Abstract

Motivation:

- Solar panels have the potential to replace less sustainable energy forms as researchers work towards maximizing their efficiency for small-scale applications.

Challenges:

- Variable output voltage from the PV cell
  - Depending on UV index/sunlight intensity, temperature, positioning
- Changing Power Dissipation and Resistance values

Goals:

- Extract maximum power levels from photovoltaic cells
- Generate a stable/regulated output voltage (5V)
- Discover the ideal voltage regulator for this application

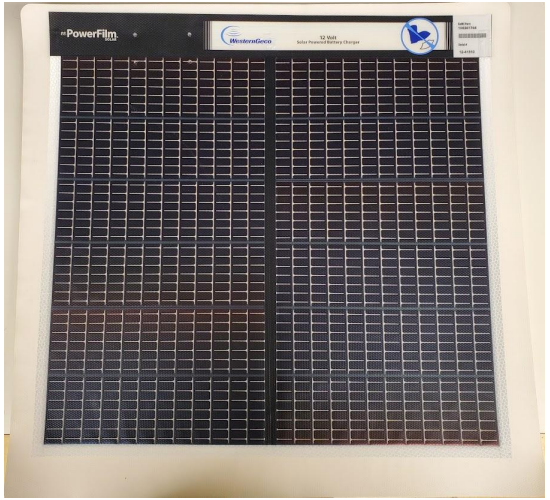
Results:

- Developing three different variations of a linear regulator (series transistor) to output a regulated voltage
- Simulating different forms of linear regulator (resistor divider with zener diode) and switching regulators

Background Information

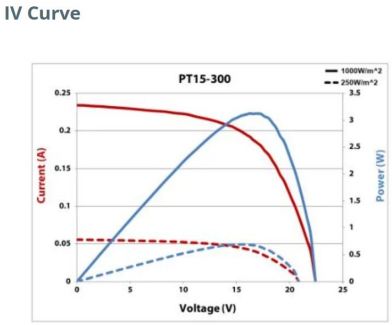
- Thin-film solar panels:
  - Advantages:
    - Lowest cost for production
    - lightweight and flexible
  - Disadvantages:
    - Lowest effectiveness in converting solar energy into electricity (10-13%)
    - shorter lifespan

Solar Panel that we are using

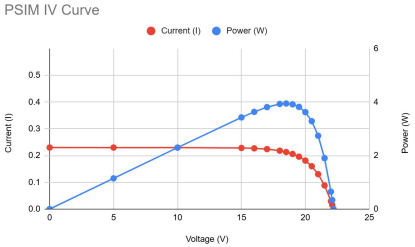


IV Curves

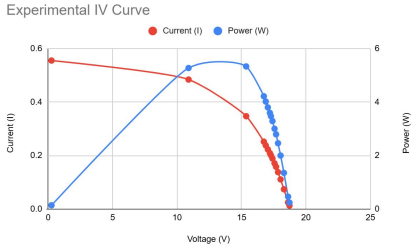
- Throughout our research, we used 3 I-V curves:



