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E344 Assignment 1

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Report submitted in partial fulfilment of the requirements of the module
Design (E) 344 for the degree Baccalaureus in Engineering in the Department of Electrical
and Electronic Engineering at Stellenbosch University.

August 14, 2021

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   I declare that the work contained in this assignment, except where otherwise stated, is my original work and that I have not previously (in its entirety or in part) submitted it for grading in this module/assignment or another module/assignment.

22546448 Studentenommer / *Student number*	Handtekening / *Signature*
MC van der Berg Voorletters en van / *Initials and surname*	August 14, 2021 Datum / *Date*

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Nomenclature

Variables and functions

V	Voltage over the module
V_{oc}	Open source voltage
V_{STC}	Standard test condition voltage
$V_{T-coeff}$	Temperature Coefficient of V_{oc}
I	Current flowing threw the module
I_{sc}	Short circuit current
P	power output of the module
P_{max}	Maximum power
P_{STC}	Standard test condition power
T_{cell}	Temperature of the cell

Acronyms and abbreviations

PV	Photovoltaic
STC	Standard Test Conditions
MPPT	Maximum power point tracking

Chapter 1

Solar photovoltaic cells and solar modules

1.1. The photovoltaic effect

A PV cell is an energy harvesting technology, that converts solar energy into electricity through the photovoltaic effect (PV). The photovoltaic cell is a specially treated semi-conductor layer. This layer consist of two other layers: the p-type and n-type layer, forming a pn-junction.This pn-junction is what actually converts the Sun's energy into useful electricity through a process called the photovoltaic effect.By joining these two semiconductor regions creates a electric field. As a result electrons move to the positive p-type side and holes move to the negative n-type side. This creates a depletion region. When sunlight hits the depletion region, photons energise the atoms and separate holes and electrons.These holes and electrons are then pulled away from each other by the still existing electric field. If the pn-junction is connected into a circuit, the electrons will flow from the n-type side through the circuit to the p-type side. Therefore current will be present. [4] On either side of the semiconductor is a layer of conducting material. The conducting material is placed at the back of the cell and not on the front as to not to block the suns radiation from reaching the semiconductor. The last layer is the anti-reflection coating layer that is placed on the illuminated side of the cell. This is a requirement as all semiconductors are reflective and the sunlight that is reflective is energy that is not converted into electricity. [1]

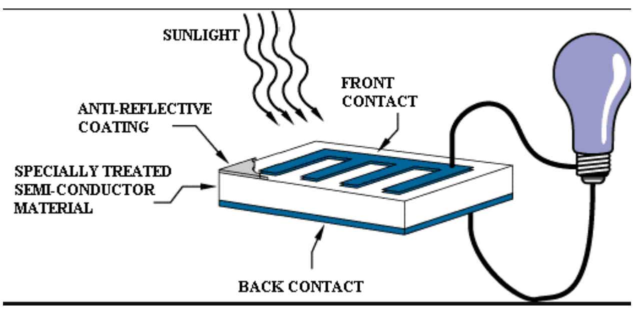

Figure 1.1: Basic operation of a photovoltaic cell [1].

A photovoltaic cell is however not ideal. In practise it can only convert a percentage of the solar energy it receives into electrical energy, the average efficiency of a solar panel is between 17 to 19 percent. This could be due to many reasons such the material of the panel component,reflective efficiency and Thermodynamic efficiency [5]

1.2. The I-V-curve

A photovoltaic cell has a I-V curve that indicates the relationship between voltage and current of the cell under certain conditions.This relationship is almost parallel with the Voltage axis, but at the knee of this curve the current that is produced if more voltage is introduced drops drastically until the curve is in a open-circuit state and the voltage is equal to the open-circuit voltage.

The open-circuit voltage V_{OC} is the maximum voltage attainable by a photovoltaic cell. This voltage will be reached when the circuit is in a open circuit configuration, therefore the current will be zero as can also be seen on the **Figure 1.2** this value however is not fixed for a cell as many factors may change this value se **1.3. Standard Test Conditions**. The open circuit voltage of a single cell is typically 0.6V. [2]. Our specific solar module has a $V_{OC} = 21.6V$. [6]

The photovoltaic cell also has a short circuit configuration where the voltage over the cell is zero but maximum current is flowing through the circuit. This maximum current is denoted as I_{sc} on **Figure 2.1**. The short-circuit current is a result of light-generated carriers that are gathered by the cell. For ideal solar cells the short-circuit current is identical to the light-generated current. There are many factors that influence the short-circuit value such as: the area of the cell,the number of photons, the spectrum of the incident light, the optical properties and the collection probability. Our specific solar module has a $I_{sc} = 0.34A$. [6]

