Laser-Based Wireless Power Transmission Receiver’s Energy Harvester: Photovoltaic Power Converter Board

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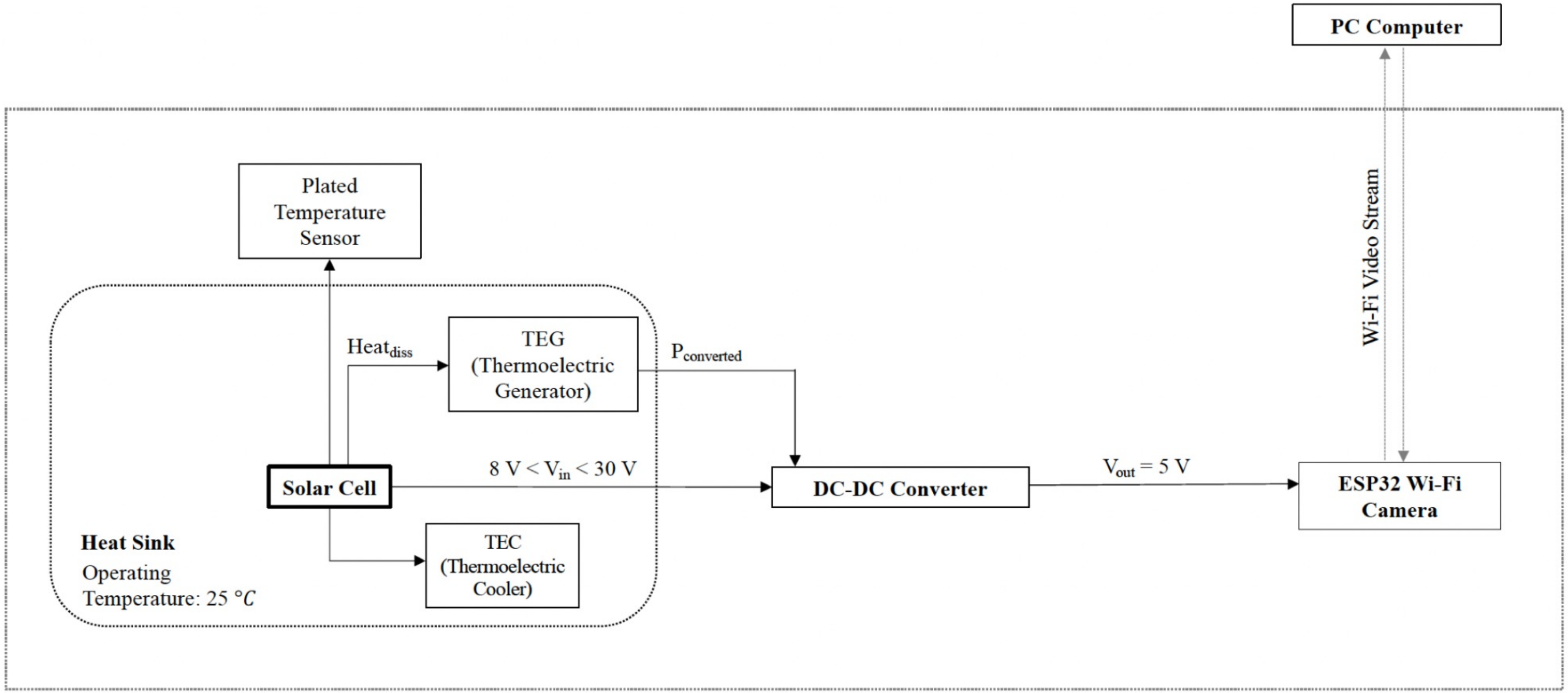
EE481. Senior Design II

Receiver Conceptual Block Diagram



Receiver Conceptual Block Diagram

Solar Cell: Si-based vertical multi-junction PV cell

Design Objective: Rapid Prototyping for Testing

- To replace the isolated LM2596 DC-DC Converter board with a compact Power Converter solution combined with a thermal regulation and energy harvesting system
- To provide a spatial layout for the PV cells with consideration to the TEC's placement beneath the board
- To implement either the Buck "step-down" or Boost "step-up" voltage converter mechanism from the quad-PV array to the camera load (*Note:* The selection between Buck or Boost DC-DC Converter depends on wattage output from the 4 PV cells)
- To implement a voltage-controlled power electronic system with ON-OFF switching and low-pass filter or to provide an extension board to do so
- To make a top-layer backplane system so the PV cells can be easily soldered to the PCB solder pads without electrode wiring or external cabling and so the load camera can also be soldered to the load output connector
- To minimize conduction losses and use power distribution techniques in a condensed form
- To verify the highest efficiency power converter board as part of the testing and performance evaluation
- To provide boards with test pads for fault detection during testing

Design Tools

- TI WEBENCH Power Designer
- Autodesk EAGLE
- Digi-Key’s PCB Trace Width Calculator
- PCB fabrication machines
- Soldering equipment

39.37008 mils = 1 mm
1 mil = 0.0254 mm (millimeter)

PV Cell Form Factors

- *1 cm x 1 cm (10 mm x 10 mm)* MIH® VMJ PV Cell Form Factor (Part #: 5S1010.4)
- *2.5 cm x 2.5 cm (25 mm x 25 mm)* PV Cell Form Factor
- *5 cm x 5 cm (50 mm x 50 mm)* PV Cell Form Factor

Total number of form factors: 3

PV Cell Electrical Arrangement Types

- *Isolated: Configurable Externally for Adaptive Methods*
- *Series*
- *Parallel*

Total number of arrangements: 3

Total number of possible board prototypes: 9

Total number of design files for board prototypes: 7 (due to adjustable dimensions and tolerances from same circuitries)

ESP-32 Wi-Fi Load Input Requirements

Power consumption is

(180 mA x 5V) = 900mW = 0.9 W

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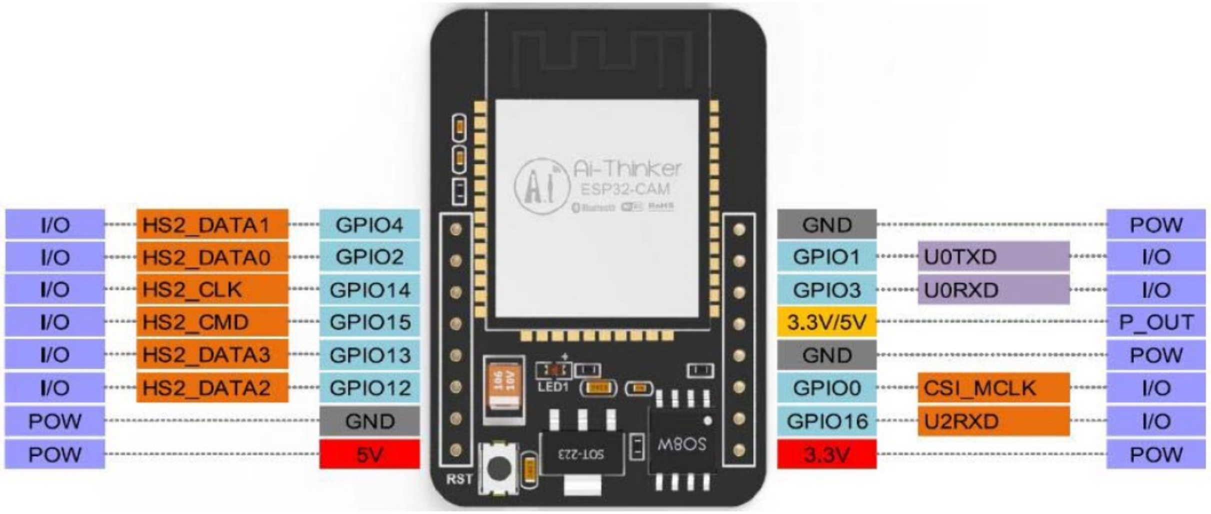


Schematic Diagram

Circuit Design #	**PV Cell Arrangement Type**	**Number of PV Cells**	**PV Cell Form Factor**	**DC-DC Converter Type**	**Voltage Output**	**Output Current**	**Expected 5V at 0.18 A achieved for load? (Y/N)**
1	Series	4	1 cm x 1 cm (10 mm x 10 mm)	Separate Buck	Vout = 29.21 V x 4 PV cells = 116.84 V	0.02029 A	
2	Isolated	1	1 cm x 1 cm (10 mm x 10 mm)	Internal Buck	Vout = 29.21 V x 1 PV cell = 29.21 V	0.02029 A	
3	Parallel	4	1 cm x 1 cm (10 mm x 10 mm)	Internal Buck	Vout = 29.21 V	0.02029 A x 4 PV cells = 0.08116 A	
4	Parallel	4	2.5 cm x 2.5 cm (25 mm x 25 mm)	Separate Boost	Vout = 2.23 V	0.0472 A at Pmpp	
5	Series	4	2.5 cm x 2.5 cm (25 mm x 25 mm)	Internal Buck	Vout = 2.23 V x 4 PV cells = 8.92 V	0.0472 A at Pmpp	
6	Series	4	5 cm x 5 cm (50 mm x 50 mm)	Internal Buck	Vout = 2.43 V x 4 PV cells = 9.72 V	0.14 A	
7	Series	4	5 cm x 5 cm (50 mm x 50 mm)	Separate Buck	Vout = 2.43 V x 4 PV cells = 9.72 V	0.14 A	
8	Parallel	4	2.5 cm x 2.5 cm (25 mm x 25 mm)	Separate Boost	Vout = 2.23 V	0.0472 A at Pmpp	
9	Parallel	4	5 cm x 5 cm (50 mm x 50 mm)	Separate Boost	Vout = 2.23 V	0.14 A x 4 PV cells = 0.56 A	

1. Design Specifications
1 cm x 1 cm MIH® VMJ PV Cell Form Factor,
4-PV, Series; Extension Board: Configurable for Externally Adaptive Load Circuitry

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -) x 4 PV cells = 8 leads
  - TEG module's 2 leads (+ and -)
  - TEC module's 2 leads (+ and -)
- **Outputs:**
  - ESP-32 Wi-Fi camera

Internals:

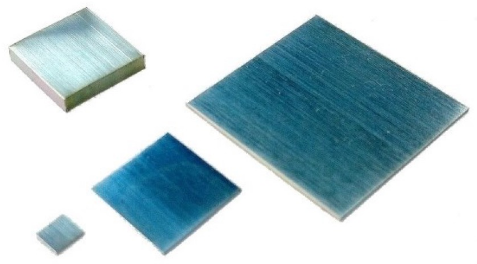
- Pads for soldered PV cells
- I/O Ports as Female Connectors

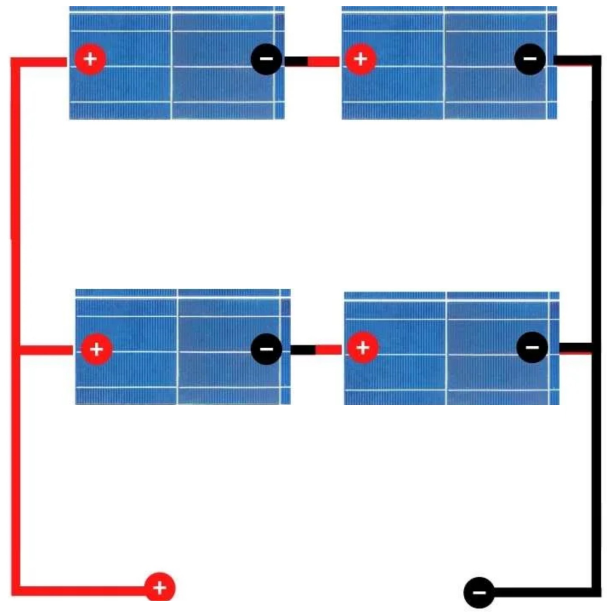
Voltage Requirements:

- **Input:**
  - Each PV cell has a 0.02029 A maximum current output
  - Each PV cell has a 29.21 V maximum voltage output
  - Each PV cell has a 0.59267 W maximum power output
  - Total max V_{out} = 29.21 V x 4 PV cells; Voltage output = 116.84 V for a series connection
  - Total max current = 0.02029 A for a series connection
- **Output:** 5 V at 180 mA *or .18 A = 0.9 W

Miscellaneous:

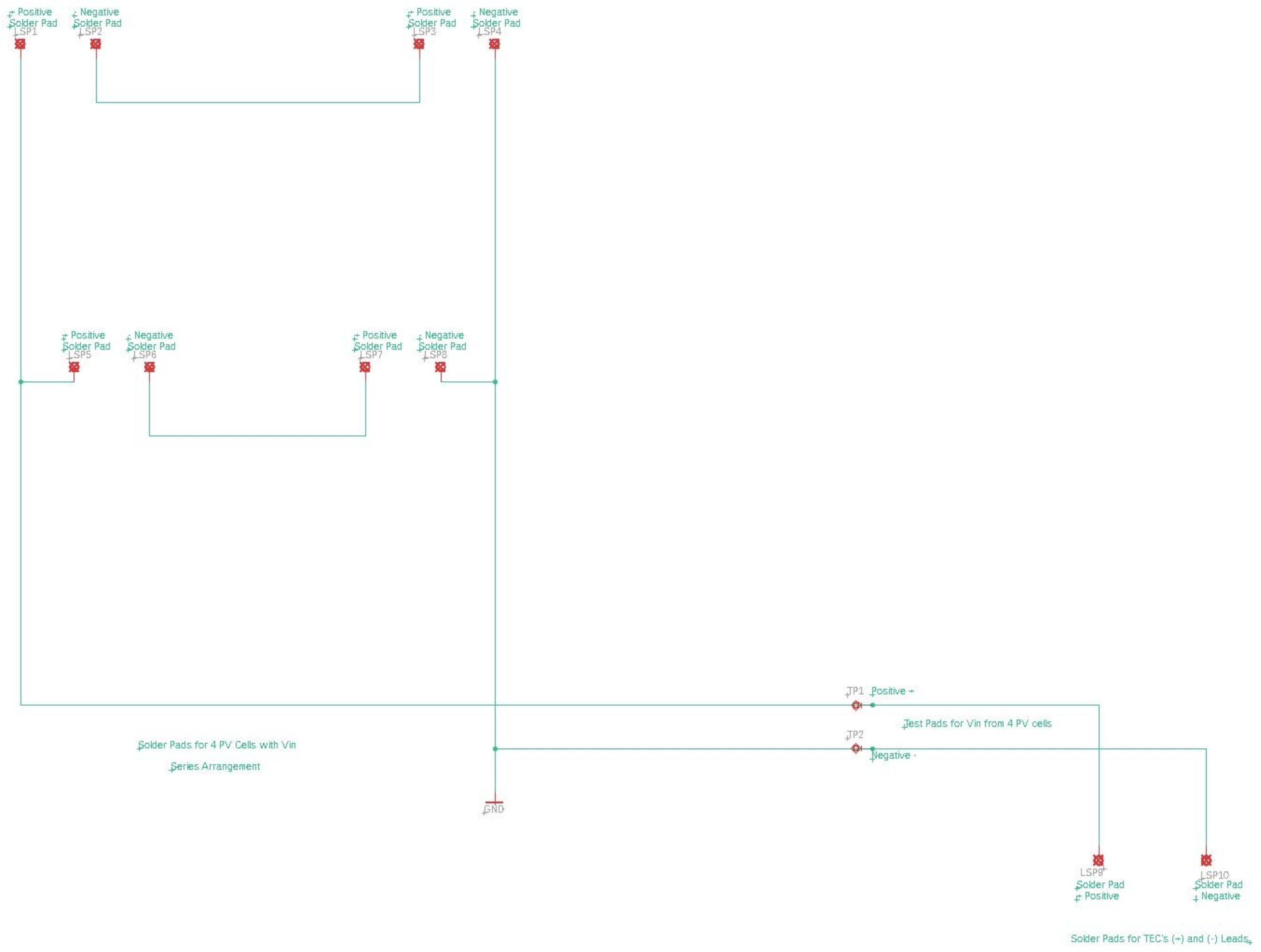
- Heat Sink





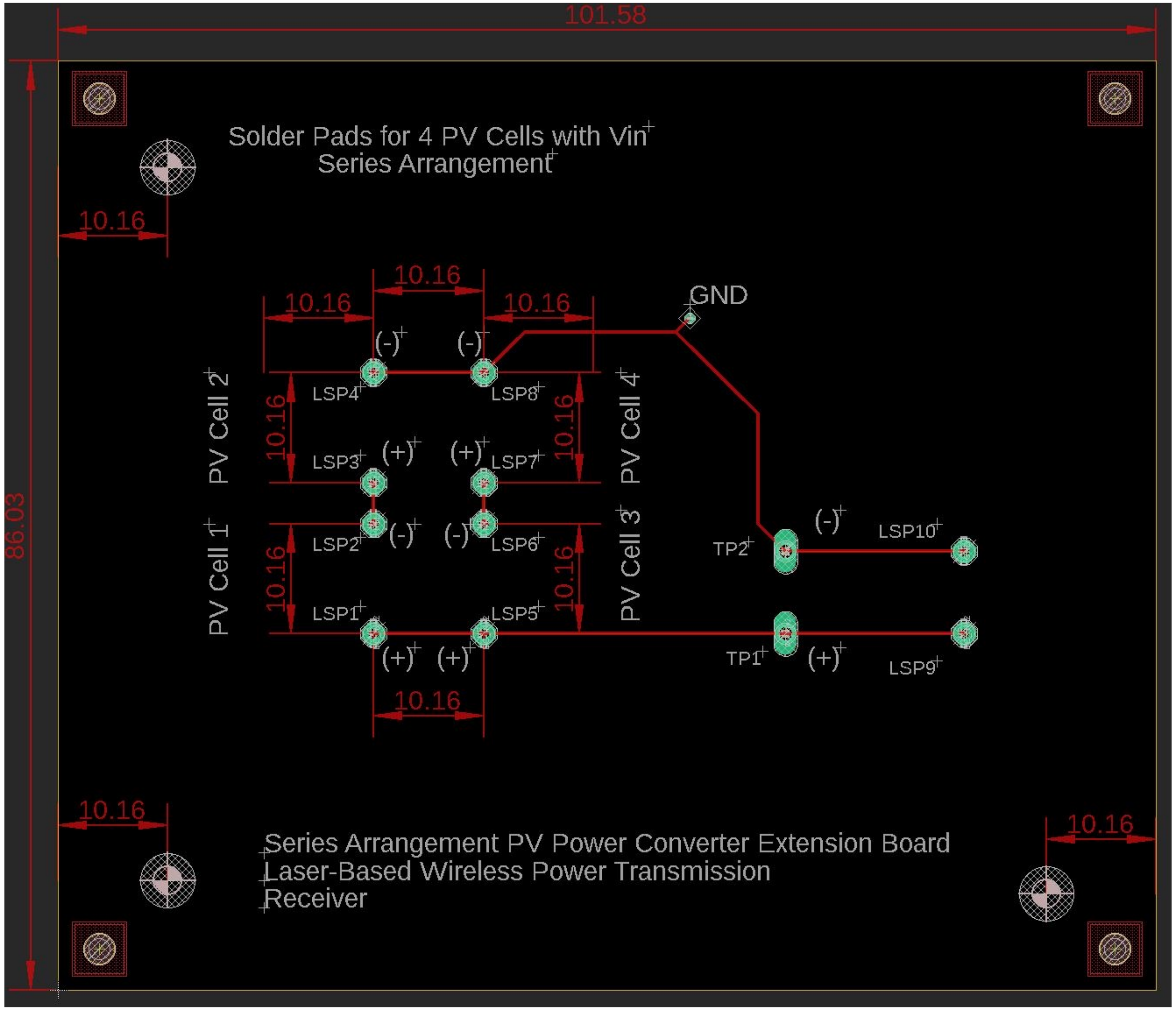
*Required Separately: **Buck DC-DC Converter** circuit: **116.84 V to 5 V**

1.

