DC-DC Converter for Solar Powered Phone Chargers

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Abstract

The process of converting sunlight directly into electrical power has been widely researched for its applications across various fields. Our research is specifically catered to garnering a more thorough understanding of how photovoltaic cells (solar panels) can contribute to the renewable energy movement as researchers work towards improving their efficiency. The electrical current produced in a photovoltaic (PV) cell is created when sunlight excites and frees up electrons that transfer energy through electron-hole pairs across the cell. However, due to the variable sunlight absorbed by a PV cell, a voltage regulator is necessary to stabilize the output voltage such that it can be used to charge a cell phone. Our research centers individually around investigating and creating different forms of voltage regulators and examining their efficiency while taking into account our desired resistance and power dissipation levels. Throughout this program, we simulated both switching and linear regulators and eventually developed three different variations of a series transistor voltage regulator. These designs aim to support more stable and efficient energy use from solar panels in small-scale applications.

Background

Our research is centered around solar energy systems and addressing the variability in electricity supplied through the photovoltaic (PV) cells. More specifically, we had to step down the high variable voltage (10-19V) of a thin-film PV cell to a lower stable voltage (5V) that is fed into a phone.

Thin-film cell:
- Lightweight and flexible photovoltaic cells that have low efficiency levels

Voltage:
- the electrical potential difference between two points in an electric circuit

Current:
- the rate that electrons flow through a point

Power:
- the rate at which electrical energy is transferred

Linear Regulator:
- Steps down voltage by dissipating excess voltage as heat

Series Transistor:
- Linear voltage regulator made up of a transistor, resistor, and zener diode
- **Transistor:** compares the input and output and sends out the regulated voltage
- **Resistor:** Limits the voltage for the output and limits the current to protect electronics
- **Zener Diode:** Allows current to flow when a certain voltage (Zener Voltage) is reached. This acts like a reference voltage for the input voltage to be compared with.

Experimental Methods

Relevant Methods:
- Measuring the current of our PV cell at various voltages on PSIM to create an I-V Curve
- Measuring the voltage of our thin-film panel at various resistance values using a variable resistor and a multimeter to create an I-V Curve
- Modeling the behavior of several types of voltage regulators on PSIM and simulating their behavior when connected to the PV cell model we created previously
  - Values tracked on Google Sheets and graphs created from the data
- Constructing linear regulators using soldering guns, electrical wires, electrolytic capacitors, and NPN transistors

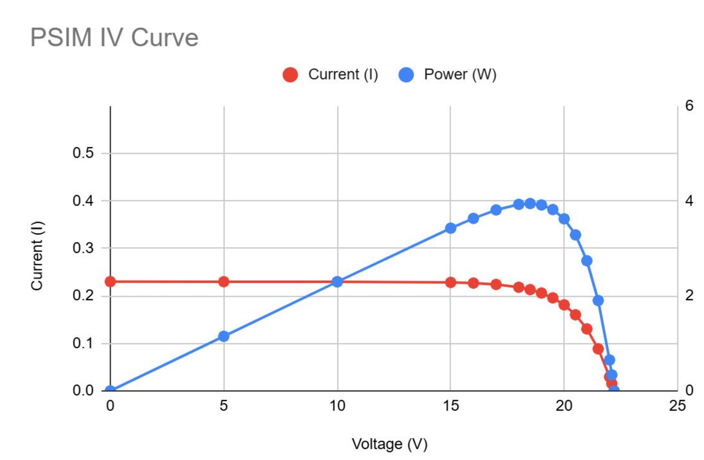
Relevant equations:

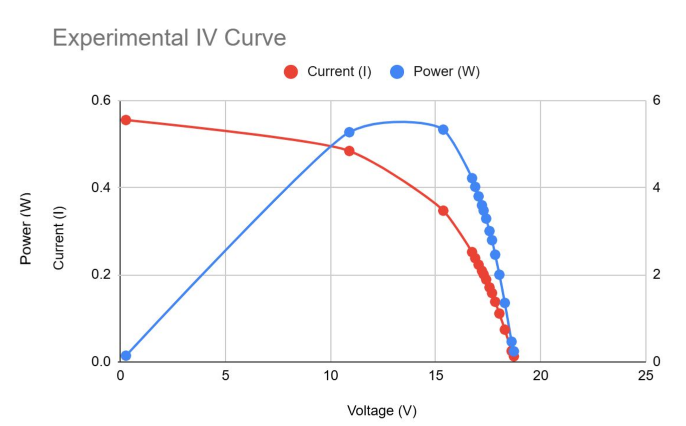
Power=(voltage)(current)
- Used to calculate the power of our PV cell on both PSIM and experimentally

Ohm's Law: Voltage=(current)(resistance)
- Used to calculate the resistance values required for our converters to function correctly.