IV Curve given by the manufacturer

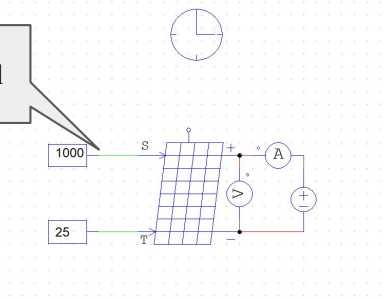


IV Curve created from PSIM data



IV Curve created from Experimental Data

Model of thin-film PV cell in PSIM

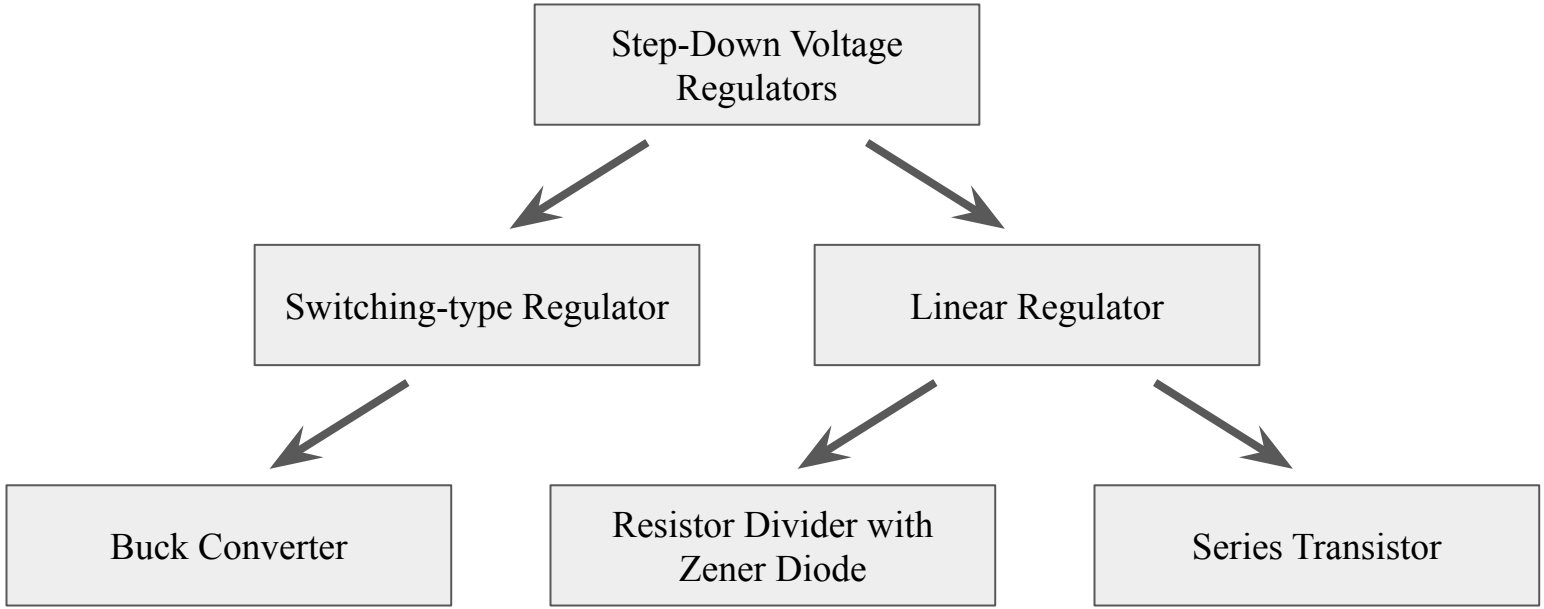






Our testing setup

Step-Down Voltage Regulator Types



Switching Regulator (Buck Converter)

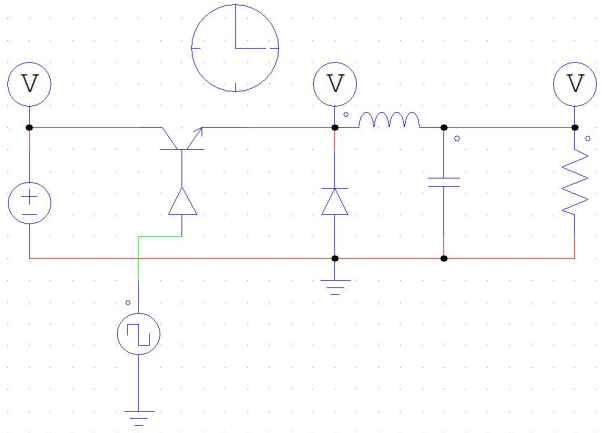
Process:

1. Switching
2. Energy Storage
3. Filtering
4. Regulation

Major Advantage: More efficient than linear regulators, especially at higher voltage conversions