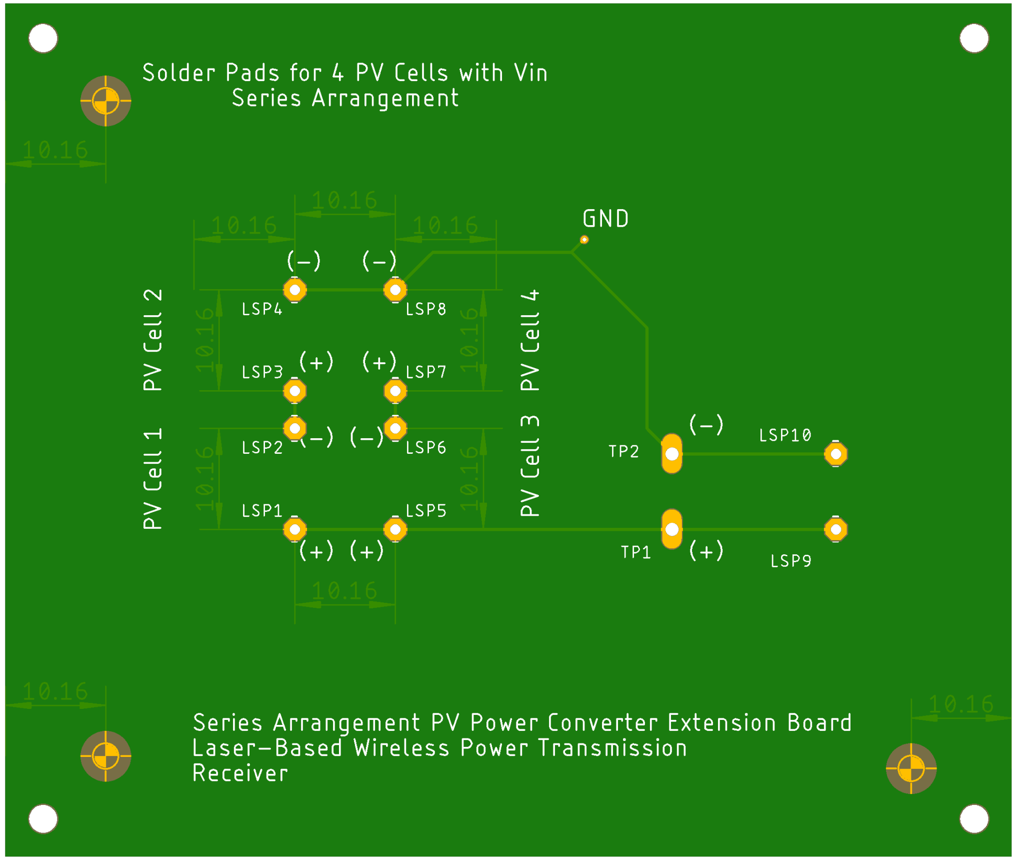


Positive Solder Pad
LSP1
Negative Solder Pad
LSP2
Positive Solder Pad
LSP3
Negative Solder Pad
LSP4
Positive Solder Pad
LSP5
Negative Solder Pad
LSP6
Positive Solder Pad
LSP7
Negative Solder Pad
LSP8
TP1
Positive +
Test Pads for Vin from 4 PV cells
TP2
Negative -
Solder Pads for 4 PV Cells with Vin
Series Arrangement
GND
LSP9
Solder Pad
Positive
LSP10
Solder Pad
Negative
Solder Pads for TEC's (+) and (-) Leads

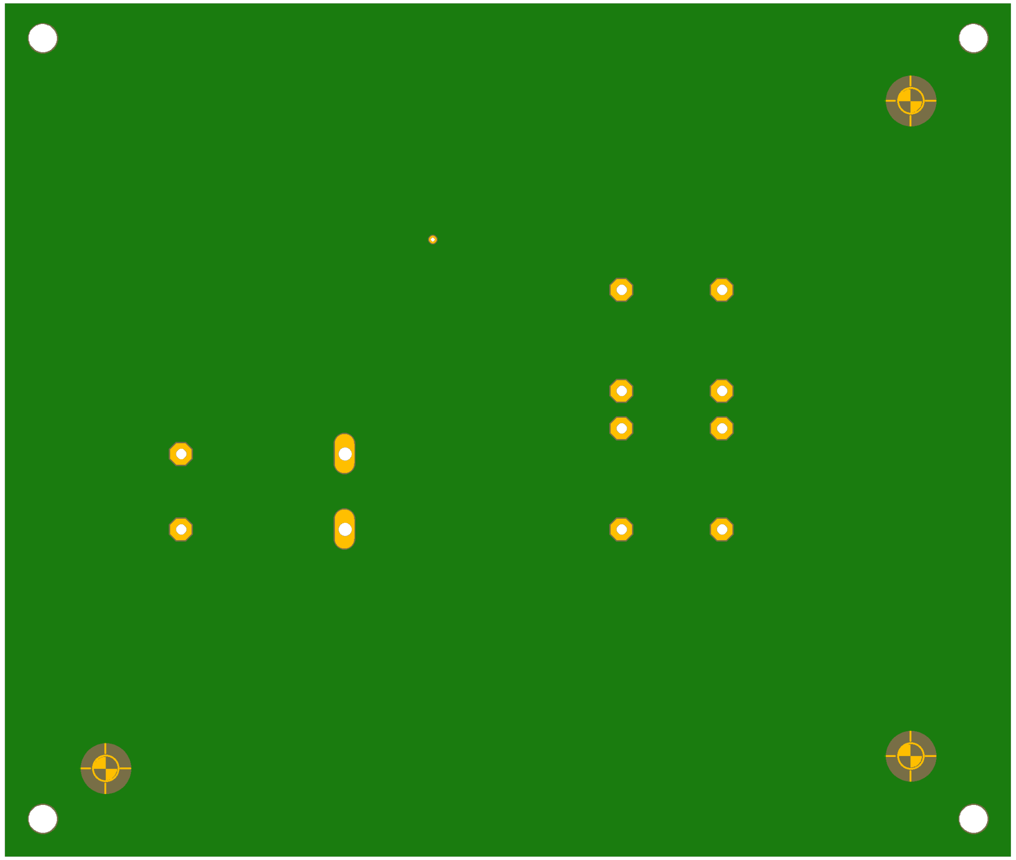
1.


101.58
86.03
Solder Pads for 4 PV Cells with Vin
Series Arrangement
10.16
GND
(-)
(+)
PV Cell 1
PV Cell 2
PV Cell 3
PV Cell 4
LSP1
LSP2
LSP3
LSP4
LSP5
LSP6
LSP7
LSP8
LSP9
LSP10
TP1
TP2
Series Arrangement PV Power Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver

1.


Solder Pads for 4 PV Cells with Vin
Series Arrangement
10.16
GND
(–) (–)
LSP4
LSP8
PV Cell 2
PV Cell 4
LSP3 (+) (+) LSP7
LSP2 (–) (–) LSP6
PV Cell 1
PV Cell 3
(–)
LSP10
TP2
LSP1
LSP5
(+) (+)
TP1
(+)
LSP9
Series Arrangement PV Power Converter Extension Board
Laser–Based Wireless Power Transmission
Receiver

Top

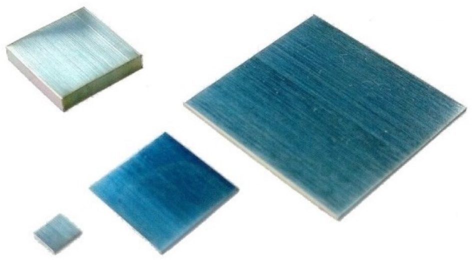


Bottom

2. Design Specifications
1 cm x 1 cm MIH® VMJ PV Cell Form Factor,
1-PV; Full Backplane Board

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -)
  - TEG module's 2 leads (+ and -)
  - TEC module's 2 leads (+ and -)
- **Outputs:**
  - ESP-32 Wi-Fi camera



Internals:

- Pads for soldered PV cells
- PWM Control DSP, MCU, or FPGA for Switch Control
- **Buck DC-DC Converter** circuit with Low-Pass Filter: **29.21 V to 5 V**
  - R, L, C, MOSFET Switch (Voltage-Controlled)
- I/O Ports as Female Connectors

Voltage Requirements:

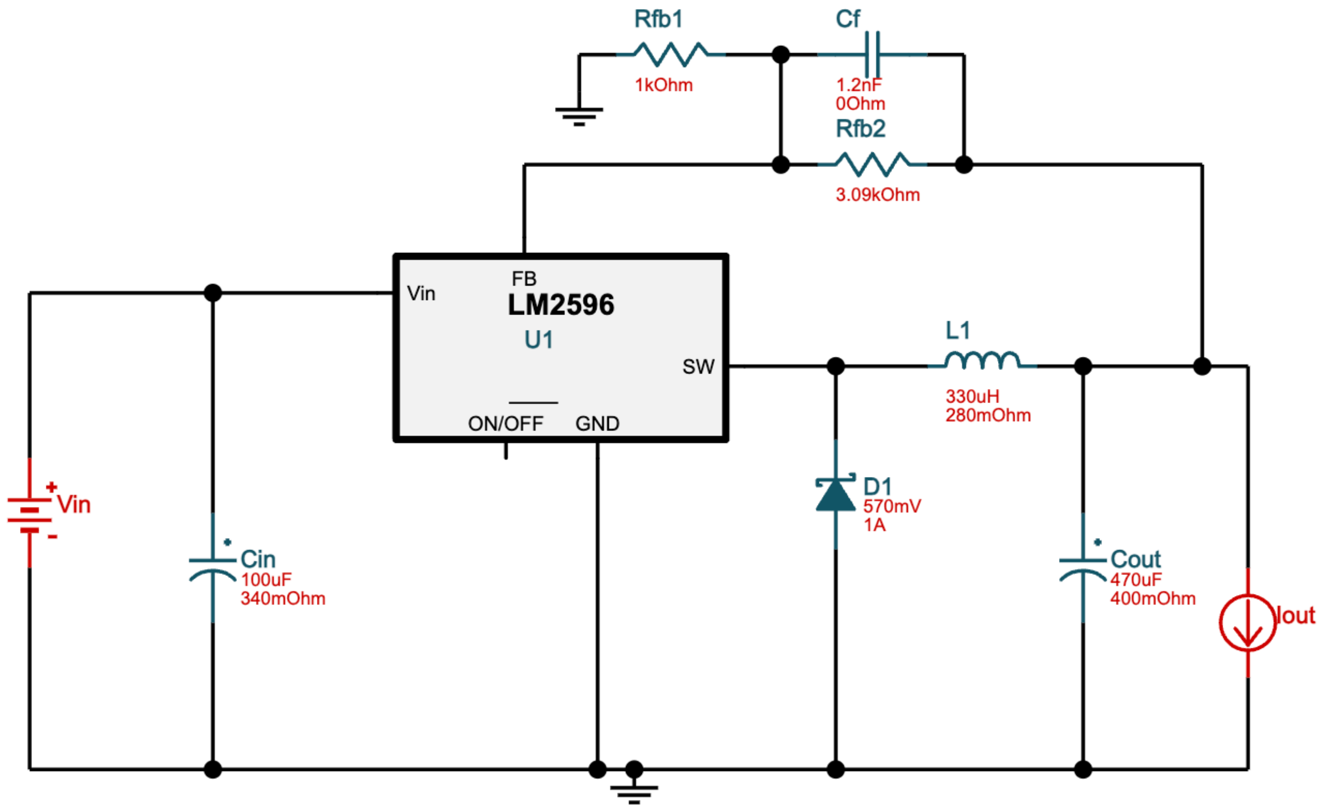
- **Input:** 8 - 30 V:
  - Each PV cell has a 0.59267 W maximum power output
  - Each PV cell has a 29.21 V maximum voltage output
  - Total max V_{out} = 29.21 V x 1 PV cell; Voltage output = 29.21 V for a single PV solution
  - Total max current = 0.02029 A for a single PV solution
- **Output:** 5 V at 180 mA *or .18 A = 0.9 W

Miscellaneous:

- Heat Sink

2. Buck DC-DC Converter

LM2596T-ADJ/NOPB - 25V-30V to 5.00V @ 0.18A. 69.4% Efficiency



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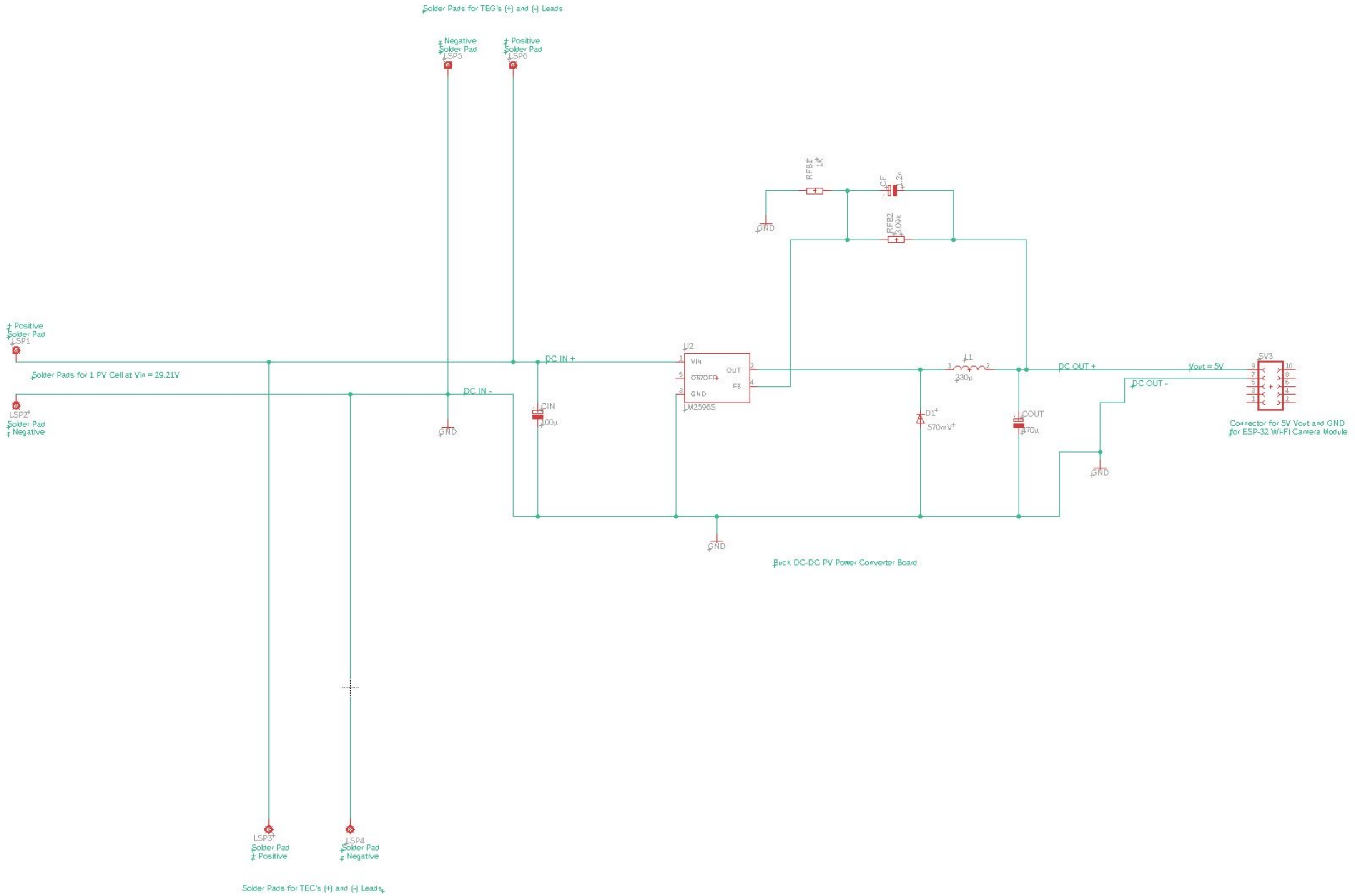
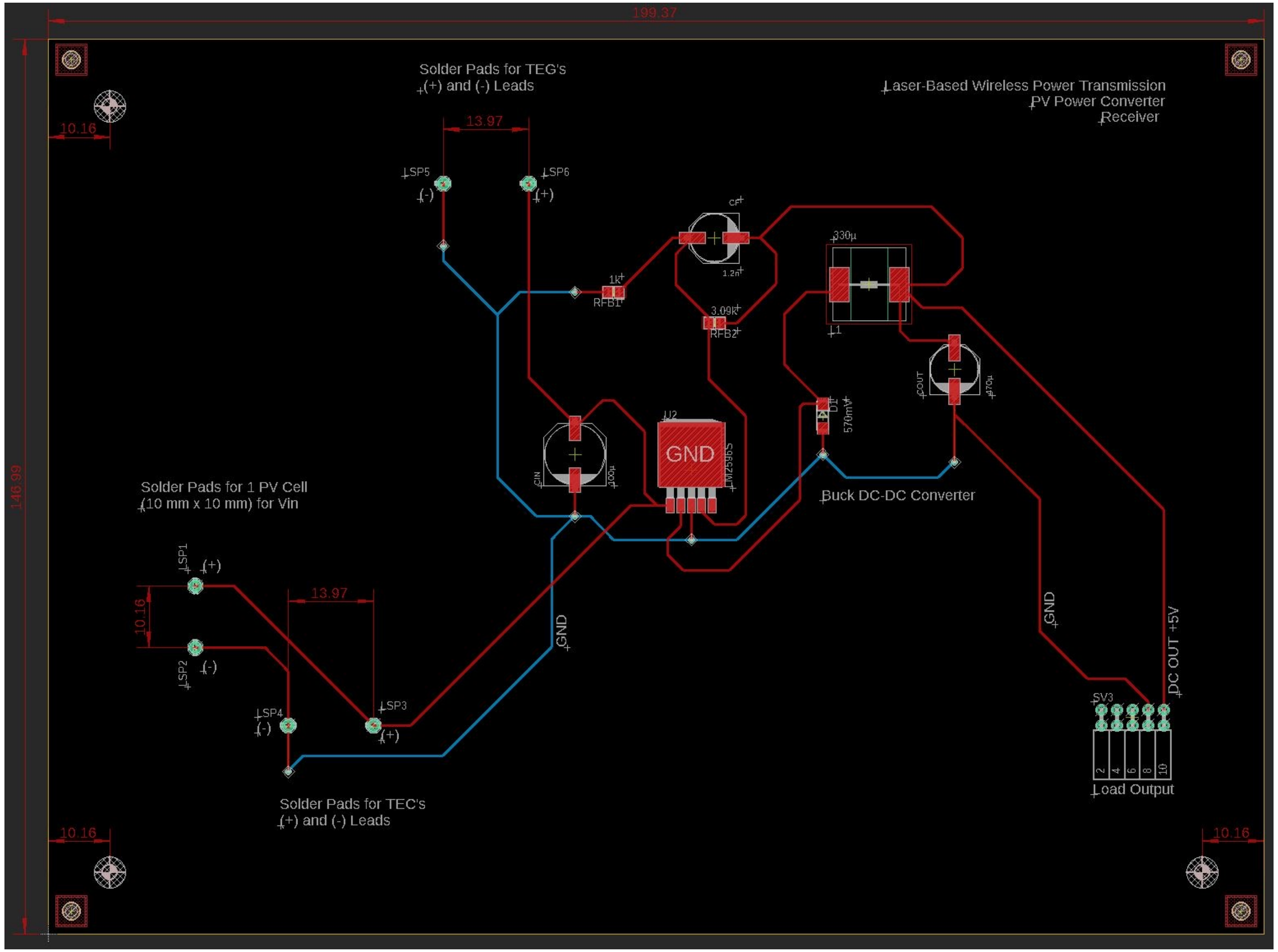


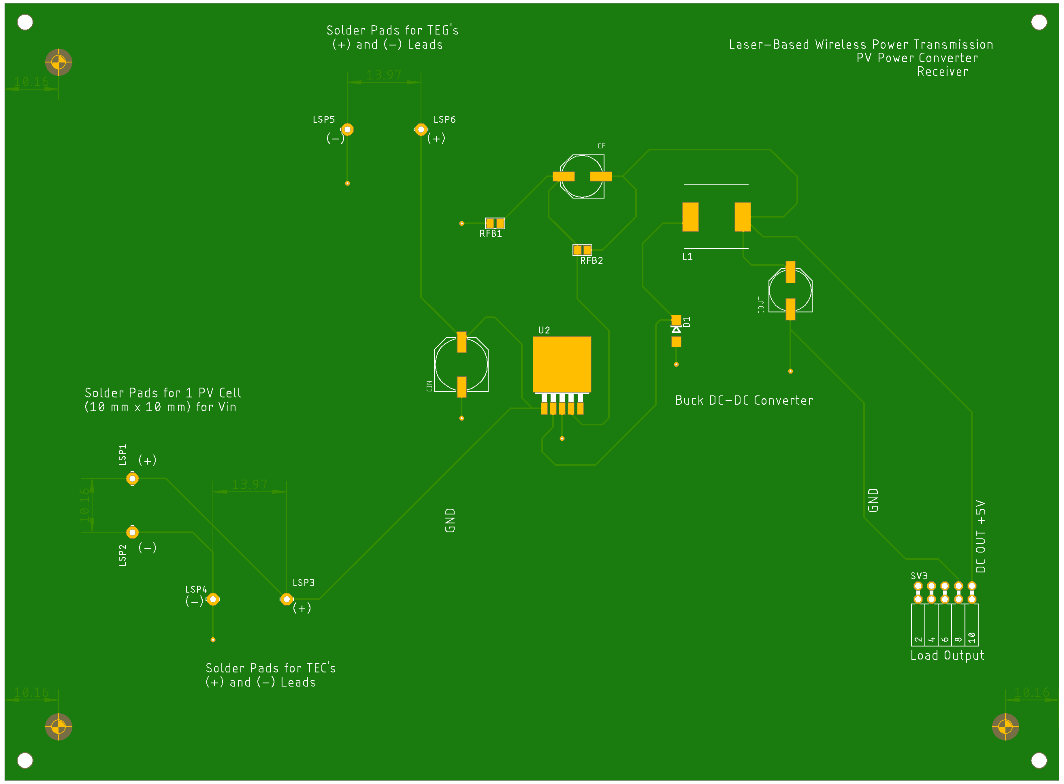
Solder Pads for TEG's (+) and (-) Leads
Negative
Solder Pad
LSP5
Positive
Solder Pad
LSP6
Positive
Solder Pad
LSP1
Solder Pads for 1 PV Cell at Vin = 29.21V
LSP2
Solder Pad
Negative
GND
DC IN +
DC IN -
CIN
100µ
RFB1
1k
CF
RFB2
3.09k
GND
U2
VIN
ON/OFF
GND
OUT
FB
LM2596S
L1
330µ
D1
570mV
COUT
470µ
DC OUT +
DC OUT -
Vout = 5V
SV3
Connector for 5V Vout and GND
for ESP-32 Wi-Fi Camera Module
GND
GND
Buck DC-DC PV Power Converter Board
LSP3
Solder Pad
Positive
LSP4
Solder Pad
Negative
Solder Pads for TEC's (+) and (-) Leads

2.