KVL (Kirchhoff's Voltage Law)
- The sum of all voltage drops around any closed loop in an electrical circuit equals zero.

KCL (Kirchhoff's Current Law)
- The sum of all currents entering and exiting a node must equal zero.

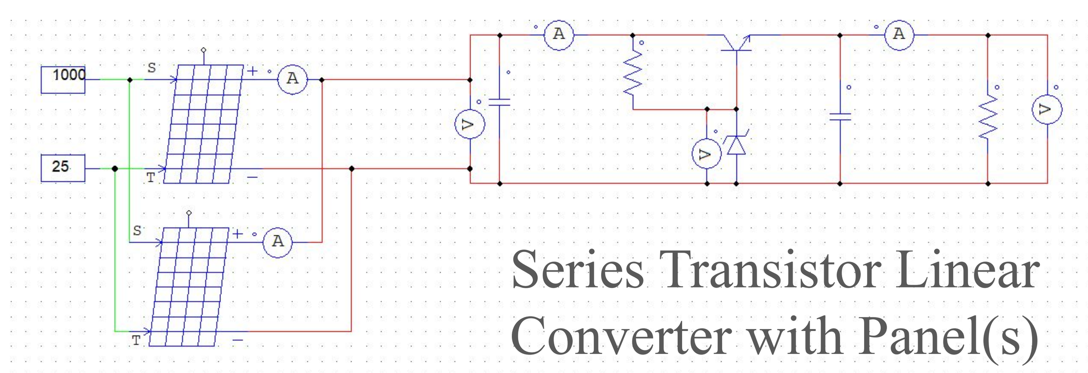




Results

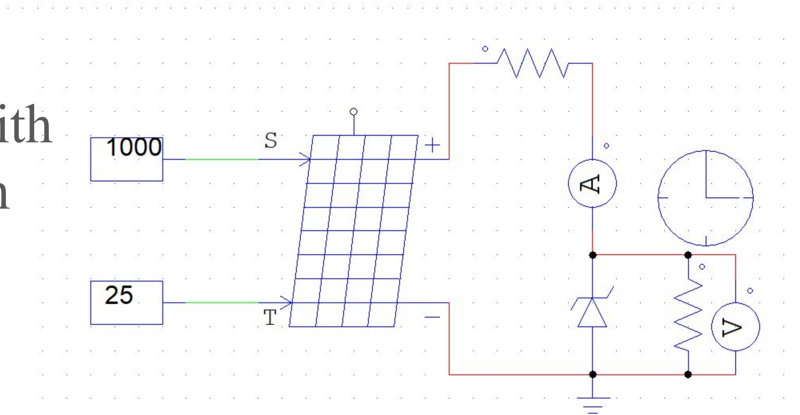
- We determined that the best converter to use for our purposes was the series transistor linear voltage regulator.
  - Easy to build
  - Stable output voltage
- Other options, such as the switching regulator and resistor divider with Zener diode linear voltage regulator were not possible
  - Switching regulator: time constraints due to the complexity of the circuit
  - Zener diode linear voltage regulator: not able to handle the current needed for the circuit to function

PSIM Models:

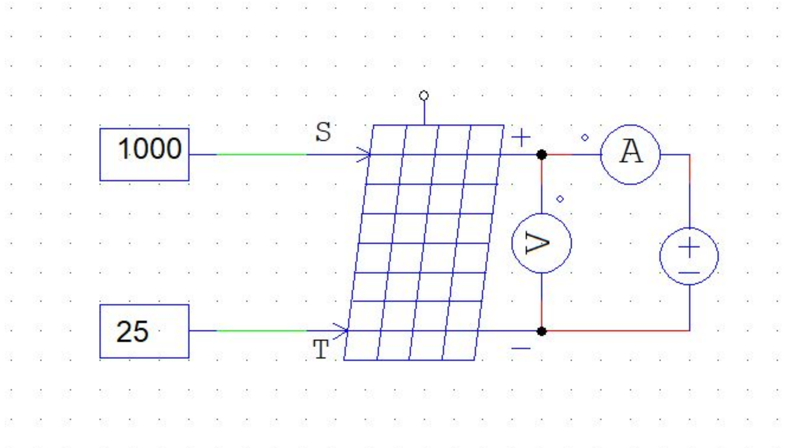


Series Transistor Linear Converter with Panel(s)