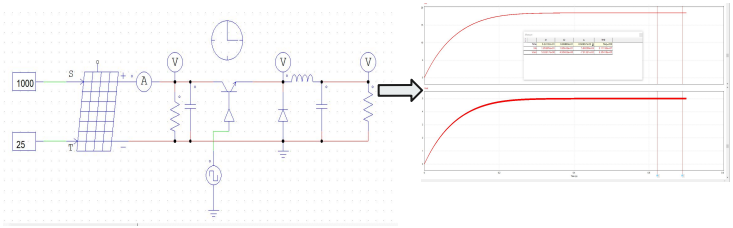
Major Disadvantage: Buck converters are generally more complex to design and implement compared to linear regulators.

Buck Converter in PSIM

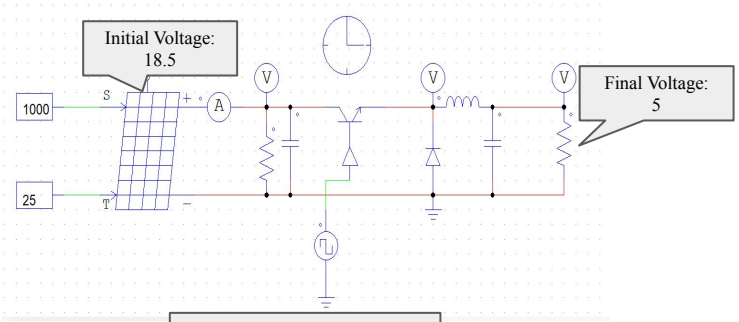


Switching Regulator (continued)

- Modeled a buck converter in PSIM
- Completed calculations in order to accurately step down the voltage to 5V
  - Updated the duty cycle from 0.5 to 0.27 based on our calculations



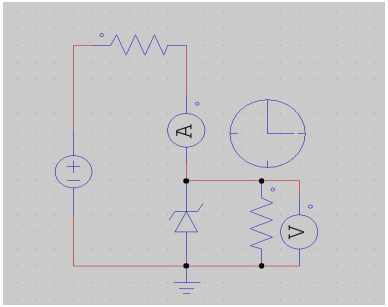
Combined the solar panel with the buck convertor and tuned the duty cycle to get the MPPT (max power point tracking)



$$\frac{\text{Final}}{\text{Initial}} = \frac{5}{18.5} = 0.27$$

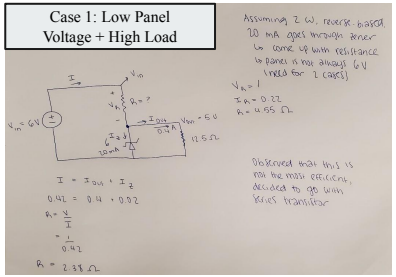
Resistor Divider with Zener diode

- One of the two kinds of linear voltage regulators
- Simulation done in PSIM
- Calculations done to see if there was a diode that would support our desired power dissipation (two cases)
- Current needed for the circuit is too large for Zener diode
- Determined we are not able to use this kind of regulator for our research