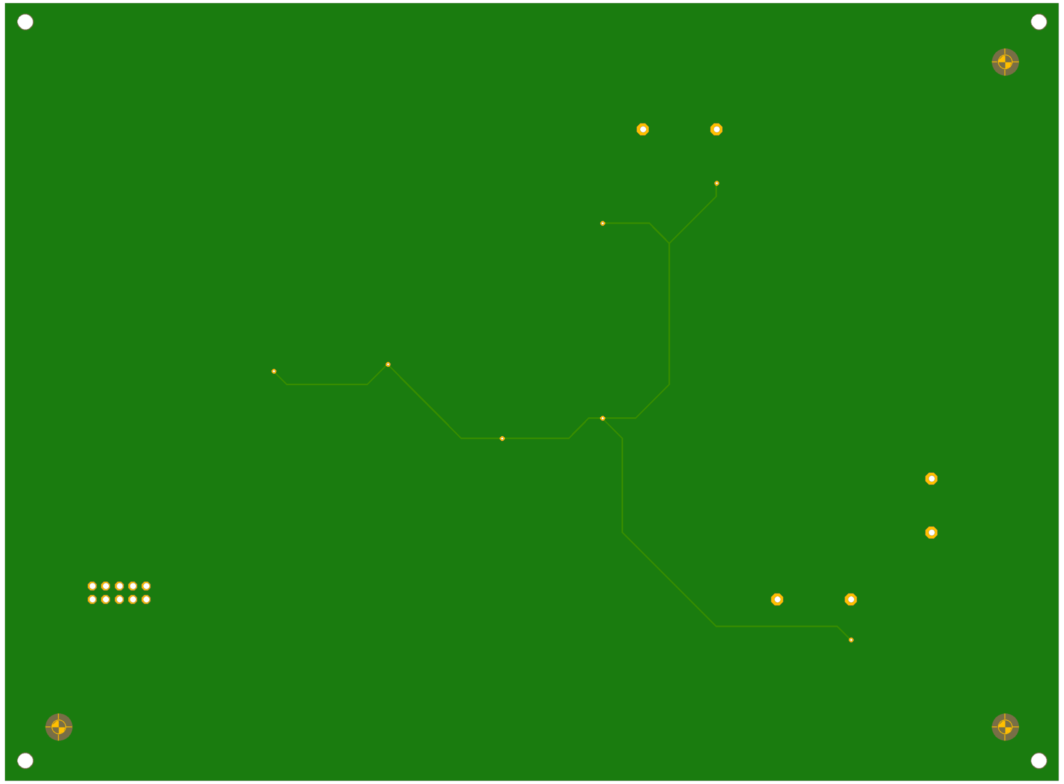


199.37
146.99
10.16
13.97
Solder Pads for TEG's
(+) and (-) Leads
Laser-Based Wireless Power Transmission
PV Power Converter
Receiver
SP5
SP6
(-)
(+)
1k
RFB1
3.09k
RFB2
330µ
L1
GND
U2
LM2596S
COUT
570mV
Buck DC-DC Converter
Solder Pads for 1 PV Cell
(10 mm x 10 mm) for Vin
SP1
SP2
SP3
SP4
GND
DC OUT +5V
SV3
Load Output
Solder Pads for TEC's
(+) and (-) Leads

2.


Solder Pads for TEG's
(+) and (–) Leads
Laser–Based Wireless Power Transmission
PV Power Converter
Receiver
LSP5
(–)
LSP6
(+)
RFB1
RFB2
L1
U2
D1
Solder Pads for 1 PV Cell
(10 mm x 10 mm) for Vin
Buck DC–DC Converter
LSP1
(+)
LSP2
(–)
GND
GND
DC OUT +5V
LSP4
(–)
LSP3
(+)
SV3
Load Output
Solder Pads for TEC's
(+) and (–) Leads

Top

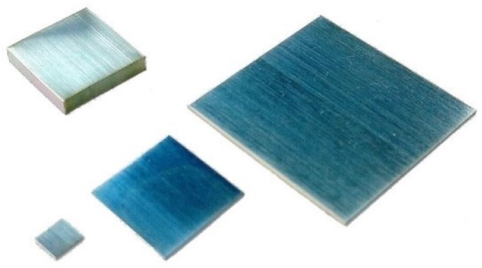


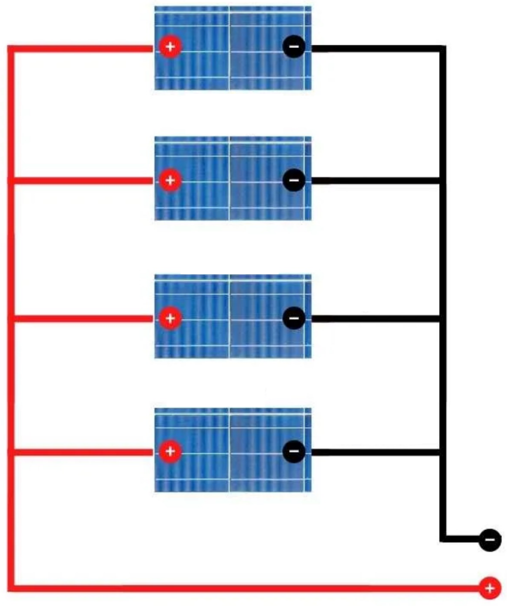
Bottom

3. Design Specifications
1 cm x 1 cm MIH® VMJ PV Cell Form Factor,
4-PV, Parallel; Full Backplane Board

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -)
  - TEG module’s 2 leads (+ and -)
  - TEC module’s 2 leads (+ and -)
- **Outputs:**
  - ESP-32 Wi-Fi camera





Internals:

- Pads for soldered PV cells
- PWM Control DSP, MCU, or FPGA for Switch Control
- **Buck DC-DC Converter** circuit with Low-Pass Filter: **29.21 V to 5 V**
  - R, L, C, MOSFET Switch (Voltage-Controlled)
- I/O Ports as Female Connectors

Voltage Requirements:

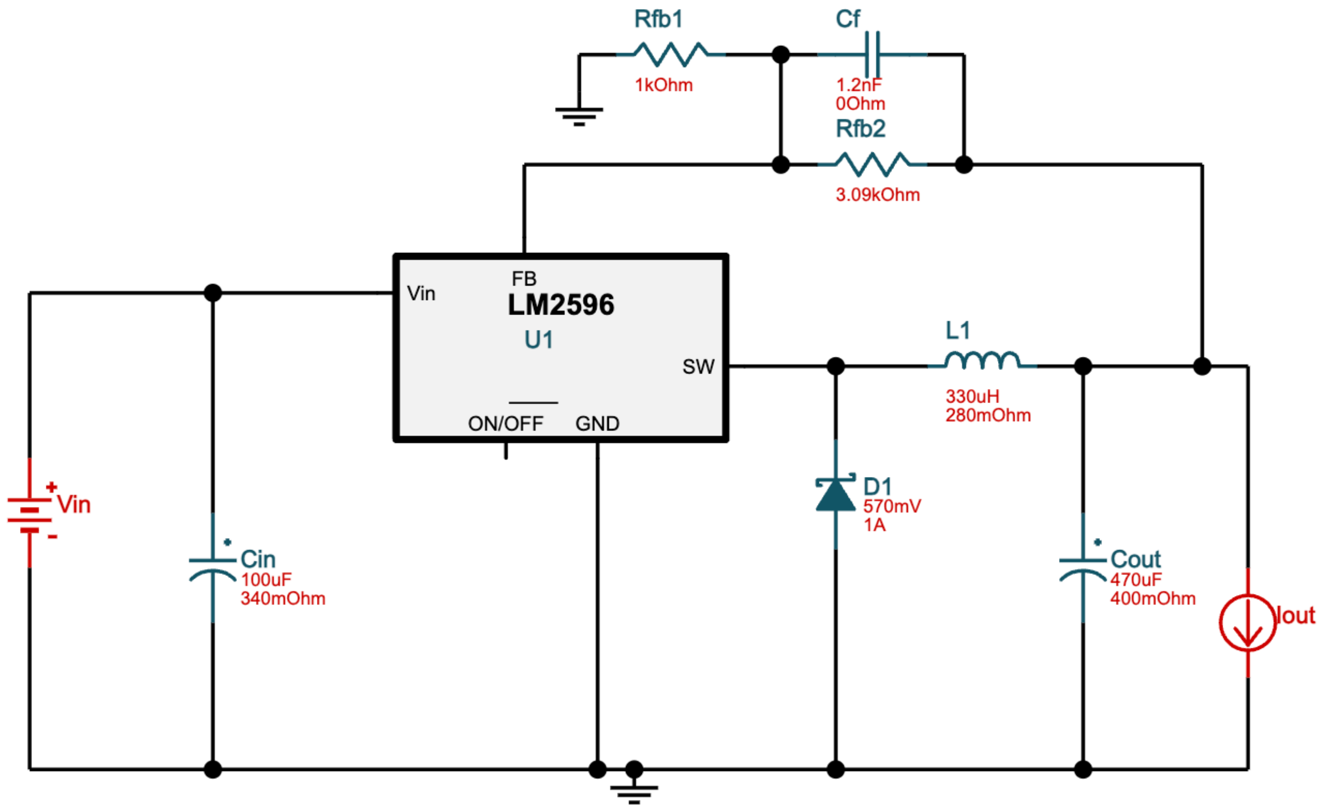
- **Input:** 8 - 30 V:
  - Each PV cell has a 0.59267 W maximum power output
  - Each PV cell has a 29.21 V maximum voltage output
  - Total V_{out} = 29.21 V for a parallel connection
  - Total current = 0.02029 A x 4 PV cells = 0.08116 A for a parallel connection
  - Total power = 29.21 V x 0.08116 A = 2.3706836 W
- **Output:** 5 V at 180 mA *or .18 A = 0.9 W

Miscellaneous:

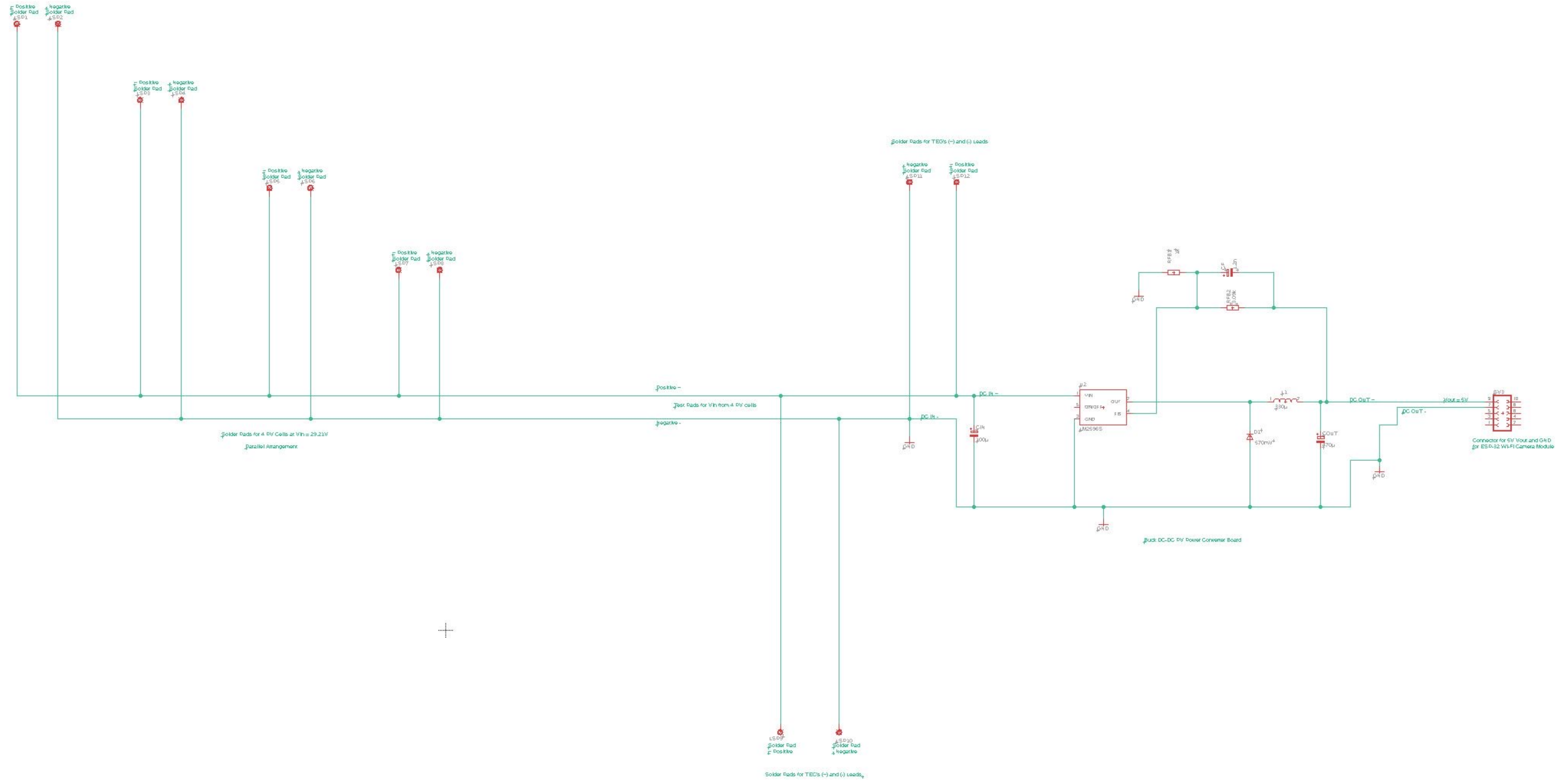
- Heat Sink

3. Buck DC-DC Converter

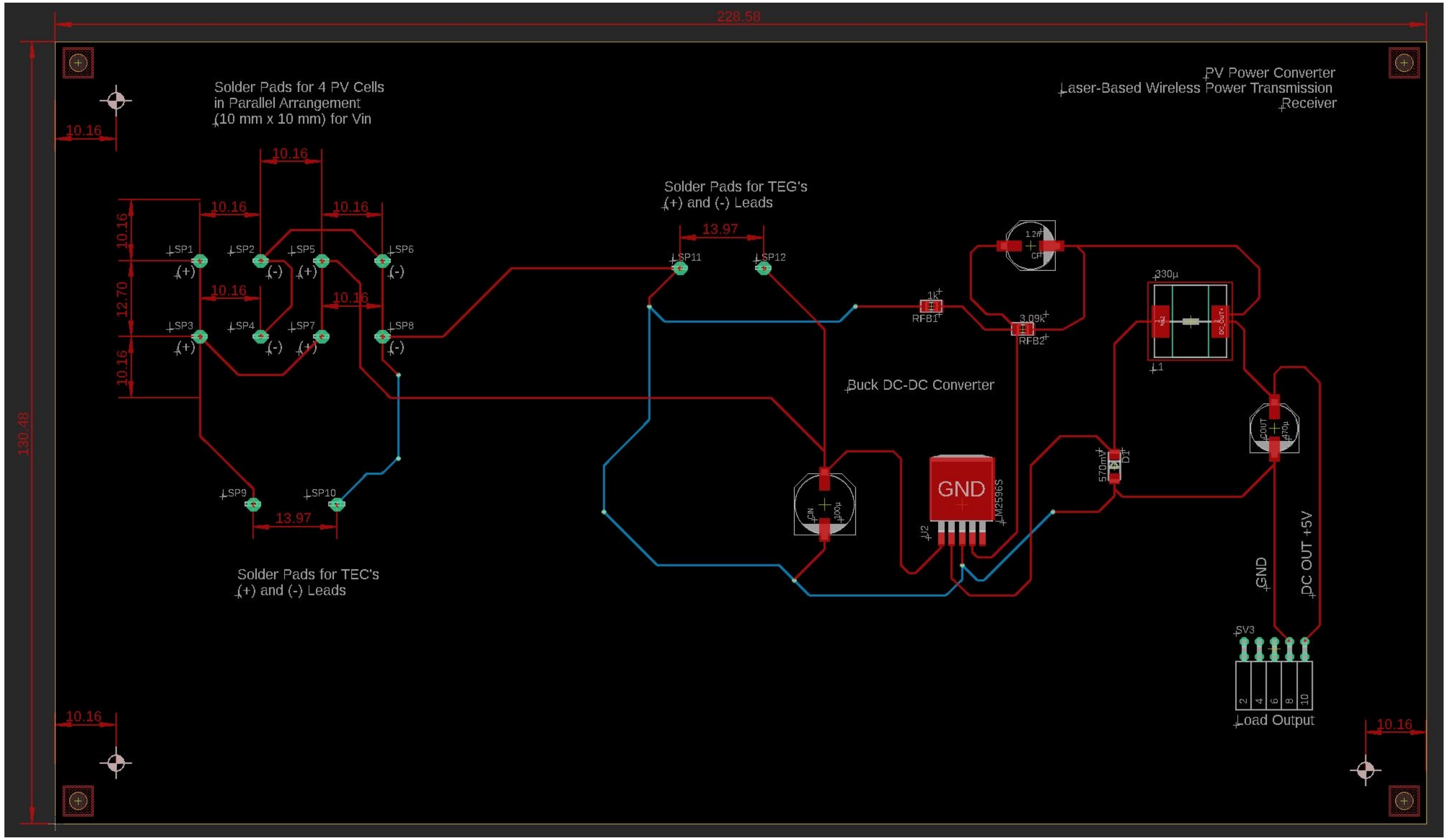
LM2596T-ADJ/NOPB - 25V-30V to 5.00V @ 0.18A. 69.4% Efficiency



3.

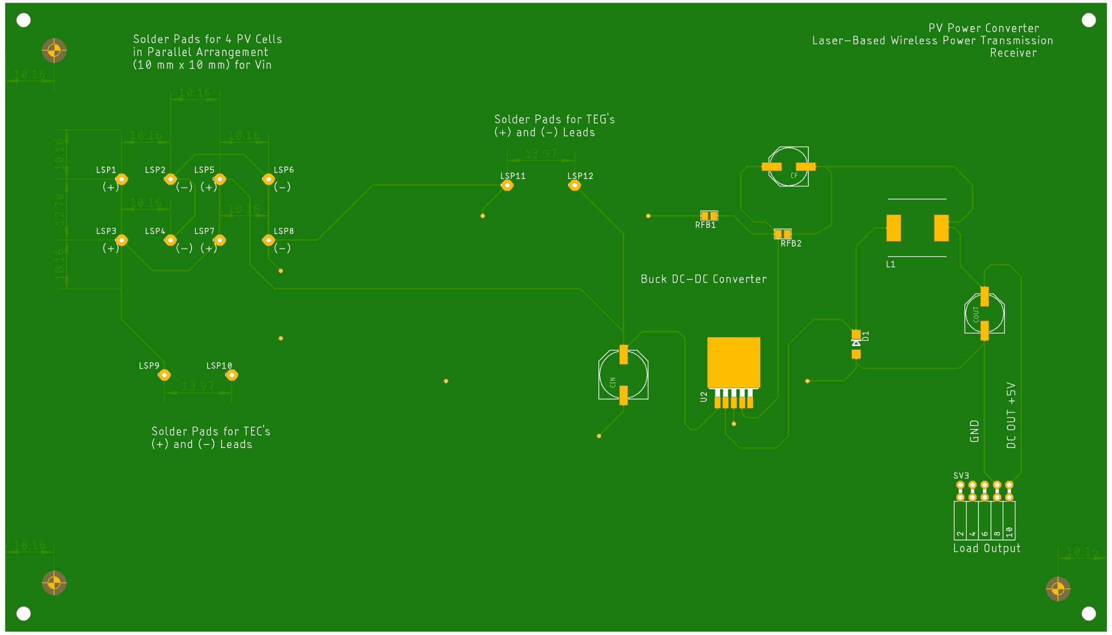

Solder Pads for TEC's (+) and (-) Leads
Positive
Negative
Test Pads for Vin from 4 PV cells
DC IN +
DC IN -
Solder Pads for 4 PV Cells at Vin = 29.21V
Parallel Arrangement
Buck DC-DC PV Power Converter Board
Vout = 5V
DC OUT +
DC OUT -
Connector for 5V Vout and GND
for ESP-32 Wi-Fi Camera Module
Solder Pad
Positive
Negative
Solder Pads for TEC's (+) and (-) Leads

3.