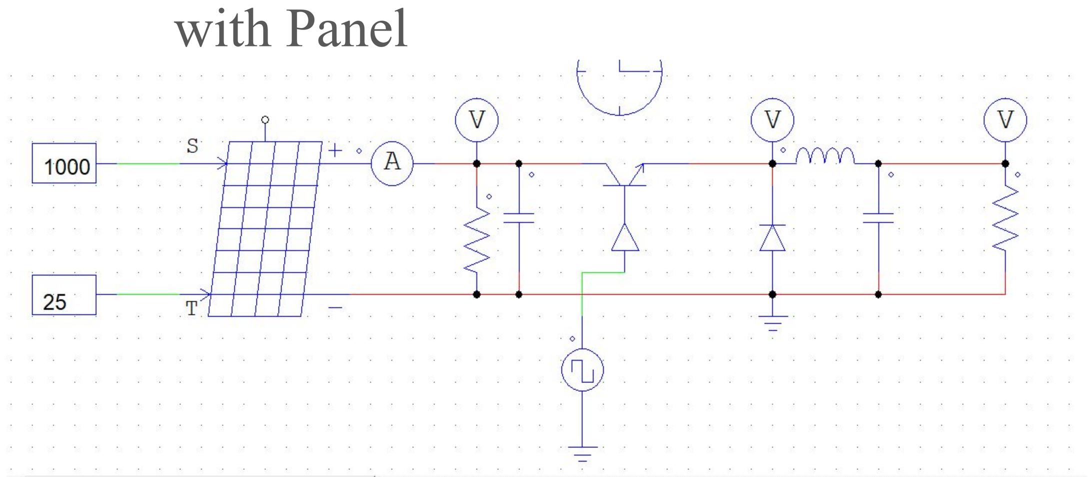
Resistor Divider with Zener Diode with Panel



Thin-Film Panel

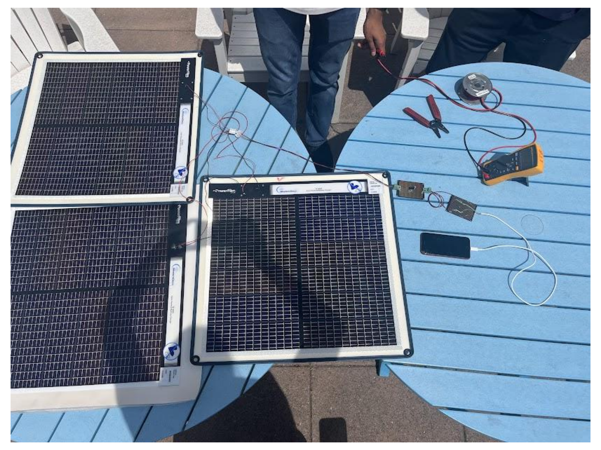


Buck Switching Converter with Panel

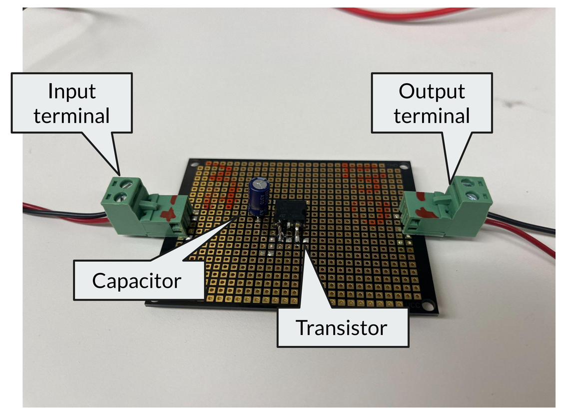


Conclusion and Future Steps

- We were able to achieve a stable 5V output voltage (< 1% error) with our linear voltage regulator, but we could have achieved an even higher level of efficiency if we had been able to use a switching regulator.
- The dissipation of excess voltage as heat was a major drawback of our linear regulators.
- Simulating a switching regulator on PSIM allowed us to determine what duty cycle and resistance values would have been used if we had actually built it.
- In the future, more efficient voltage regulators such as switching regulators will hopefully become easier to implement into electrical circuits such as this one.



Our final circuit



References

1. American Solar Energy Society. (2021). Thin-Film Solar Panels | American Solar Energy Society. Ases.org. https://ases.org/thin-film-solar-panels/
2. electronics notes. (2020). Series Voltage Regulator | Series Pass | Electronics Notes. Electronics-Notes.com. https://www.electronics-notes.com/articles/analogue_circuits/power-supply-electronics/linear-psu-series-regulator-circuit.php
3. Rome, P. (2024, July 1). Volts, Currents, and the Basic Concepts of Electricity. Data Acquisition | Test and Measurement Solutions. https://dewesoft.com/blog/volts-and-currents-explained
4. STMicroelectronics. (2025). Datasheet - L78M - Precision 500 mA regulators. Mouser.com. https://www.mouser.com/datasheet/2/389/l78m-974157.pdf

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