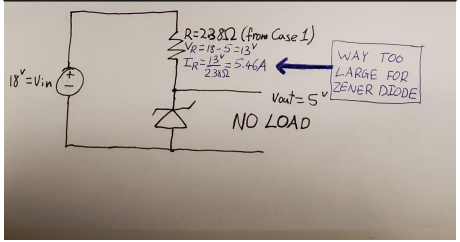


PSIM Model of Resistor Divider with Zener Diode

Case 1: Low Panel Voltage + High Load



Case 2: High Panel Voltage + Low Load



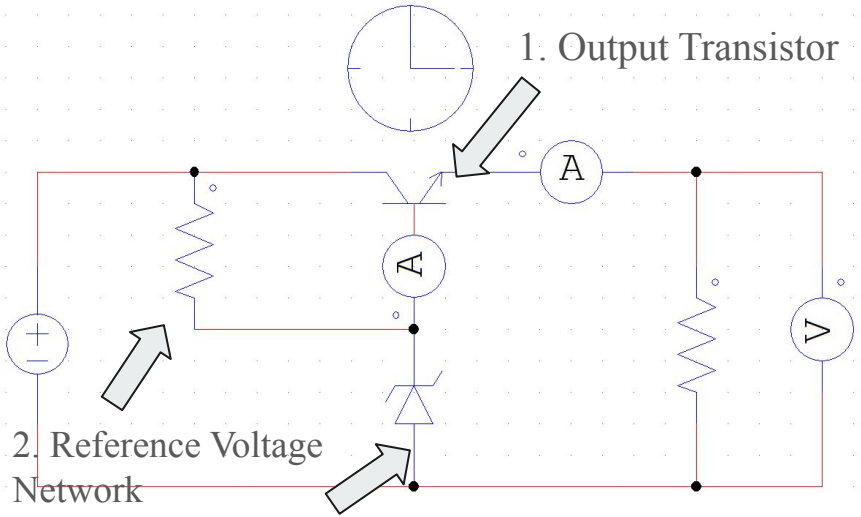
Series Transistor

Components:

1. Output Transistor
2. Reference Voltage Network

Major Advantage: More stable output

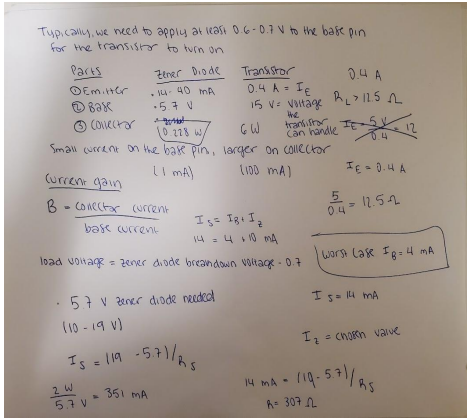
Major Disadvantage: Transistor voltage drop is dissipated as heat



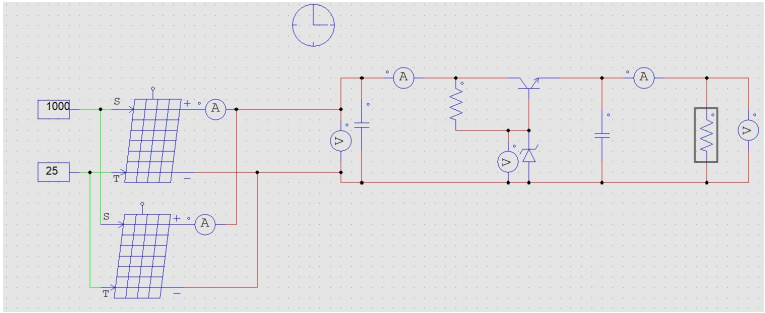
Series Transistor (continued)

- Modeled different cases of varying voltage to determine the range of current for the circuit to function
  - Then calculated the current
- Figured out the power and current needed by our Zener diode to function