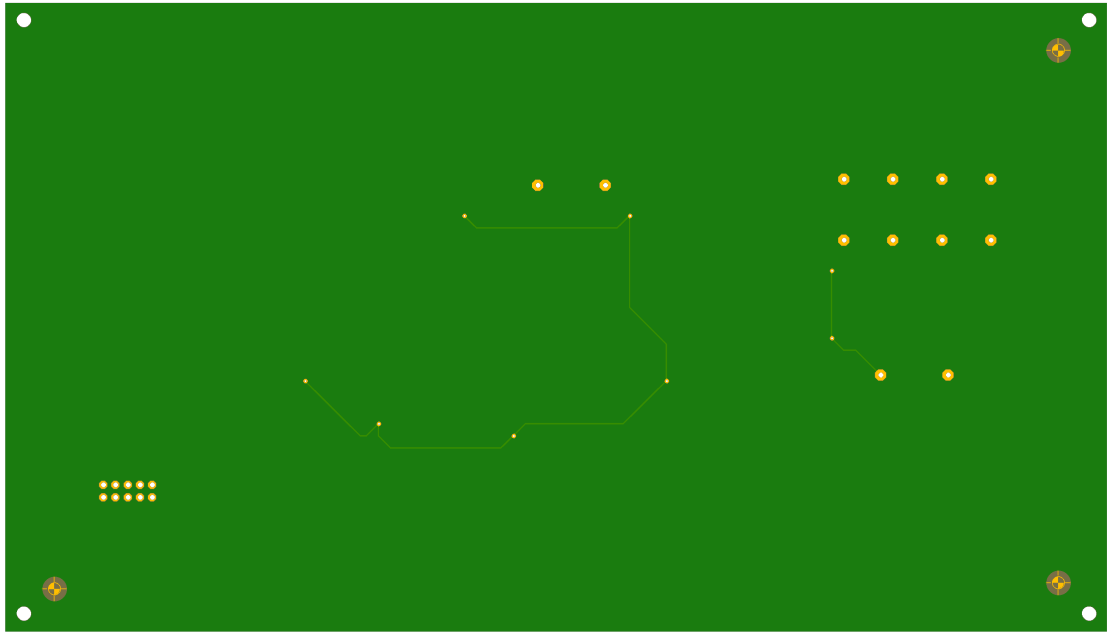
228.58
130.48
PV Power Converter
Laser-Based Wireless Power Transmission
Receiver
Solder Pads for 4 PV Cells
in Parallel Arrangement
(10 mm x 10 mm) for Vin
Solder Pads for TEG's
(+) and (-) Leads
Buck DC-DC Converter
Solder Pads for TEC's
(+) and (-) Leads
GND
LM2596S
GND
DC OUT +5V
Load Output

3.



Solder Pads for 4 PV Cells
in Parallel Arrangement
(10 mm x 10 mm) for Vin
PV Power Converter
Laser-Based Wireless Power Transmission
Receiver
Solder Pads for TEG's
(+) and (-) Leads
LSP1
LSP2
LSP5
LSP6
LSP3
LSP4
LSP7
LSP8
LSP9
LSP10
LSP11
LSP12
(+)
(-)
10.16
12.70
13.97
RFB1
RFB2
CF
L1
CIN
COUT
U2
D1
Buck DC-DC Converter
GND
DC OUT +5V
SV3
2
4
6
8
10
Load Output
Solder Pads for TEC's
(+) and (-) Leads

Top



Bottom

4. Design Specifications,
2.5 cm x 2.5 cm PV Cell Form Factor,
4-PV, Parallel; Extension Board:
Configurable for Externally Adaptive Load Circuitry

Peripherals:

- **Inputs:**
    - PV Array: 2 leads (+ and -) x 4 PV cells = 8 leads
    - TEG module's 2 leads (+ and -)
    - TEC module's 2 leads (+ and -)
- **Outputs:**
    - ESP-32 Wi-Fi camera

Internals:

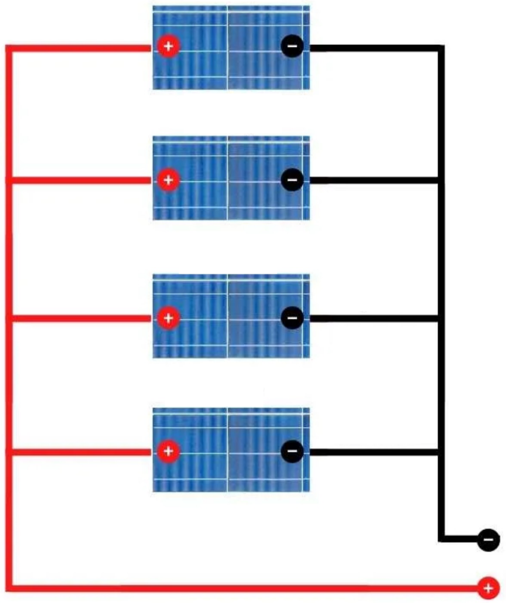
- Pads for soldered PV cells
- I/O Ports as Female Connectors

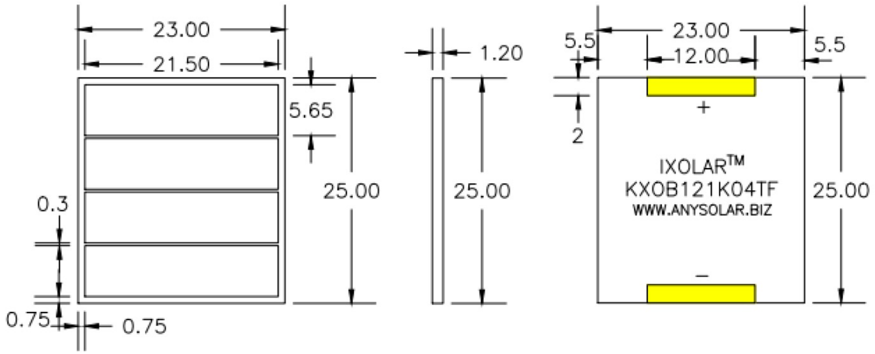
Voltage Requirements:

- **Input:**
    - Each PV cell has a 0.0472 A current output at P_{mpp}
    - Each PV cell has a 2.23 V voltage output at P_{mpp}
    - Each PV cell has a 0.1053 W maximum power output
- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W

Miscellaneous:

- Heat Sink



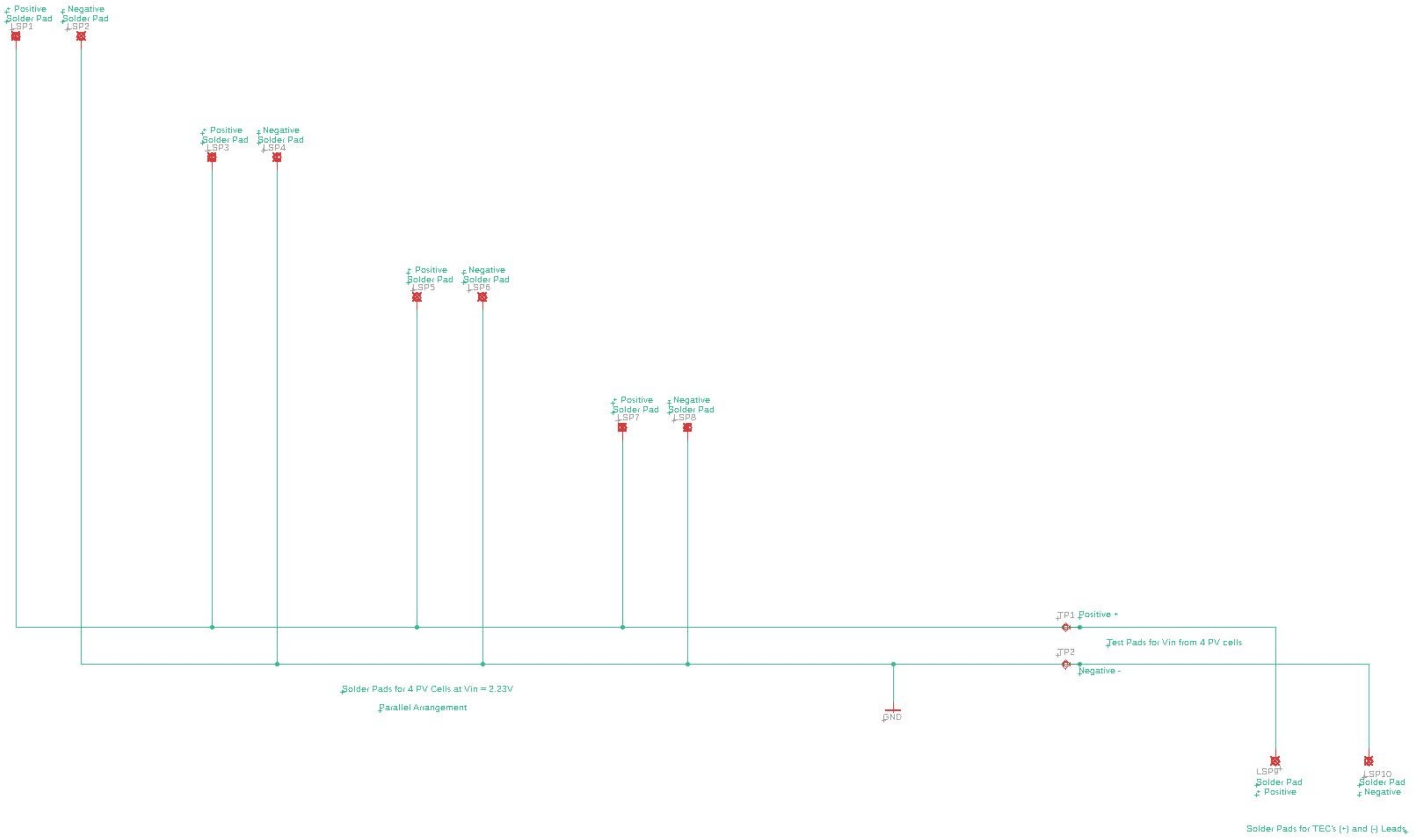


Front-side View details

Back-side View details

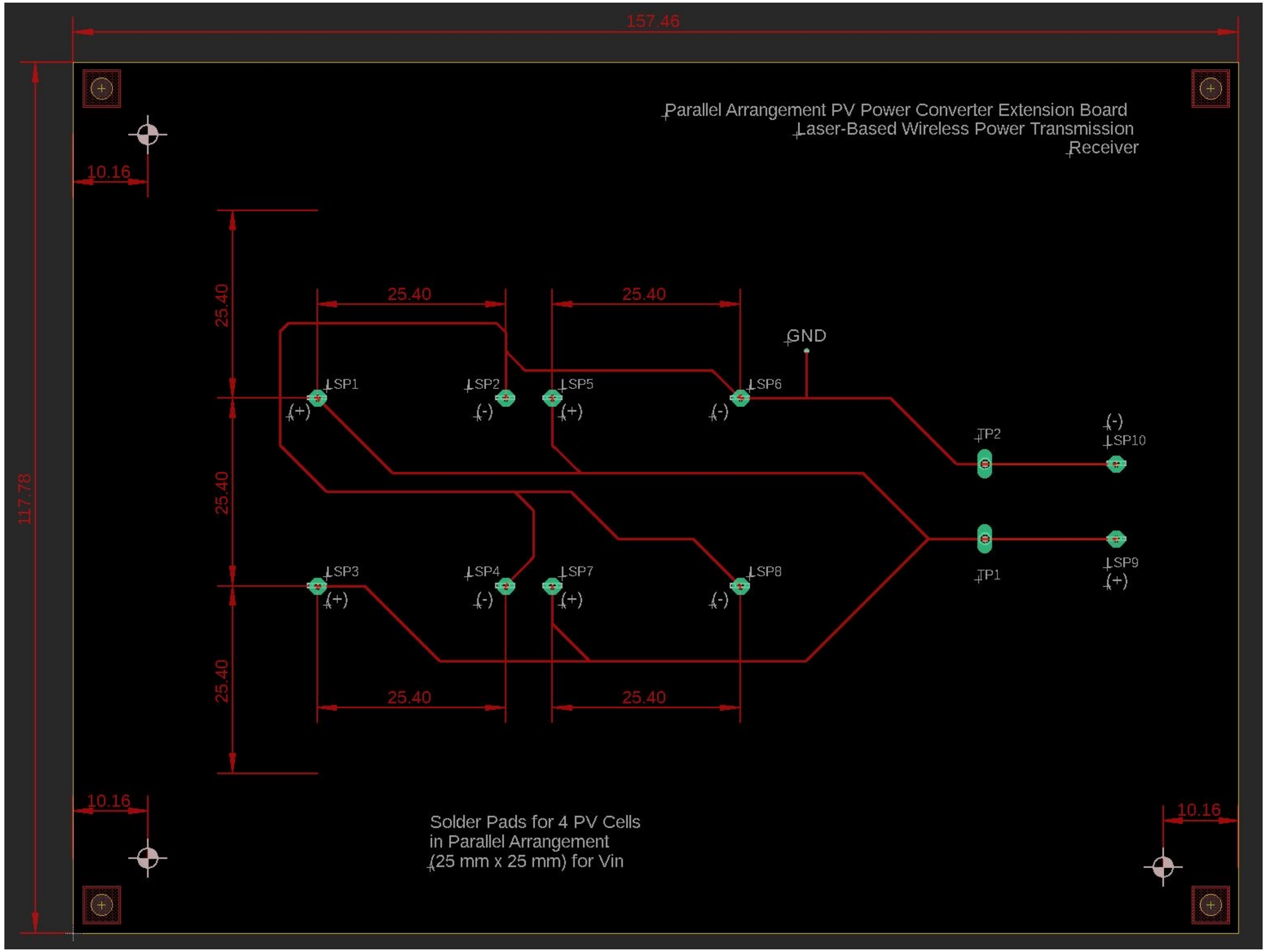
*Required Separately: **Boost DC-DC Converter** circuit: **2.23 V to 5 V**

4.

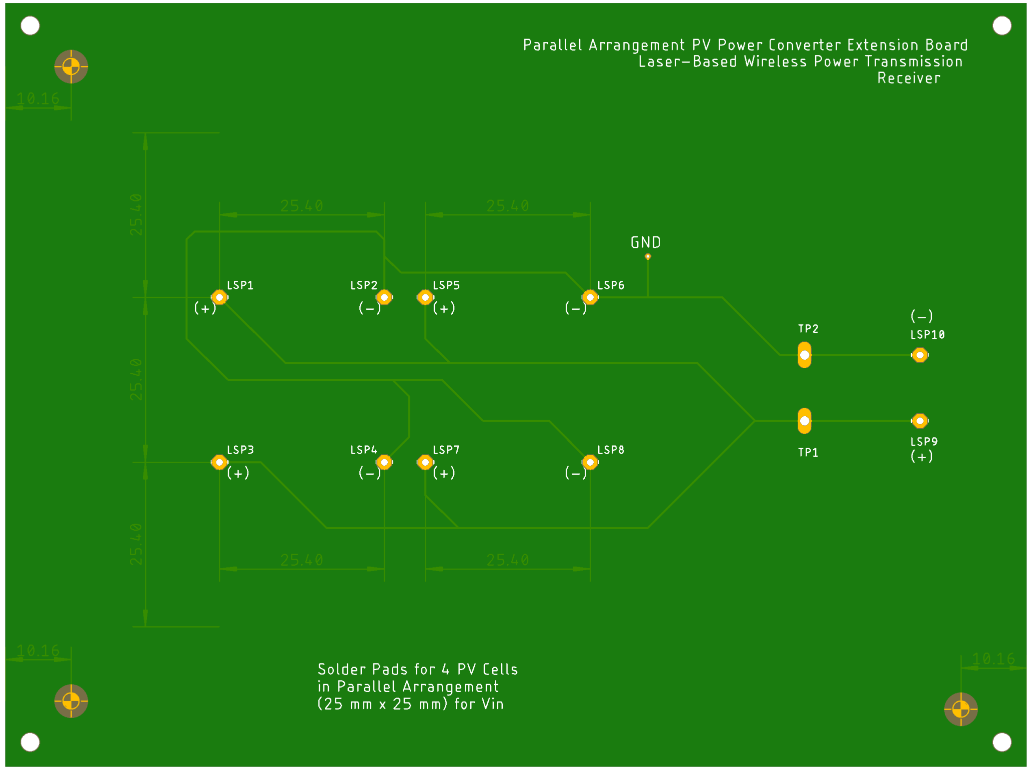


Positive Solder Pad
LSP1
Negative Solder Pad
LSP2
Positive Solder Pad
LSP3
Negative Solder Pad
LSP4
Positive Solder Pad
LSP5
Negative Solder Pad
LSP6
Positive Solder Pad
LSP7
Negative Solder Pad
LSP8
TP1 Positive +
Test Pads for Vin from 4 PV cells
TP2
Negative -
Solder Pads for 4 PV Cells at Vin = 2.23V
Parallel Arrangement
GND
LSP9
Solder Pad
Positive
LSP10
Solder Pad
Negative
Solder Pads for TEC's (+) and (-) Leads

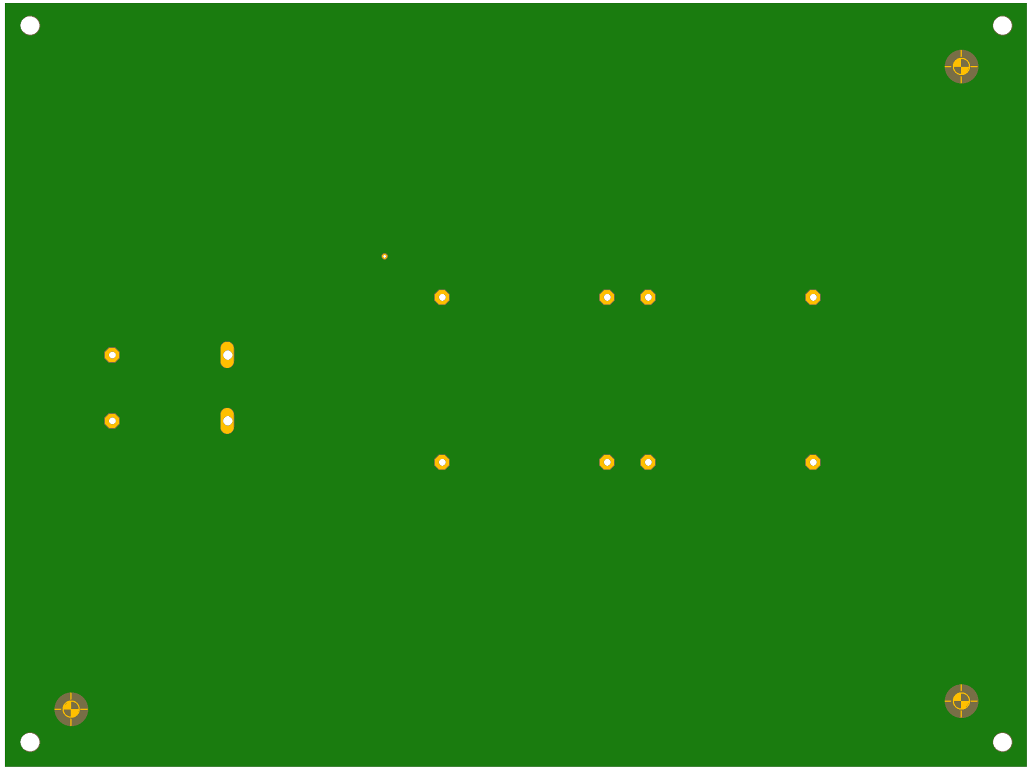
4.


157.46
117.78
10.16
10.16
10.16
Parallel Arrangement PV Power Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver
25.40
25.40
25.40
25.40
25.40
25.40
25.40
25.40
GND
SP1
SP2
SP5
SP6
(+)
(-)
(+)
(-)
TP2
(-)
SP10
TP1
SP9
(+)
SP3
SP4
SP7
SP8
(+)
(-)
(+)
(-)
Solder Pads for 4 PV Cells
in Parallel Arrangement
(25 mm x 25 mm) for Vin

4.

