently working closely with entities to finalize the testing schedule and updates will be incorporated into subsequent revisions of this technical report as soon as the uncertainties have been cleared. If you have any specific concerns or preferences related to the testing timeline, we would welcome your input to incorporate into our considerations.

Over-Voltage(OV) Test

The procedures listed below will be taken during the testing process.
Setup: Vehicle in its operation configuration minus the array the start of the test

1) DMM will be set to auto-range VDC and connected to test points.
2) The first measurement is of the test point voltage as seen at the battery module or cell back to the BPS. Correct battery polarity to be validated for the markings of the test point.
3) Safely isolate sense lead from battery back to isolate test point to provide a reference signal to the BPS.
4) The Voltage Reference positive and negative leads will be connected in parallel to the DMM's test lead.
5) Prior to connecting the sense leads to the test points, the voltage reference will be adjusted from 0 to Vmax, back to Vmin and set to Vnom as specified by in the battery manufacture documentation.
6) At Vnom the test leads will be applied to the sense point with correct polarity.
7) The BPS must then be reset and maintain active with the Vnom input.
8) After a period of 10 seconds of no change the voltage reference will be increased to Vmax or Vmax_trip depending on which is less. The rate of voltage change should be resolved at a rate that distinguishes 0.1V changes for string measurements and 0.01V changes for cell or module given the DMM sampling rate.
9) Record the measured trip point at which the relay isolates the battery pack. The actual Vmax or Vmax_trip set point need only be measured at or below the manufacture Vmax to pass. An actual trip point above Vmax requires immediate correction by the team before further BPS inspection. One additional test for Vmax may be needed if Vmax _trip point needs to be increased.
10) Return reference source to Vnom and have BPS reset to active state.

11) Proceed to Step 1 of Under-Voltage Test next if the OV test is passed.

Dates for testing: TBD**

Under-Voltage(UV) Test

Setup: Each vehicle will be in its operation configuration minus the array at the start of the test.

1) The BPS must then be reset and maintained active with the Vnom input.
2) After a period of 10 seconds of no change the voltage reference will be decreased to Vmin or Vmin_trip depending on which is greater. The rate of voltage change should be resolved at a rate that distinguishes 0.1V changes for string voltages and 0.01V changes for cell or 3.7V modules given the DMM sampling rate.
3) Record the measured trip point at which the relay isolates the battery pack. The actual Vmin or Vmin_trip set point need only be measured at or above the manufacture Vmin to pass. An actual trip point below Vmin requires immediate correction before further BPS inspection. One additional test for Vmin may be requested if lowering the Vmin _trip point is preferred.

Dates for testing: TBD**

Over-Current(OC) Test

Digital output Current Sensor

Digital sensor: a closed-loop Hall Effect Type: small gauge wire(capable of 10A) with N loop for N x Iref_max = Imax or Imax_trip.

1) With the vehicle shut off, the connections with the existing in-line sensor with the reference sensor setup with wire a loop will be exchanged.
2) The leads to the current loop will be connected to a reference current source that is in series with the DMM's test lead. The DMM will be placed in current mode for 0-10A range. Prior to resetting the BPS the current loop will be adjusted from 0A to Iref_max, back to 0A as specified by the battery manufacture documentation and N x Iref_max scalar value (representing charging or discharging).
3) The BPS must then be reset and maintain active with the 0A current loop input.
4) After a period of 10 seconds of no change the current reference will be increased to Iref_max. The rate of current change should be resolved at a rate that distinguishes 0.1A changes given the DMM sampling rate.
5) Record the measured trip point at which the relay isolates the battery pack. The actual Imax or Imax_trip set point need only be measured at or below the manufacture Imax to pass. One additional test for Imax may be requested if Imax _trip point is requested to increase.
6) Test will be repeated for step 4 through 7 with the current loop inputs reversed to cover charging and discharge limits.

Dates for testing: TBD**

Over-Temperature Test

Setup: Each vehicle will be in its operation configuration minus the array at the start of the test. The battery box may require being opened to apply a thin-film heating element and thermocouple in proximity to a BPS temperature sensor prior to test.

1) DMM will be set to temperature readout in Celsius and thermocouple temperature probes added.
2) Prior to adding the temperature probe to the battery pack a test will be performed to check the ability of the heating element to raise the DMM temperature readout to the Tmax specified by the battery manufacture documentation.
3) The temperature probe and thin-film heating element will need to be placed in immediate proximity to one BPS temperature sensor or identical sensor board within the battery pack prior to testing. The element may need to be taped in place. If possible the lid should be returned to minimize wind or direct sunlight.
4) The first measurement is of the ambient temperature of the pack at the BPS temperature sensor without the heating element.
5) The BPS must be reset and remain active with the Tamb input.
6) After a period of 10 seconds of no change the temperature will be raised for the sensor to Tmax_Charge or Tmax_trip_Charge depending on which is less. The rate of temperature change should be resolved at a rate that distinguishes 1-degree Celsius given the DMM sampling rate.
7) Record the measured trip point at which the relay isolates the battery pack. The actual Tmax_Charge or Tmax_trip_Charge set point need only be measured at or below the manufacture Tmax to pass. One additional test to Tmax may be requested if raising the Tmax _trip point is preferred.
8) Test will be repeated for step 5 through 7 with the temperature raised to cover discharge limits at Tmax_Discharge or Tmax_trip_Discharge.

Dates for testing: TBD**

Re-Testing

In case of the need for corrections, re-testing will be needed and considered complete if and only if:

1) All test cases that revealed problems in the previous testing have been repeated and the results have met the passing criteria.
2) All test cases that revealed no problems during the previous testing, but test components that are affected by the corrections, have been repeated and the results have met passing criteria.

7. Battery Cell Manufacturing URL

https://www.samsungsdi.com/index.html