All of our calculations displayed



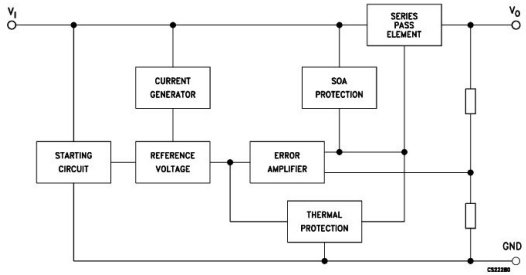
PSIM model of Series Transistor



Series Transistor with Feedback Network

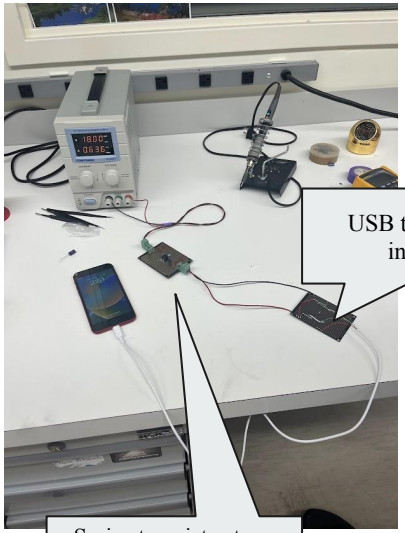
- Components:
  - Feedback network
  - Error Amplifier
- Major advantages:
  - Maintain a stable output voltage
  - Prevent overheating or damage to the transistor
  - Adjust dynamically to changes in load or sunlight
- Major disadvantage:
  - More complicated to build (coding required)

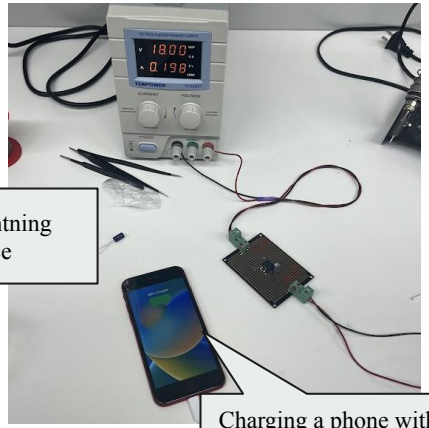
A block diagram of our specific D2pak series transistor



Troubleshooting

- At first, the phone would not take in any power
  - lightning cables needed data to run through the wire in order for the phone to start charging
- made a USB to Lightning cable interface with multiple resistors to simulate data flowing through the lighting cable





Evaluation Of the Solar-Powered Phone Charger

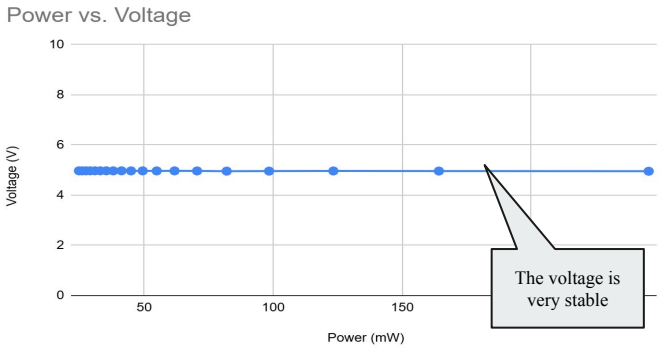
Benefits:

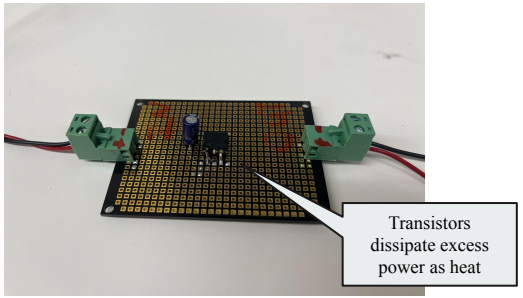
- Maintained a very stable output voltage (<1 % error)
- Fairly simple circuit

Drawbacks:

- The transistor started to overheat
- Three panels were needed due to the converter's dissipative properties.

Our testing results





Acknowledgements

Power Electronics and Renewable Energy Systems Laboratory
Mahshid Amirabadi, Ph.D, Associate Professor of Electrical and Computer Engineering
Karen Abbaskhanian, Ph.D. Student
Center for STEM Education
Claire Duggan, Executive Director
Jennifer Love, Associate Director
D'mitra Mukasa. Ahmed Othman, Victoria Berry, YSP Coordinators
Nicolas Fuchs, Program Manager
Mary Howley. Administrative Officer