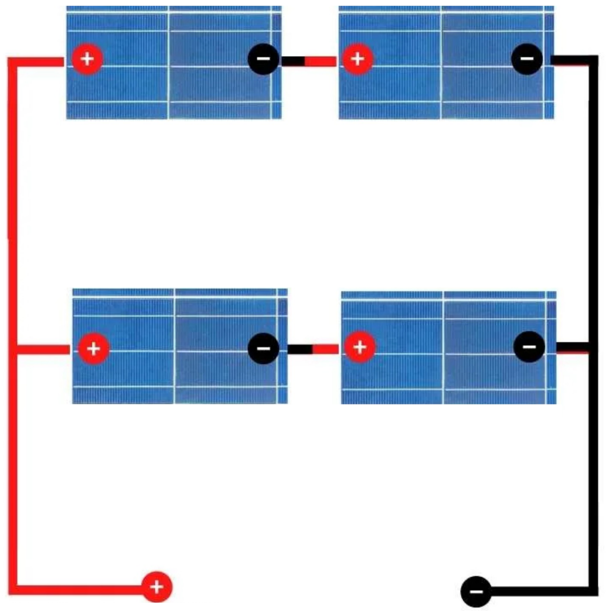

Parallel Arrangement PV Power Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver
GND
LSP1
(+)
LSP2
(-)
LSP5
(+)
LSP6
(-)
TP2
(-)
LSP10
TP1
LSP9
(+)
LSP3
(+)
LSP4
(-)
LSP7
(+)
LSP8
(-)
Solder Pads for 4 PV Cells
in Parallel Arrangement
(25 mm x 25 mm) for Vin

Top



Bottom

5. Design Specifications,
2.5 cm x 2.5 cm PV Cell Form Factor,
4-PV, Series; Full Backplane Board



Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -) leads
  - TEG module's 2 leads (+ and -)
  - TEC module's 2 leads (+ and -)

- **Outputs:**
  - ESP-32 Wi-Fi camera

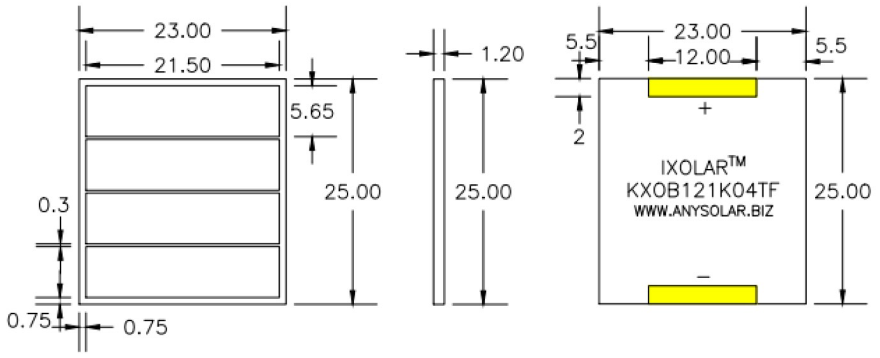
Internals:

- Pads for soldered PV cells
- PWM Control DSP, MCU, or FPGA for Switch Control
- **Buck DC-DC Converter** circuit with Low-Pass Filter: **8.92 V to 5 V**
  - R, L, C, MOSFET Switch (Voltage-Controlled)
- I/O Ports as Female Connectors

Voltage Requirements:

- **Input:** 8 - 30 V:
  - Each PV cell has a 0.1053 W maximum power output
  - Each PV cell has a 2.23 V voltage output at Pmpp
  - Total V_{out} = 2.23 V x 4 PV cells; Voltage output = 8.92 V for a series connection
  - Total current = 0.0472 A current output at Pmpp for a series connection

- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W



Front-side View details

Back-side View details

Miscellaneous:

- Heat Sink

6. Design Specifications, *5 cm x 5 cm* PV Cell Form Factor, *4-PV, Series; Full Backplane Board*

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -) leads
  - TEG module's 2 leads (+ and -)
  - TEC
- **Outputs:**
  - ESP-32 Wi-Fi camera

Internals:

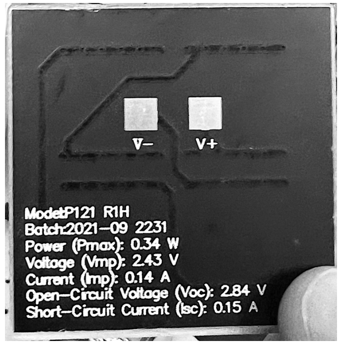
- Pads for soldered PV cells
- PWM Control DSP, MCU, or FPGA for Switch Control
- **Buck DC-DC Converter** circuit with Low-Pass Filter: **9.72 V to 5 V**
  - R, L, C, MOSFET Switch (Voltage-Controlled)
- I/O Ports as Female Connectors

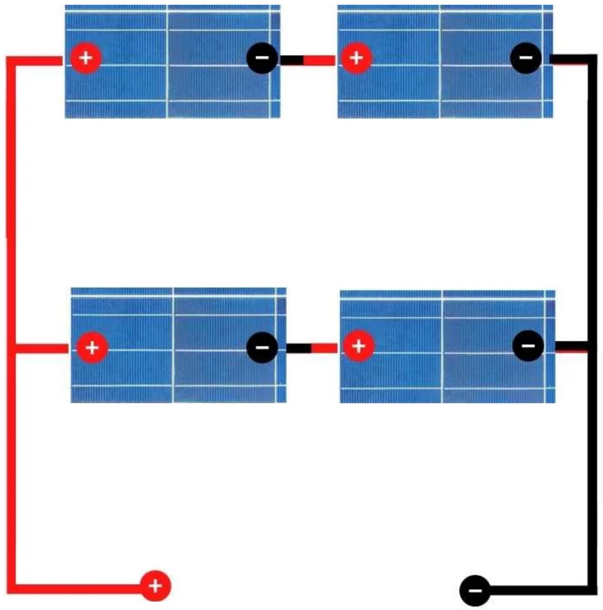
Voltage Requirements:

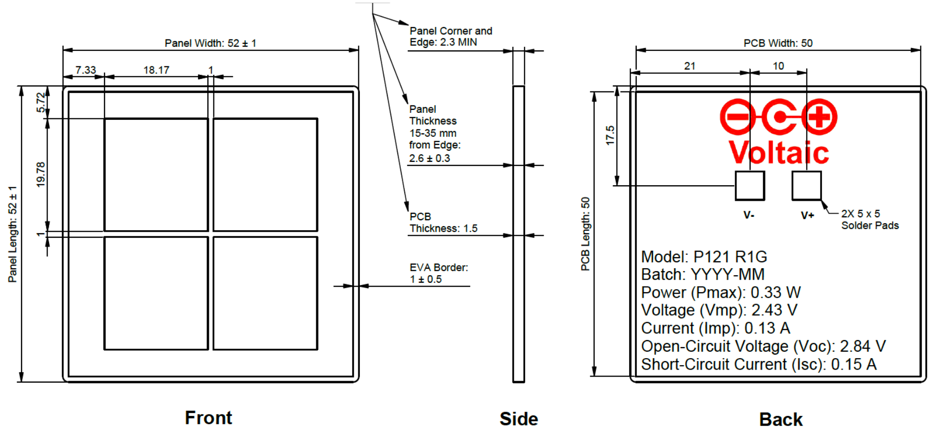
- **Input:** 8 - 30 V:
  - Each PV cell has a 0.34 W power output
  - Each PV cell has a 2.43 V voltage output
  - Total V_{out} = 2.43 V x 4 PV cells; Voltage output = 9.72 V for a series connection
  - Total current = 0.14 A for a series connection
- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W

Miscellaneous:

- Heat Sink

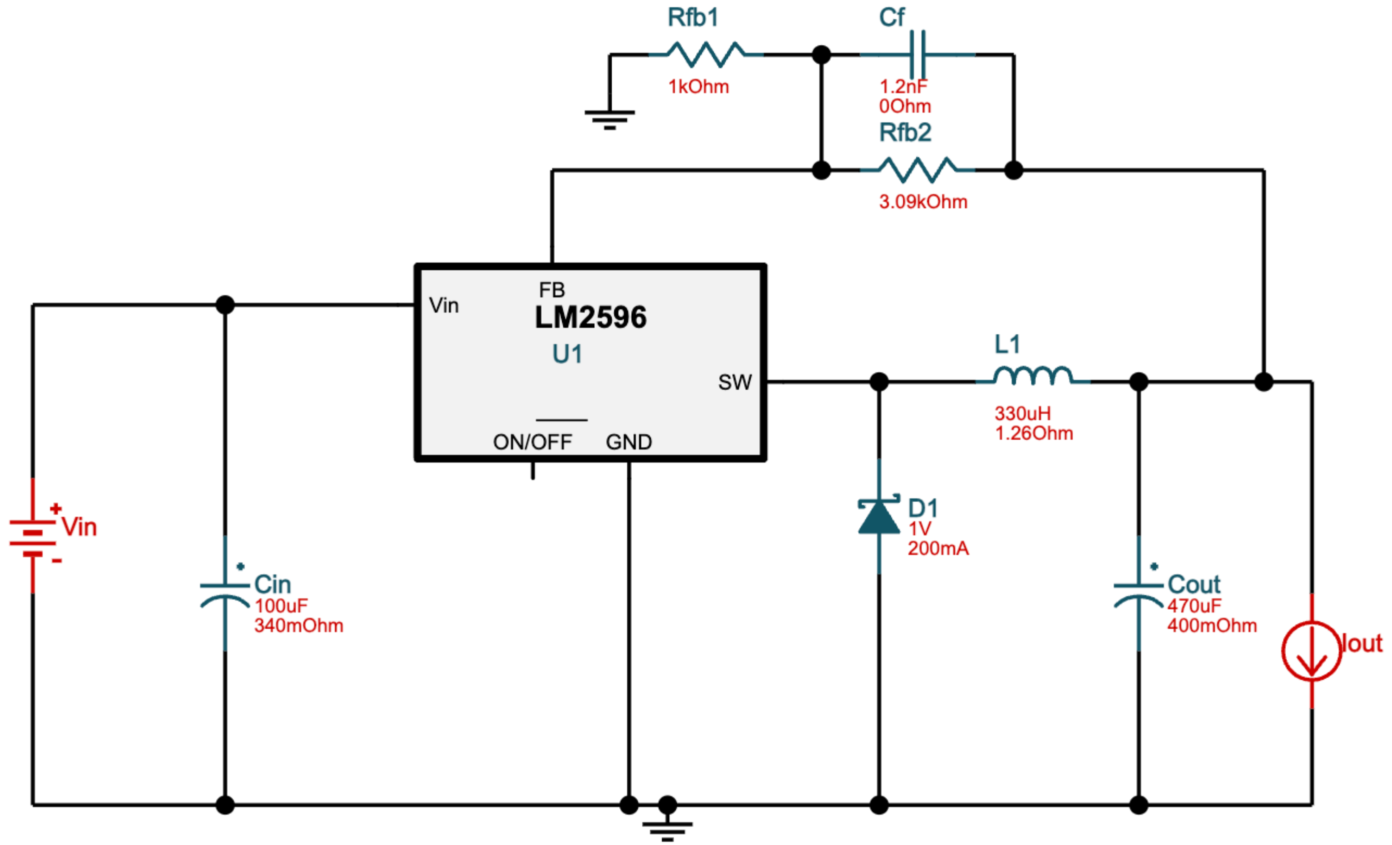




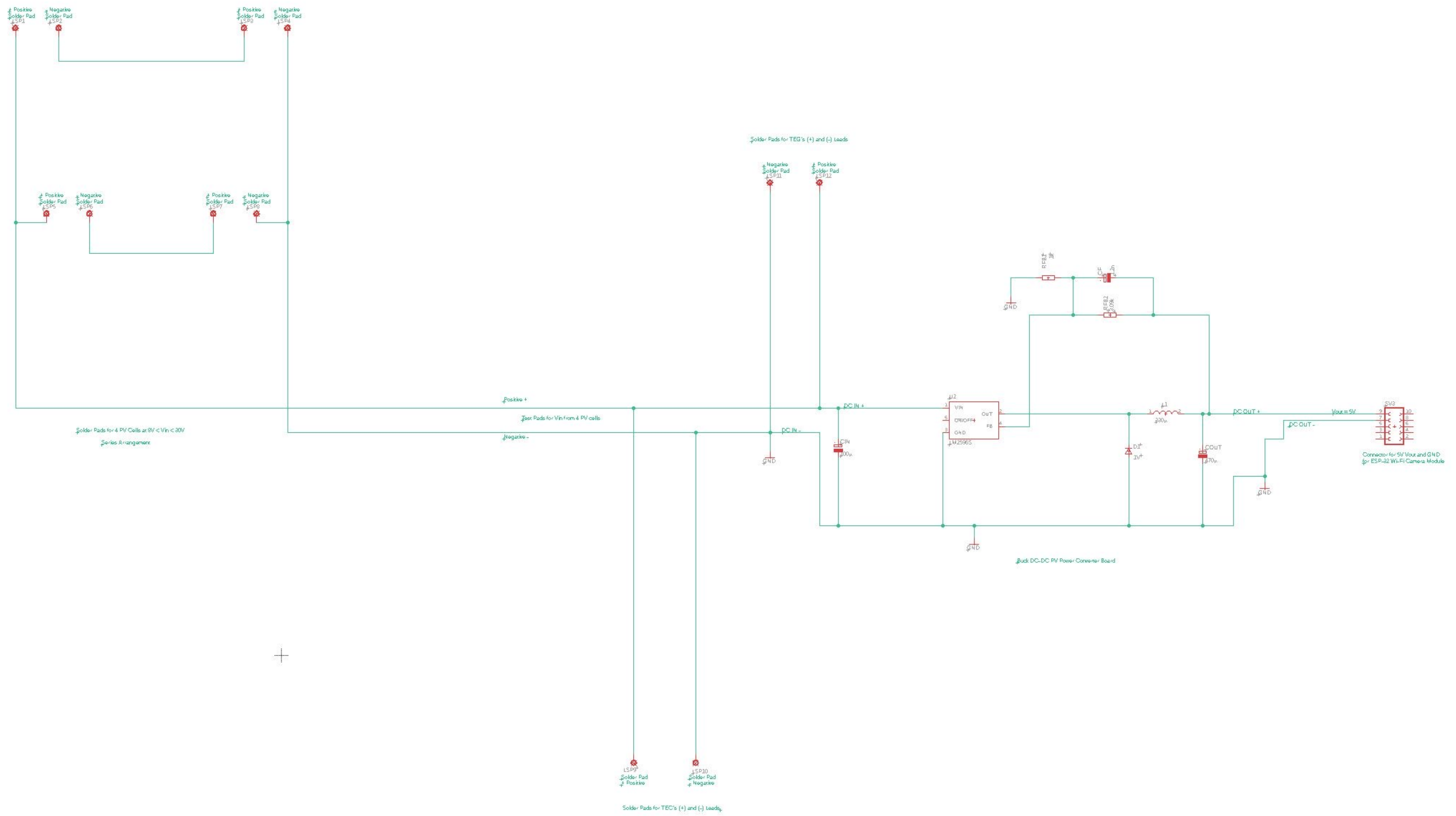


5 & 6. Buck DC-DC Converter

LM2596T-ADJ/NOPB - 8V-30V to 5.00V @ 0.18A. 68.8% Efficiency

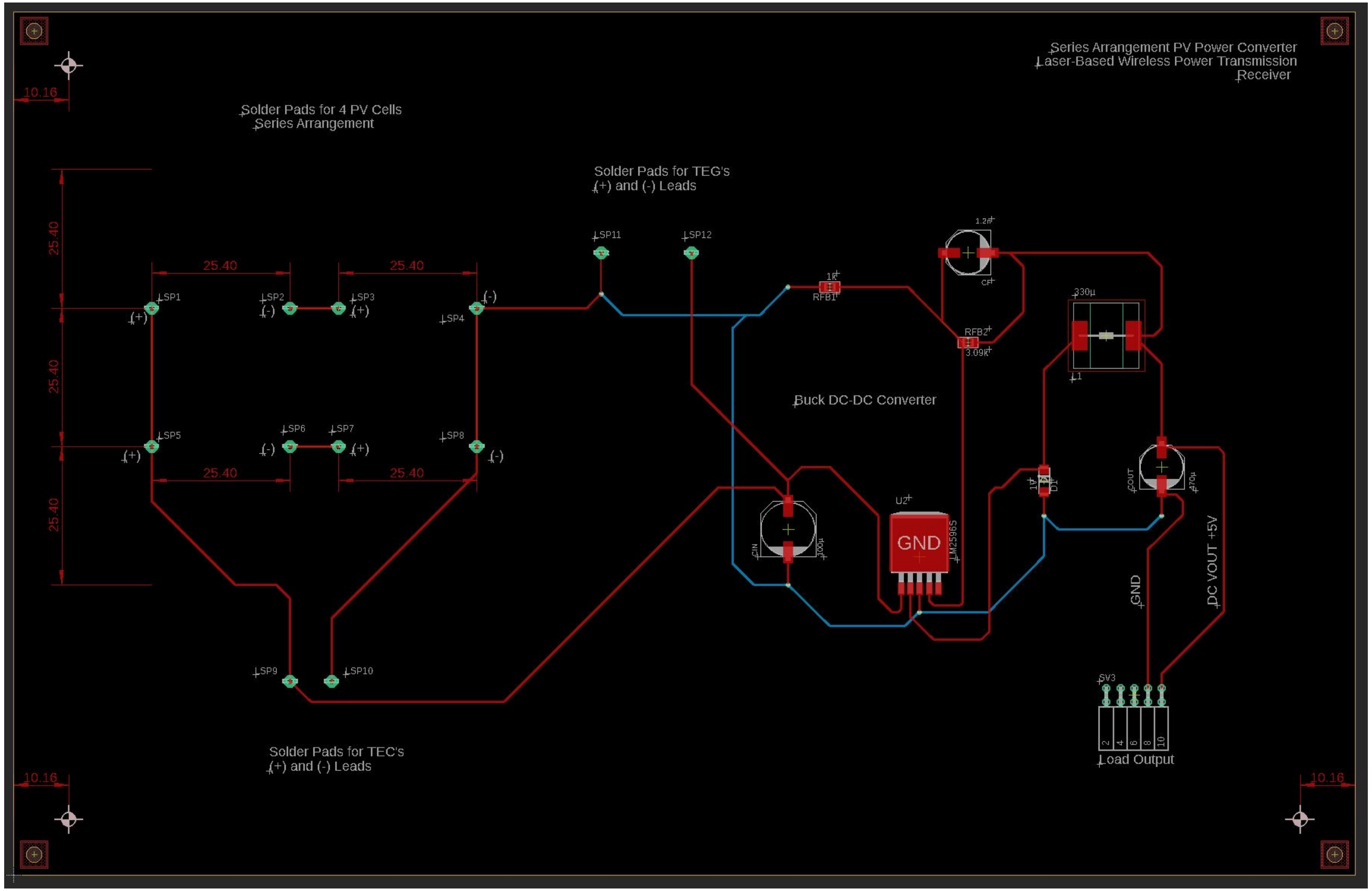


5 & 6.



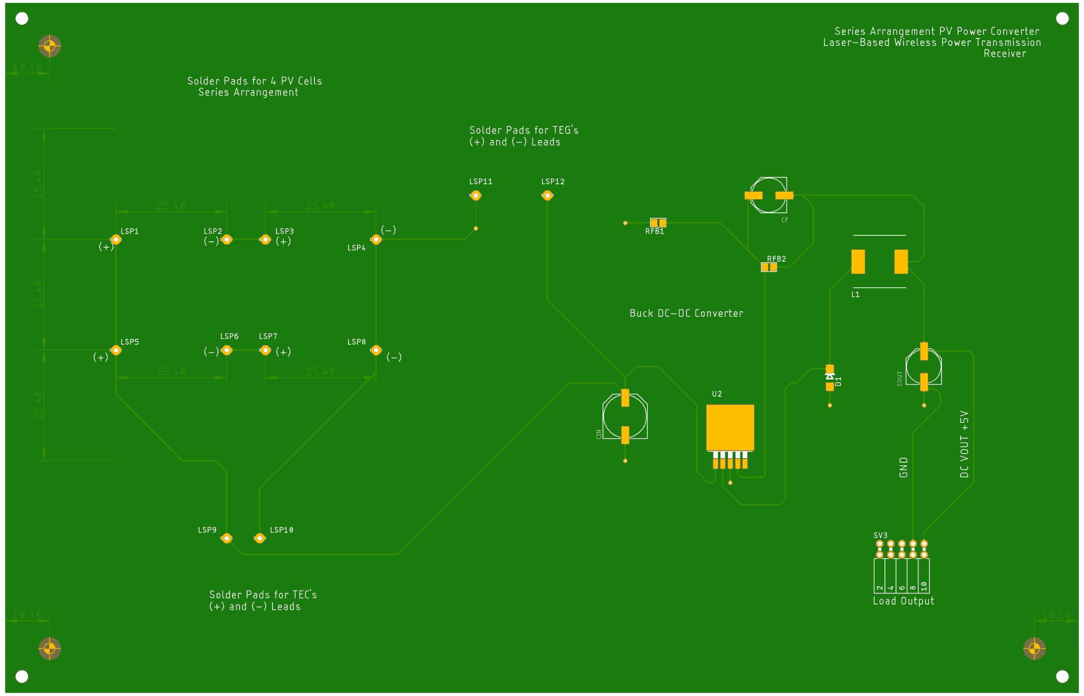
Positive Solder Pad
Negative Solder Pad
Solder Pads for TEG's (+) and (-) Leads
Solder Pads for 4 PV Cells at 9V < Vin < 30V
Series Arrangement
Positive +
Test Pads for Vin from 4 PV cells
Negative -
DC IN +
DC IN -
GND
CIN
U2
VIN
ON/OFF
GND
OUT
FB
LM2596S
L1
D1
COUT
DC OUT +
DC OUT -
Vout = 5V
SV3
Connector for 5V Vout and GND
for ESP-32 Wi-Fi Camera Module
Buck DC-DC PV Power Converter Board
Solder Pads for TEC's (+) and (-) Leads

5.

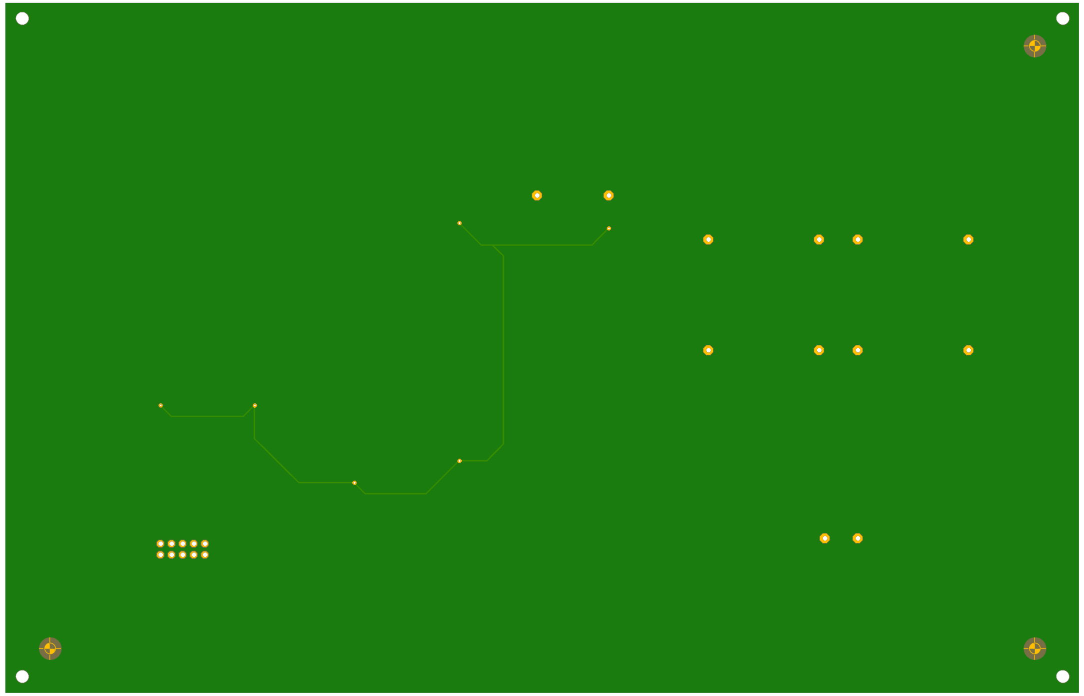


Series Arrangement PV Power Converter
Laser-Based Wireless Power Transmission
Receiver
Solder Pads for 4 PV Cells
Series Arrangement
Solder Pads for TEG's
(+) and (-) Leads
Buck DC-DC Converter
Solder Pads for TEC's
(+) and (-) Leads
Load Output
GND
DC VOUT +5V
10.16
25.40
SP1
SP2
SP3
SP4
SP5
SP6
SP7
SP8
SP9
SP10
SP11
SP12
(+)
(-)
RFB1
RFB2
3.09k
330µ
U2
LM2596S
SV3

5.

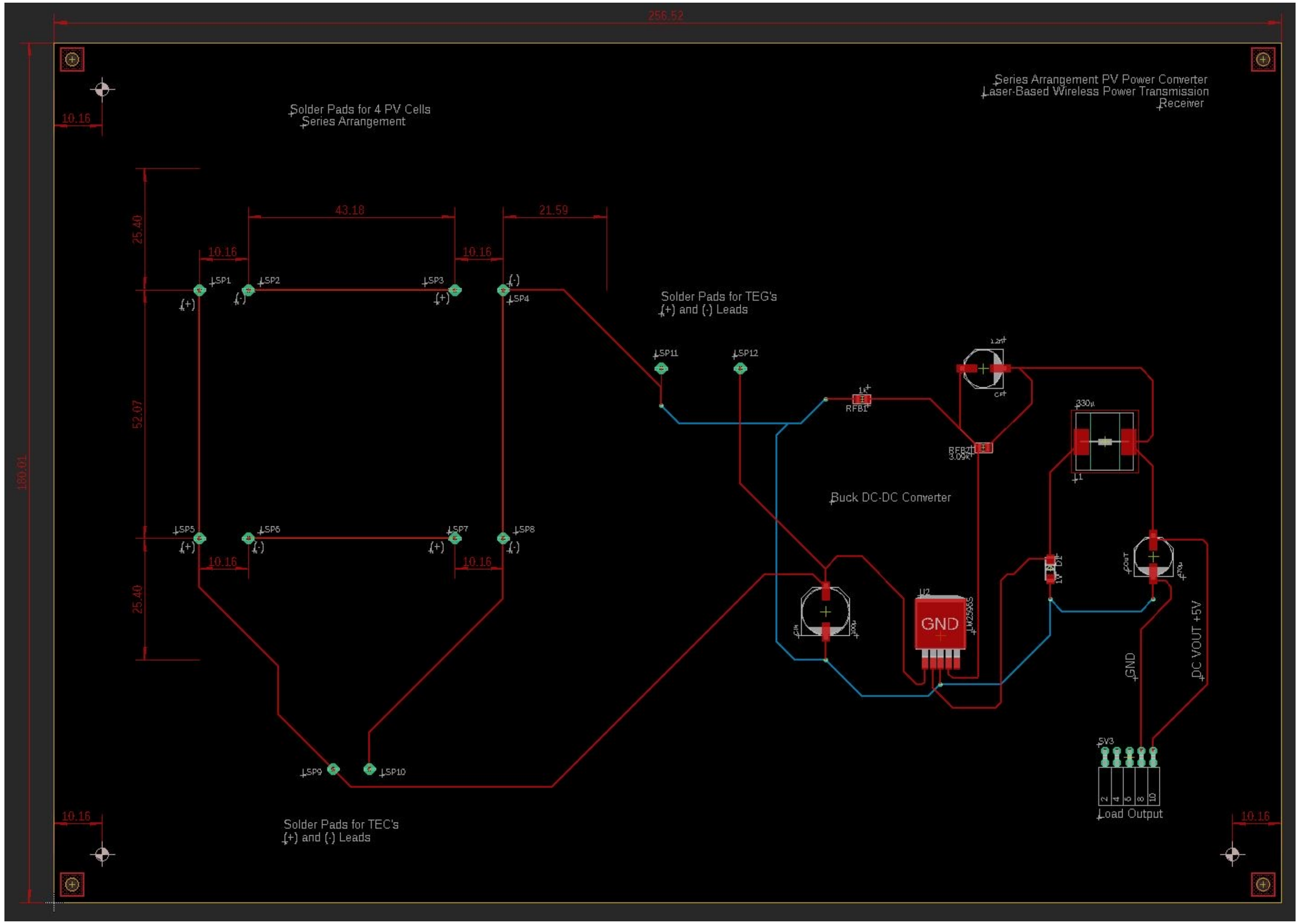

Series Arrangement PV Power Converter
Laser–Based Wireless Power Transmission
Receiver
Solder Pads for 4 PV Cells
Series Arrangement
Solder Pads for TEG's
(+) and (–) Leads
LSP1
LSP2
LSP3
LSP4
LSP5
LSP6
LSP7
LSP8
LSP9
LSP10
LSP11
LSP12
(+)
(–)
25.40
10.16
RFB1
RFB2
CF
L1
Buck DC–DC Converter
U2
CIN
D1
COUT
GND
DC VOUT +5V
SV3
2
4
6
8
10
Load Output
Solder Pads for TEC's
(+) and (–) Leads

Top



Bottom

6.

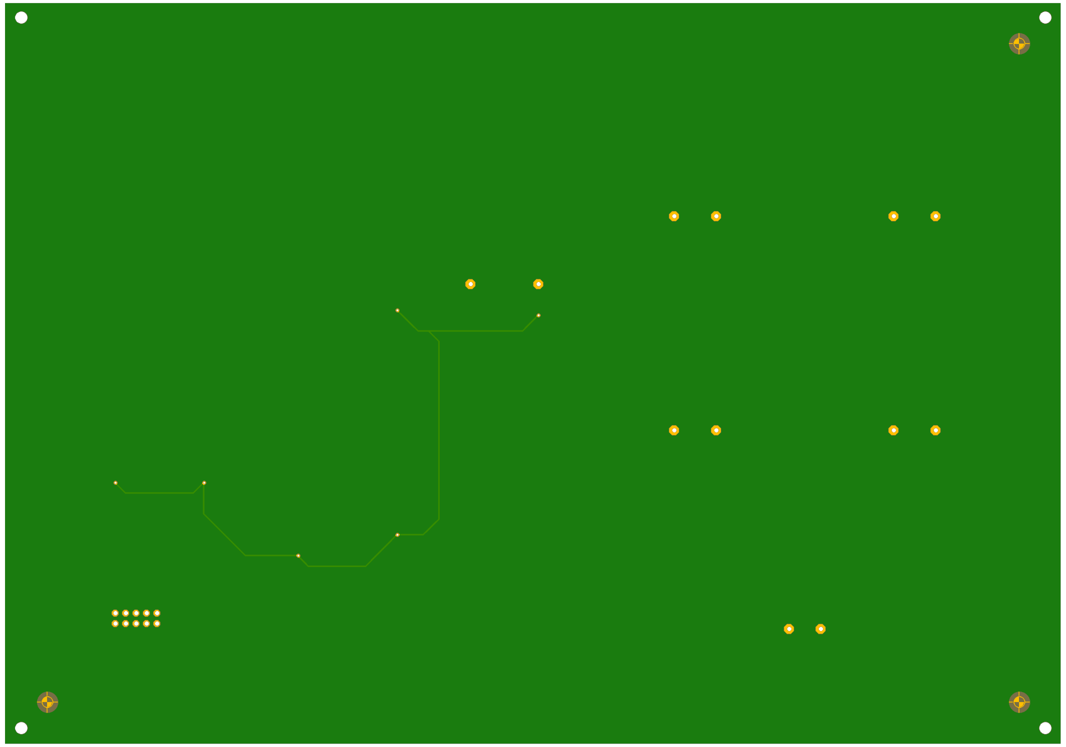


Series Arrangement PV Power Converter
Laser-Based Wireless Power Transmission
Receiver
Solder Pads for 4 PV Cells
Series Arrangement
Solder Pads for TEG's
(+) and (-) Leads
Buck DC-DC Converter
Solder Pads for TEC's
(+) and (-) Leads
Load Output
GND
DC VOUT +5V
256.52
43.18
21.59
10.16
25.40
52.07

6.

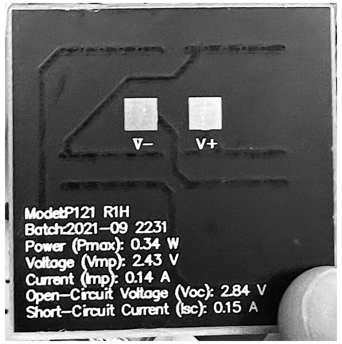
Series Arrangement PV Power Converter
Laser–Based Wireless Power Transmission
Receiver
Solder Pads for 4 PV Cells
Series Arrangement
Solder Pads for TEG's
(+) and (–) Leads
Buck DC–DC Converter
Solder Pads for TEC's
(+) and (–) Leads
Load Output
GND
DC VOUT +5V

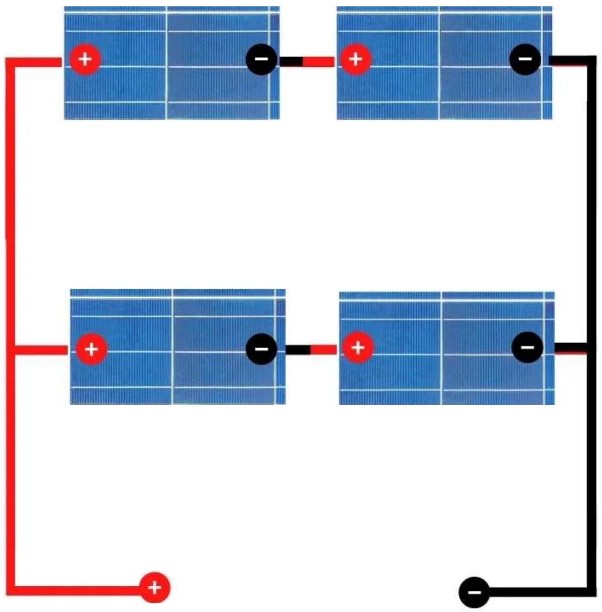
Top



Bottom

7. Design Specifications,
5 cm x 5 cm PV Cell Form Factor,
4-PV, Series; Backplane Extension Board





Peripherals:

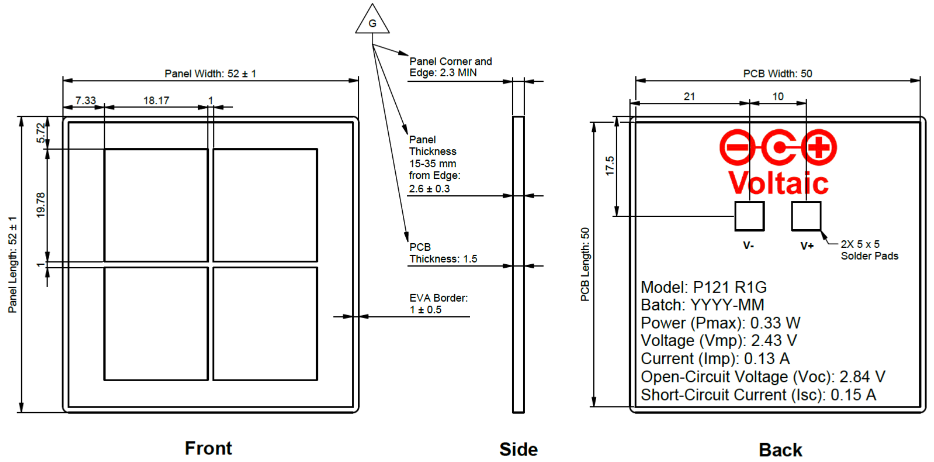
- **Inputs:**
  - PV Array: 2 leads (+ and -) x 4 PV cells = 8 leads
  - TEG module's 2 leads (+ and -)
  - TEC module's 2 leads (+ and -)
- **Outputs:**
  - ESP-32 Wi-Fi camera

Internals:

- Pads for soldered PV cells
- I/O Ports as Female Connectors

Voltage Requirements:

- **Input:** 8 - 30 V:
  - Each PV cell has a 0.34 W power output
  - Each PV cell has a 2.43 V
  - Total V_{out} = 2.43 V x 4 PV cells; Voltage output = 9.72 V for a series connection
  - Total current = 0.14 A for a series connection
- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W

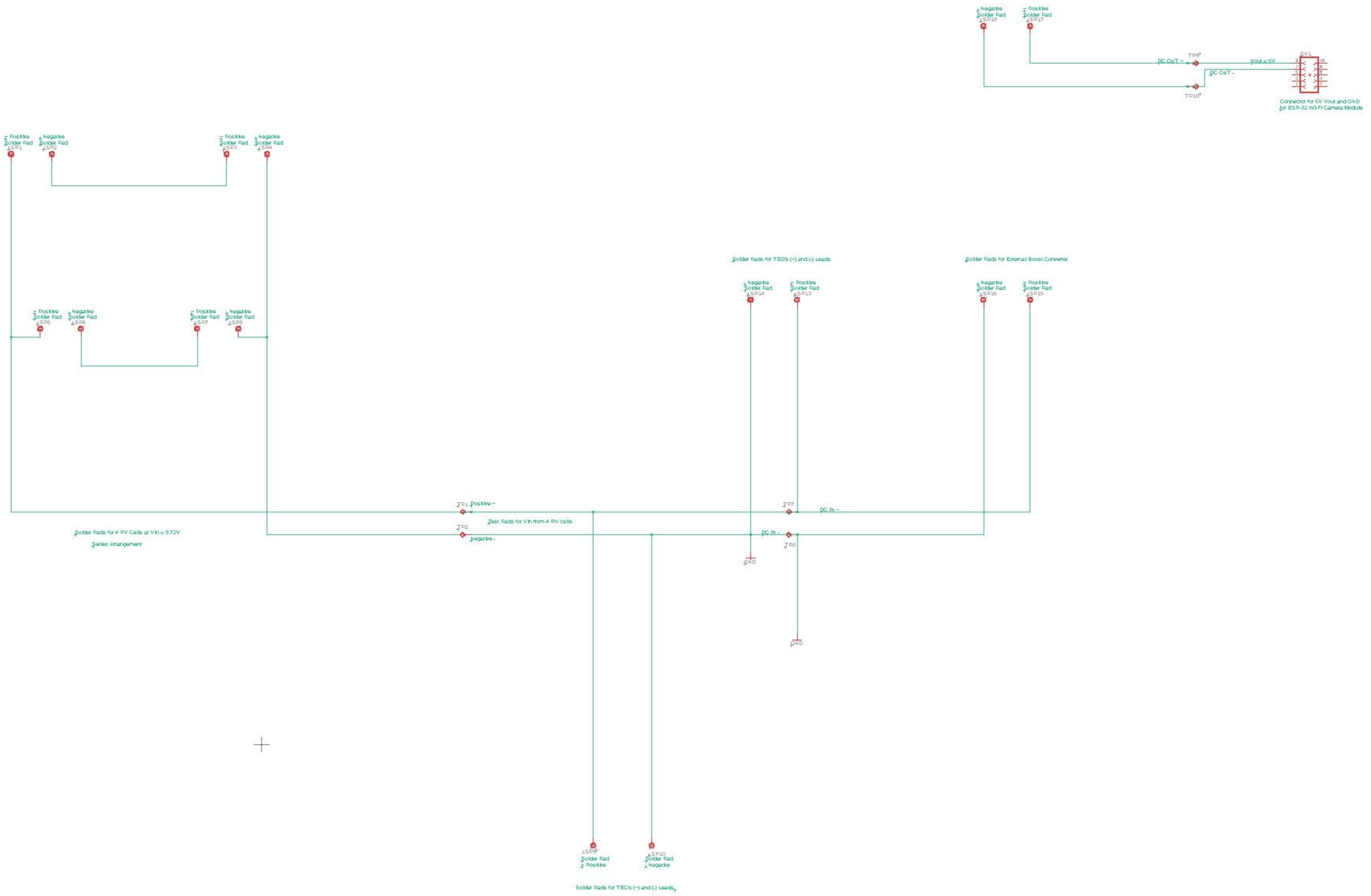


Miscellaneous:

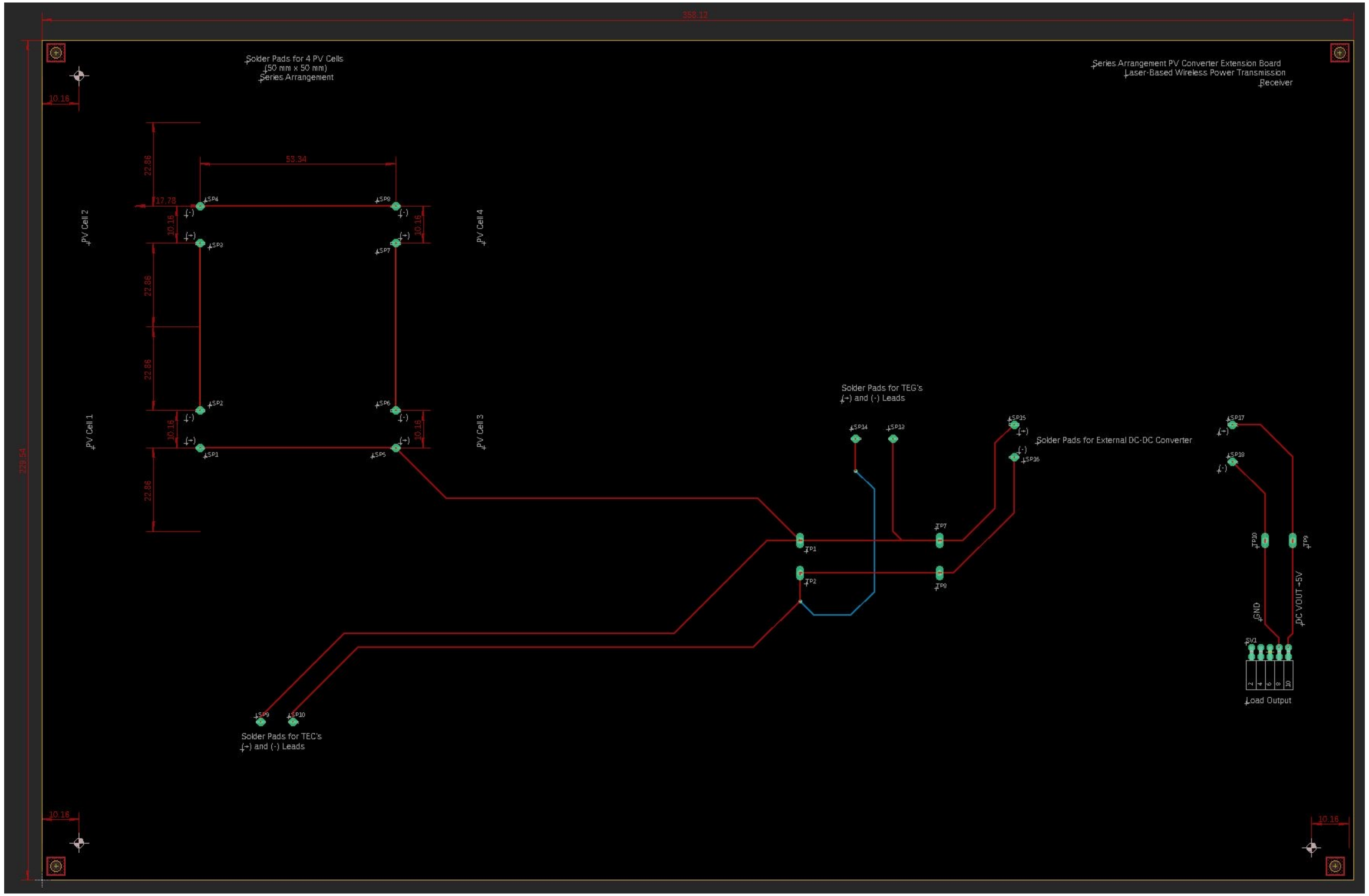
- Heat Sink

*Required Separately: **Buck DC-DC Converter** circuit: **9.72 V to 5 V**

7.


Connector for 5V Vout and GND
for ESP-32 Wi-Fi Camera Module
Vout = 5V
DC OUT +
DC OUT -
Solder Pads for TEC's (+) and (-) Leads
Solder Pads for External Boost Converter
Test Pads for Vin from 4 PV cells
Solder Pads for 4 PV Cells at Vin = 9.72V
Series Arrangement
DC IN +
DC IN -
GND

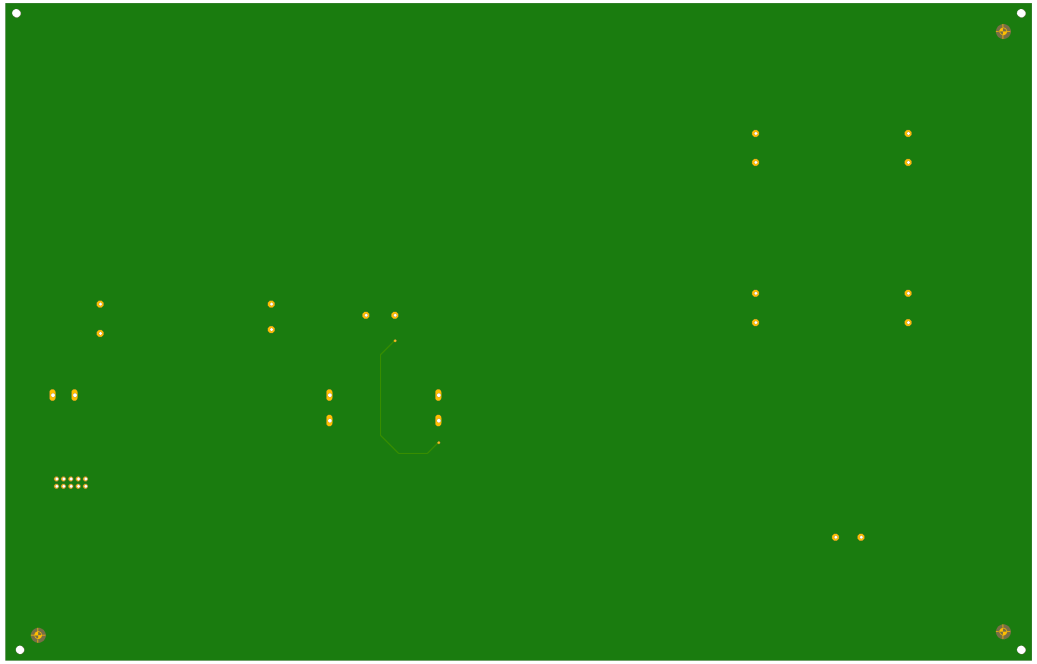
7.


Solder Pads for 4 PV Cells
(50 mm x 50 mm)
Series Arrangement
Series Arrangement PV Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver
PV Cell 2
PV Cell 4
PV Cell 1
PV Cell 3
Solder Pads for TEG's
(+) and (-) Leads
Solder Pads for External DC-DC Converter
GND
DC VOUT +5V
Load Output
Solder Pads for TEC's
(+) and (-) Leads

7.

Solder Pads for 4 PV Cells
(50 mm x 50 mm)
Series Arrangement
Series Arrangement PV Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver
PV Cell 1
PV Cell 2
PV Cell 3
PV Cell 4
Solder Pads for TEG's
(+) and (-) Leads
Solder Pads for External DC-DC Converter
GND
DC VOUT +5V
Load Output
Solder Pads for TEC's
(+) and (-) Leads

Top



Bottom

8. Design Specifications,
2.5 cm x 2.5 cm PV Cell Form Factor,
4-PV, Parallel; Backplane Extension Board

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -)
  - TEG module's 2 leads (+ and -)
  - TEC module's 2 leads (+ and -)
- **Outputs:**
  - ESP-32 Wi-Fi camera

Internals:

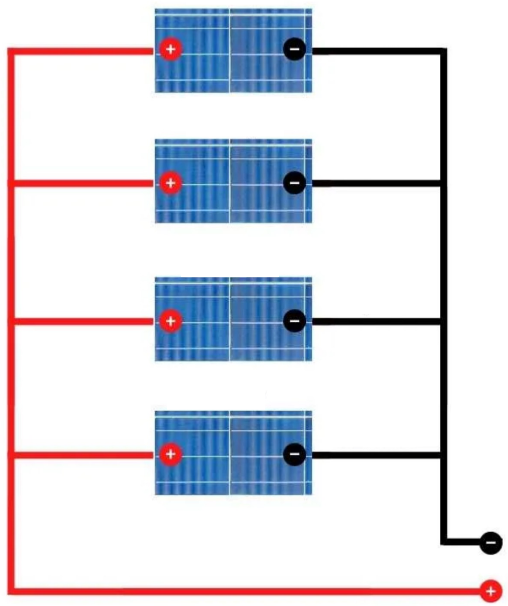
- Pads for soldered PV cells
- I/O Ports as Female Connectors

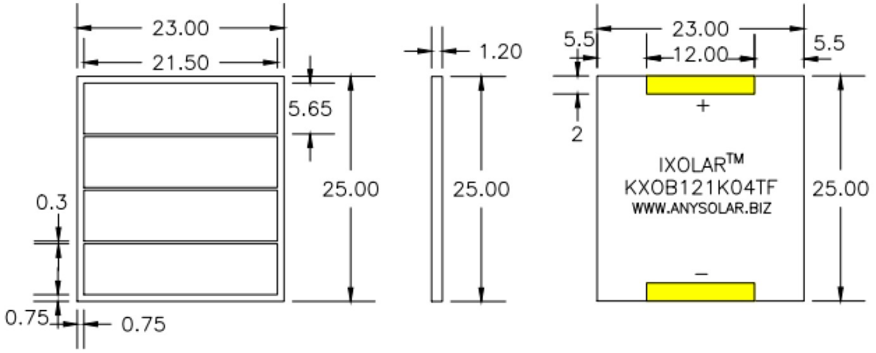
Voltage Requirements:

- **Input:**
  - Each PV cell has a 0.1053 W maximum power output
  - Each PV cell has a 2.23 V voltage output at Pmpp
  - Total V_{out} = 2.23 V for a parallel connection
  - Total current = 0.0472 A x 4 PV cells = 0.1888 A for a parallel connection
  - Total power = 2.23 V x 0.1888 A = 0.421024 W
- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W

Miscellaneous:

- Heat Sink





Front-side View details

Back-side View details

*Required Separately: **Boost DC-DC Converter** circuit: **2.23 V to 5 V**

9. Design Specifications,
5 cm x 5 cm PV Cell Form Factor,
4-PV, Parallel; Backplane Extension Board

Peripherals:

- **Inputs:**
  - PV Array: 2 leads (+ and -)
  - TEG module's 2 leads (+ and -)
  - TEC
- **Outputs:**
  - ESP-32 Wi-Fi camera

Internals:

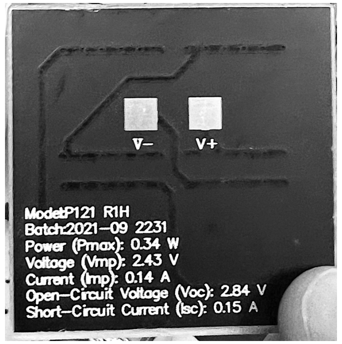
- Pads for soldered PV cells
- I/O Ports as Female Connectors

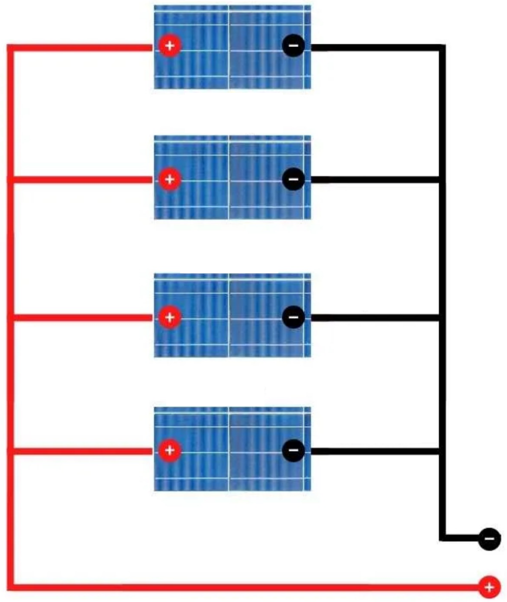
Voltage Requirements:

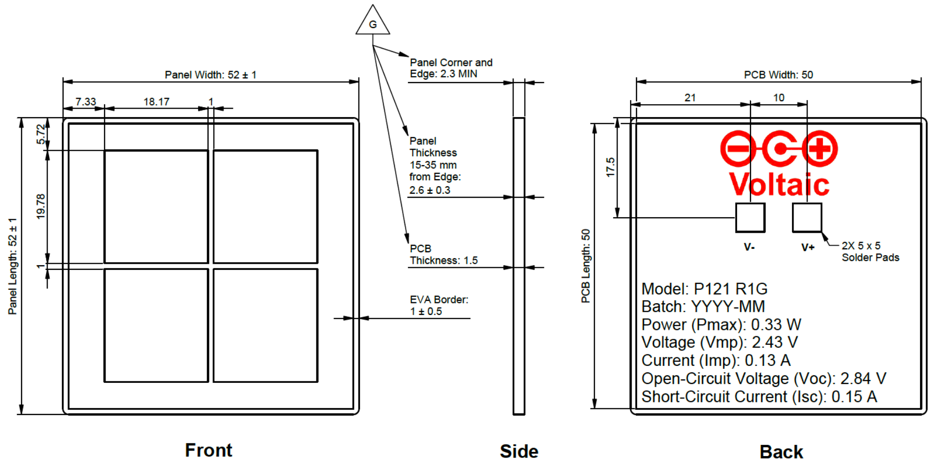
- **Input:**
  - Each PV cell has a 0.34 W power output
  - Each PV cell has a 2.43 V voltage output
  - Total V_{out} = 2.43 V for a parallel connection
  - Total current = 0.14 A x 4 PV cells = 0.56 A for a parallel connection
  - Total power = 2.43 V x 0.56 A = 1.3608 W
- **Output:** 5 V at 180 mA or 0.18 A = 0.9 W

Miscellaneous:

- Heat Sink

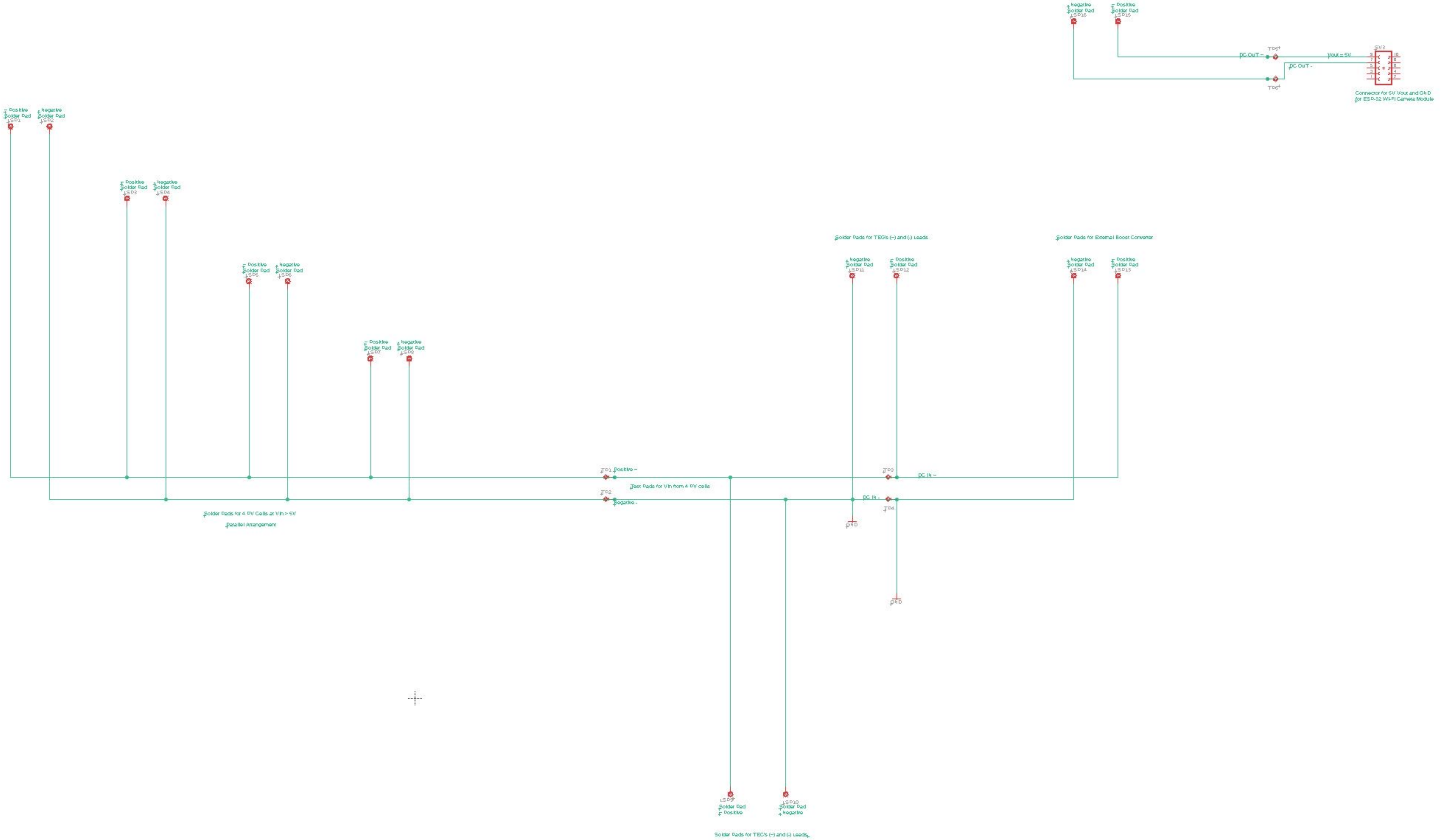






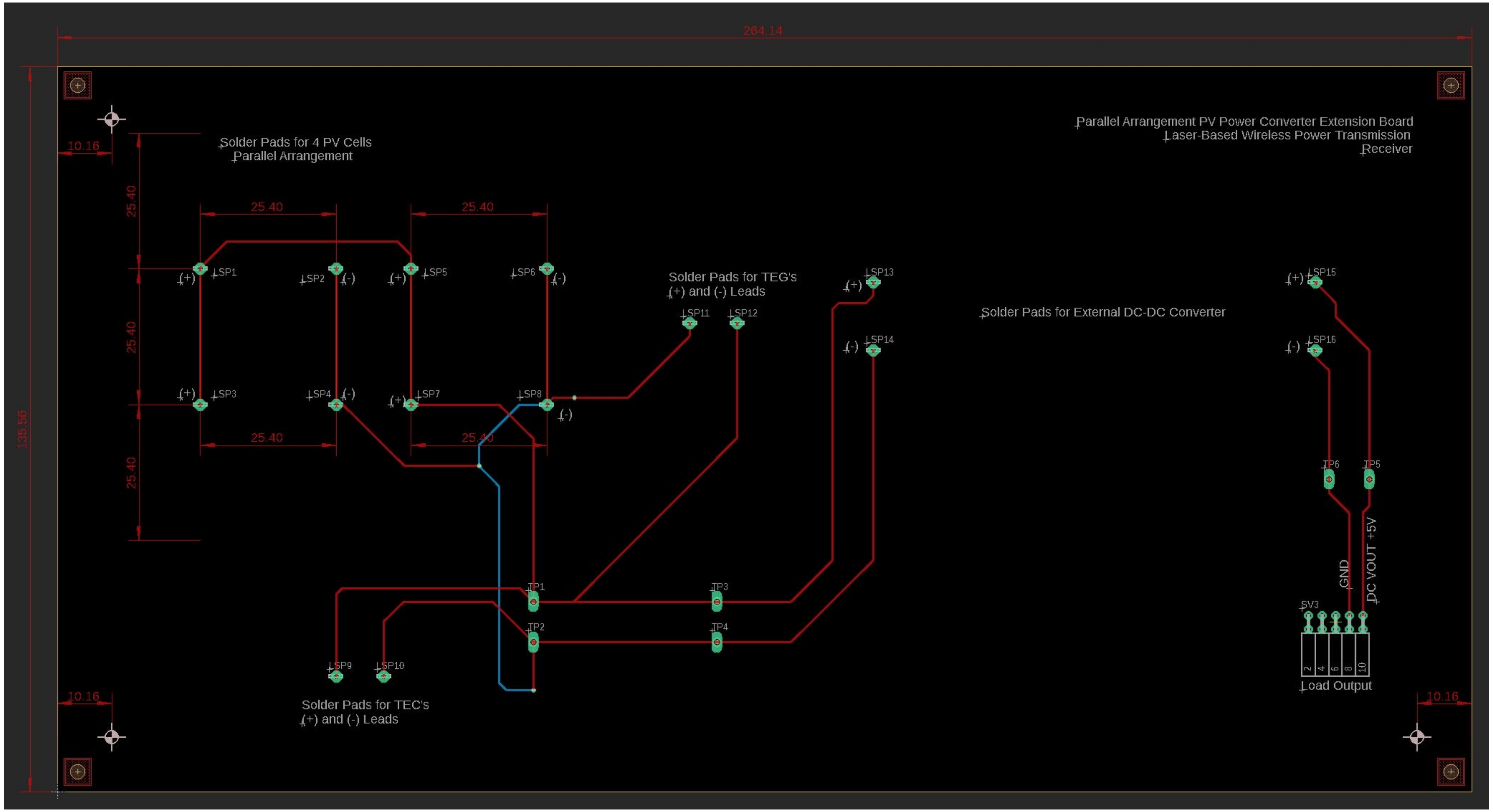
*Required Separately: **Boost DC-DC Converter** circuit: **2.43 V to 5 V**

8 & 9.



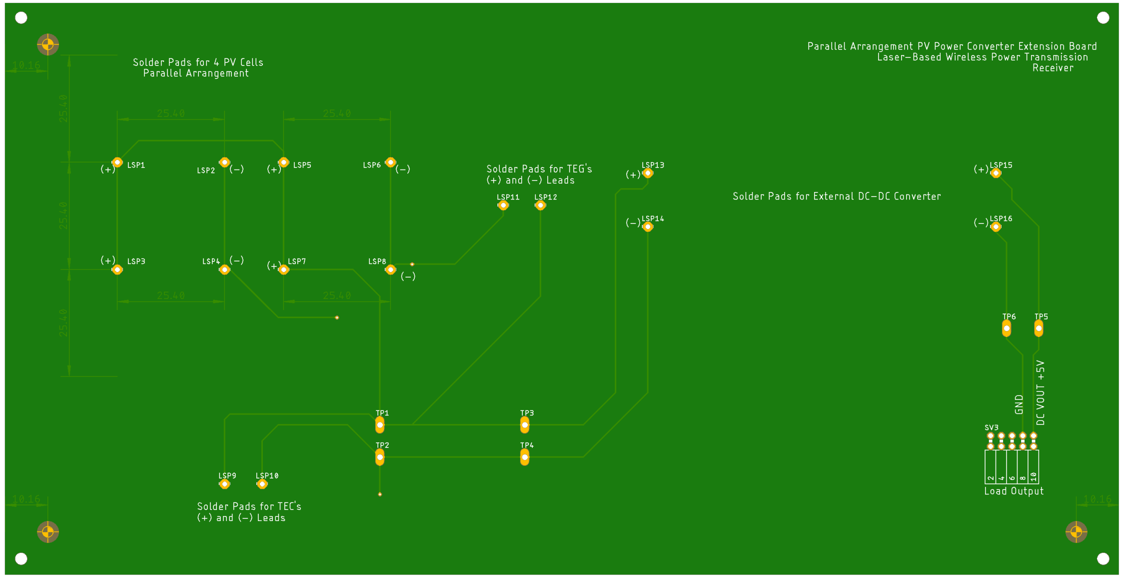
Negative Solder Pad SD16
Positive Solder Pad SD15
DC OUT −
TP5
Vout = 5V
DC OUT -
TP6
SV3
Connector for 5V Vout and GND
for ESP-32 Wi-Fi Camera Module
Positive Solder Pad SD1
Negative Solder Pad SD2
Positive Solder Pad SD3
Negative Solder Pad SD4
Positive Solder Pad SD5
Negative Solder Pad SD6
Positive Solder Pad SD7
Negative Solder Pad SD8
Solder Pads for TEG's (–) and (-) Leads
Negative Solder Pad SD11
Positive Solder Pad SD12
Solder Pads for External Boost Converter
Negative Solder Pad SD14
Positive Solder Pad SD13
TP1 Positive −
Test Pads for Vin from 4 PV cells
TP2 Negative -
TP3
DC IN −
DC IN -
TP4
GND
GND
Solder Pads for 4 PV Cells at Vin > 5V
Parallel Arrangement
SD9 Solder Pad Positive
SD10 Solder Pad Negative
Solder Pads for TEG's (–) and (-) Leads

8.



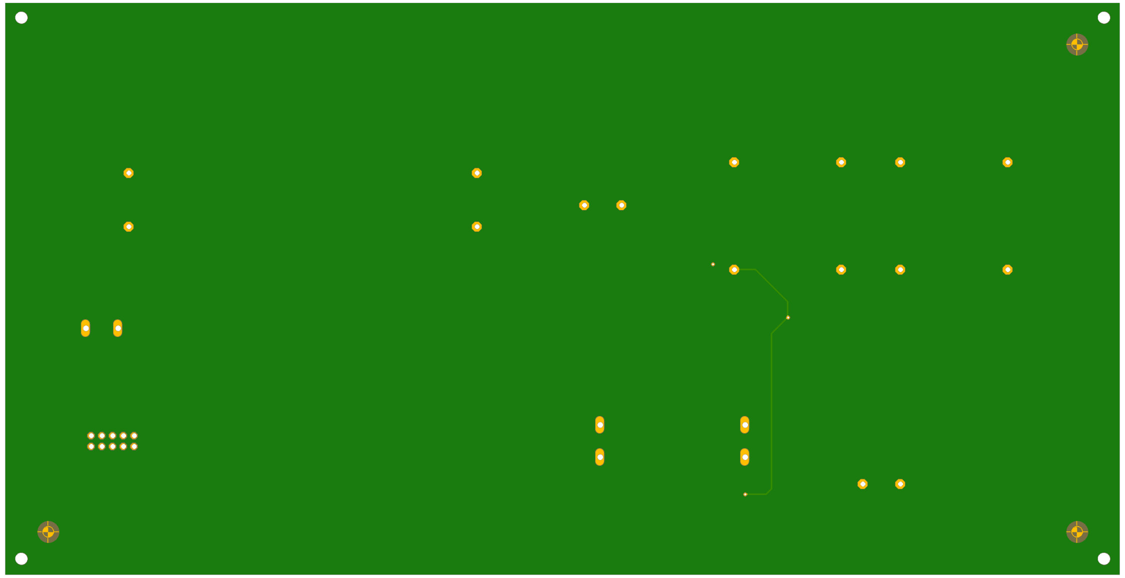
264.14
135.56
10.16
Solder Pads for 4 PV Cells
Parallel Arrangement
Parallel Arrangement PV Power Converter Extension Board
Laser-Based Wireless Power Transmission
Receiver
25.40
SP1
SP2
SP3
SP4
SP5
SP6
SP7
SP8
(+)
(-)
Solder Pads for TEG's
(+) and (-) Leads
SP11
SP12
SP13
SP14
Solder Pads for External DC-DC Converter
SP15
SP16
TP1
TP2
TP3
TP4
TP5
TP6
GND
DC VOUT +5V
SV3
Load Output
SP9
SP10
Solder Pads for TEC's
(+) and (-) Leads

8.



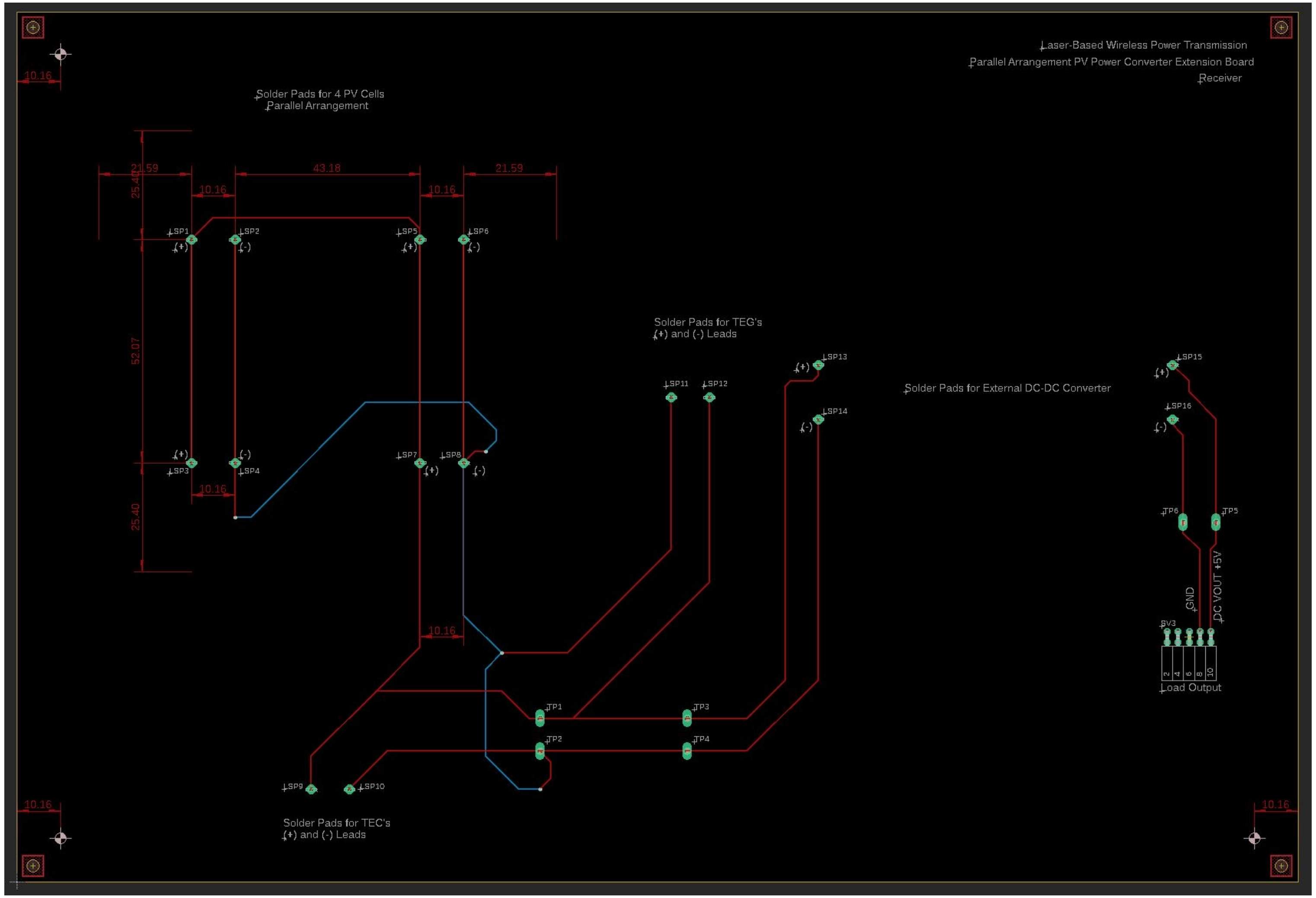
Solder Pads for 4 PV Cells
Parallel Arrangement
LSP1
LSP2
LSP3
LSP4
LSP5
LSP6
LSP7
LSP8
Solder Pads for TEG's
(+) and (−) Leads
LSP11
LSP12
LSP13
LSP14
TP1
TP2
TP3
TP4
LSP9
LSP10
Solder Pads for TEC's
(+) and (−) Leads
Parallel Arrangement PV Power Converter Extension Board
Laser–Based Wireless Power Transmission
Receiver
Solder Pads for External DC–DC Converter
LSP15
LSP16
TP6
TP5
GND
DC VOUT +5V
SV3
Load Output

Top



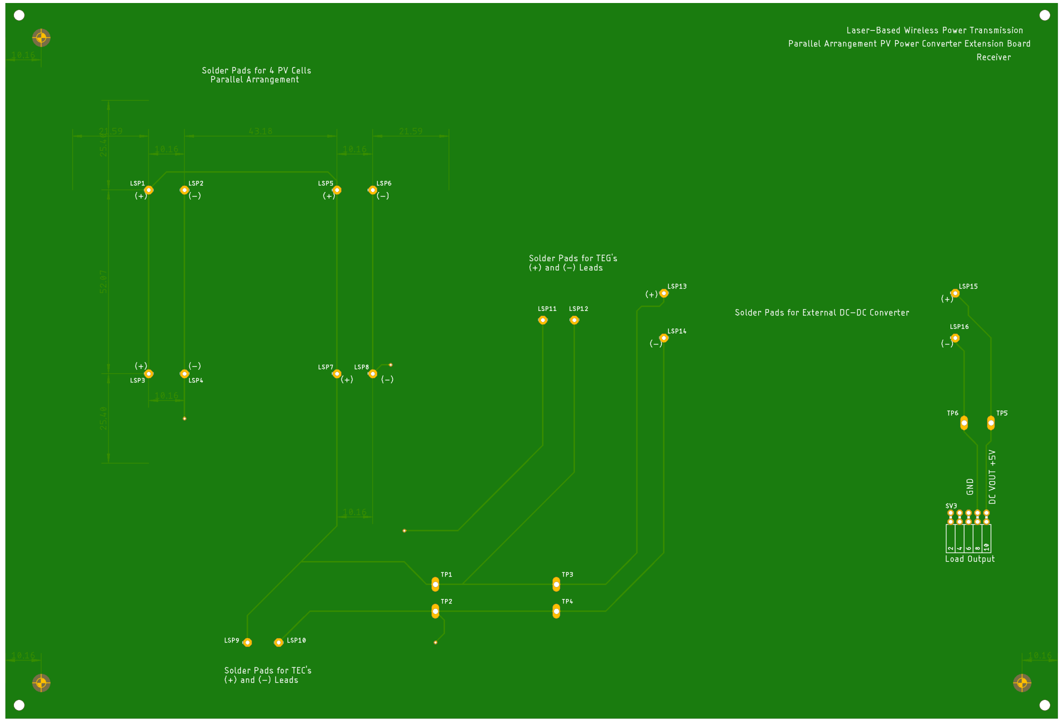
Bottom

9.



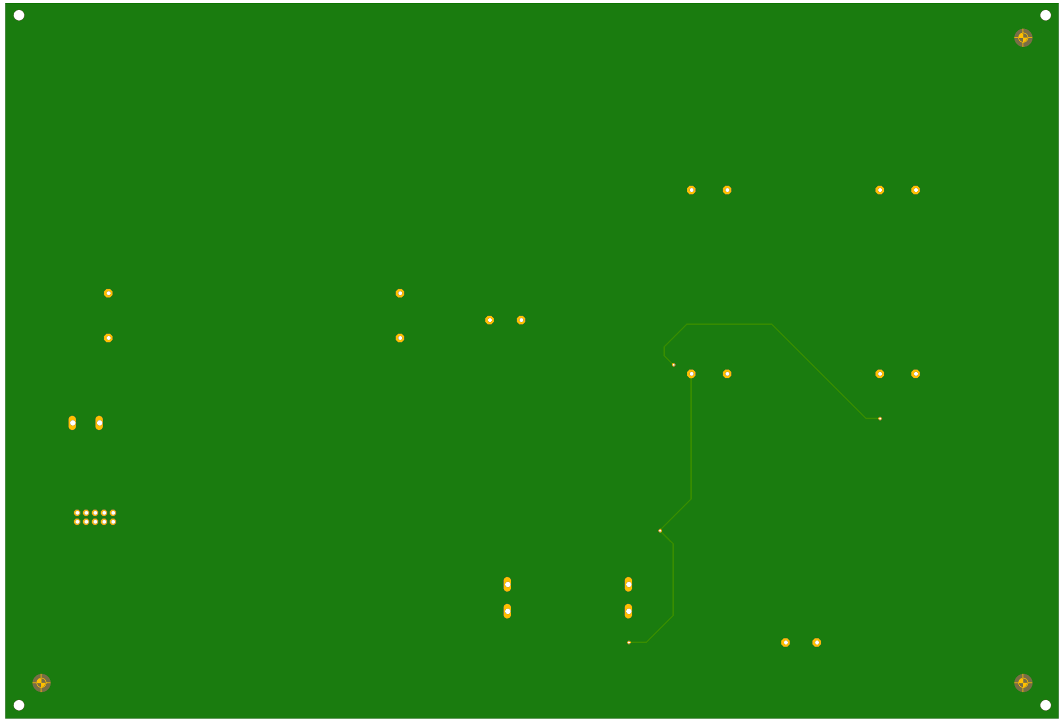
Laser-Based Wireless Power Transmission
Parallel Arrangement PV Power Converter Extension Board
Receiver
Solder Pads for 4 PV Cells
Parallel Arrangement
Solder Pads for TEG's
(+) and (-) Leads
Solder Pads for External DC-DC Converter
Solder Pads for TEC's
(+) and (-) Leads
Load Output
GND
DC VOUT +5V

9.



Laser–Based Wireless Power Transmission
Parallel Arrangement PV Power Converter Extension Board
Receiver
Solder Pads for 4 PV Cells
Parallel Arrangement
LSP1
(+)
LSP2
(–)
LSP5
(+)
LSP6
(–)
(+)
LSP3
(–)
LSP4
LSP7
(+)
LSP8
(–)
Solder Pads for TEG's
(+) and (–) Leads
LSP11
LSP12
LSP13
(+)
LSP14
(–)
Solder Pads for External DC–DC Converter
LSP15
(+)
LSP16
(–)
TP6
TP5
GND
DC VOUT +5V
SV3
Load Output
TP1
TP2
TP3
TP4
LSP9
LSP10
Solder Pads for TEC's
(+) and (–) Leads

Top



Bottom

Printed Circuit Board Design
Standard Performance Considerations (IPC-2221A)

From IPC-2221A Specifications (May 2003):

- General Requirements on Trace Thicknesses and Tolerances (pg. 4)
- Local and Global Fiducials Clearance and Placement (pg. 34-36)
- Mechanical Mounting Hole Placement and Dimensions (pg. 33)
- Power distribution considerations (pg. 37)
- Method of heatsink mounting (e.g., adhesive bond, rivet, screw, etc.) to printed board (pg. 50-52)
- Fabrication: 8 Board Panelization (pg. 36)

(Source: http://www-eng.lbl.gov/~shuman/NEXT/CURRENT_DESIGN/TP/MATERIALS/IPC-2221A(L).pdf)

PCB Fabrication: Panelization and Files Generation

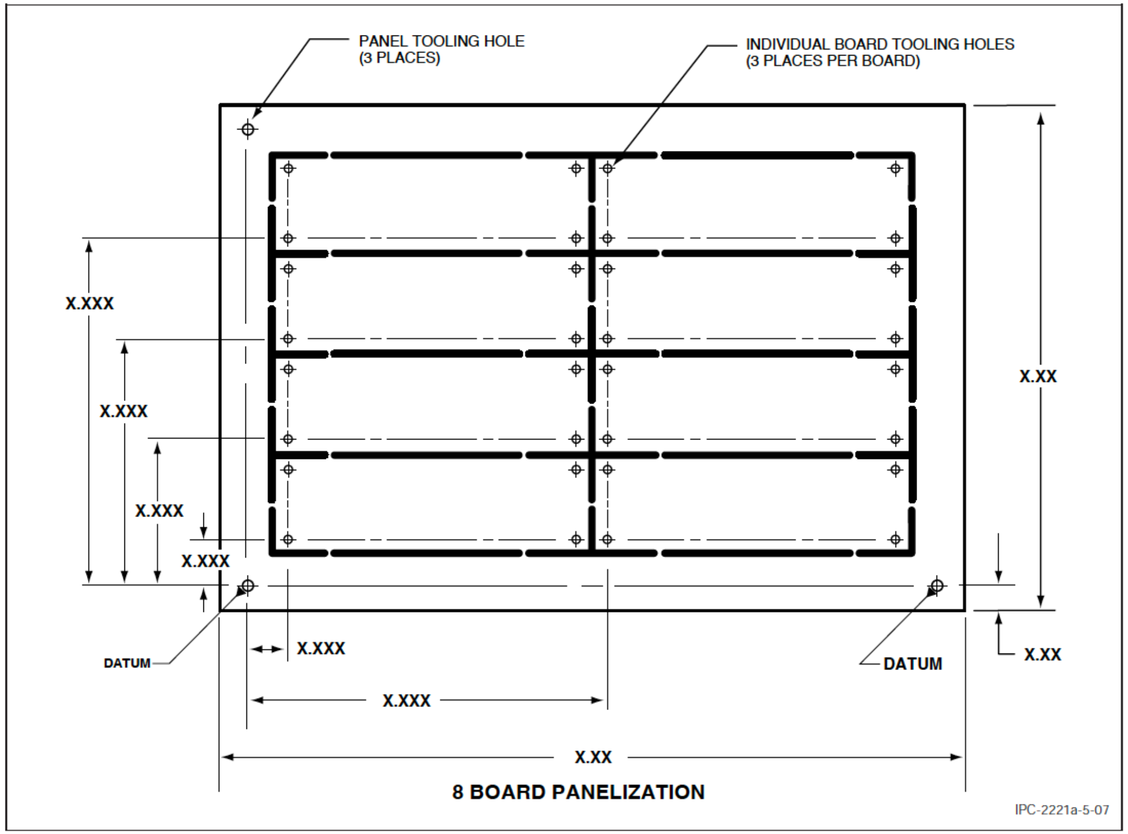


Figure 5-7 Fiducials, mm

Files Generation Requirements from EAGLE:

1. Download and store predefined CAM files (EAGLE Versions provided by JLCPCB)

2. Generate files for PCB fabrication:
   - 2a. Use CAM Processor in EAGLE
   - 2b. Load CAM Job File and Process Job
   - 2c. Locate ZIP File with Gerber and Drill Files with JLCPCB Naming Conventions
     - -Delete unnecessary *.gpi* and *.dri* files
3. Download a 3rd-party Gerber Viewer Application for final inspection:
   - 3a. Export Gerber/Drill Files into a Gerber Viewer
4. Generate BOM and Centroid Files for SMT for Surface Mount PCB Assembly Service

(Source: https://support.jlcpcb.com/article/137-how-to-generate-gerber-and-drill-files-in-autodesk-eagle)