This is not very large but these cells are connected in series with one another to produce a larger voltage value. These are called solar modules. Our specific module has 36 cells in series with one another [2]

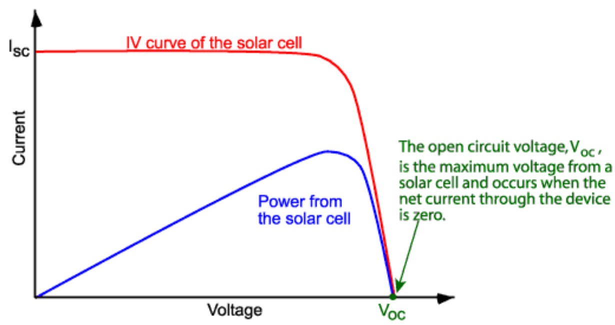

Figure 1.2: IV curve of a solar cell [2].

As can be seen on **Figure 1.2** The equation P = IV can be used to calculate a power curve. The maximum power will be produced when the voltage is regulated to be at the knee of the IV-curve, however the IV-curve is not static and may change due to many factors as mentioned above. As a result the maximum power point is not static and has to be tracked to optimise the power efficiency of the solar cell. This is known as maximum power point tracking or MPPT [7]. Our specific solar module has a $P_{max} = 5W$. [6]

1.3. Standard Test Conditions

All PV module manufacturers have to test the modules they produce. These manufacturers do this by implementing the standard test conditions(STC). The three main elements that are tested are temperature, irradiance and air mass. All three these elements effect the IV-curve as well as the maximum power point, it is thus important to know how the module will perform under these conditions. [8]

Temperature: As mentioned above the efficiency of the cell decreases as the cell temperature increases. The STC for cell temperature is $25°C$. The change in temperature and the effect thereof can be calculated by doing the following calculations:

$$V = V_{STC} + V_{T-coeff} * (T_{cell} - 25)$$

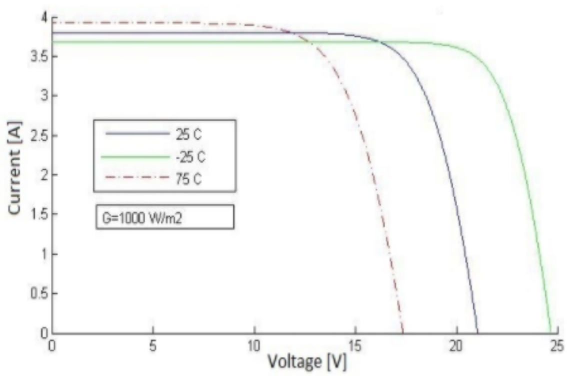

Figure 1.3: Tempreture effect on the I-V curve [3].

$$P = P_{STC} + P_{T-coeff} * (T_{cell} - 25)$$

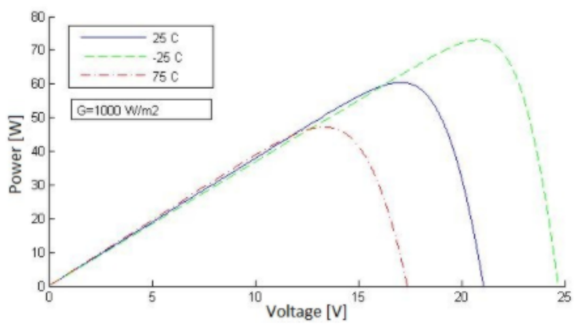

Figure 1.4: Tempreture effect on the P-V curve [3].

Irradiance:Irradiance represents the power output of the sun per unit area. The STC value for irradiance is $1000W/m^2$. This value may range from $0W/m^2$ to $1250W/m^2$. Higher irradiance leads to higher current values flowing threw the module.

Air mass:Air mass represents the amount of atmosphere the sunlight has to pass through before reaching the earth. The STC value of Air mass is 1.5 AM. This value may range allot depending on location, time of year and time of day.

Chapter 2

Lead acid batteries

Chapter 3

High-side switching circuit

3.1. Intro

Introduce the reader to **what you want to present** in this chapter (i.e. what are you trying to achieve by initiating this communication?). Try to put yourself in the readers' shoes - what would you ~~like~~ need to see to be convinced that the author (1) knew what they were doing and understood what they had to do (2) properly designed for the requirements, (3) simulation-tested their design, and (4) correctly and critically assessed the outcome.

Include any references to literature you feel is needed. In this section, you put a very short summary of infrormation you gatherered from literature (papers, web sites, datasheets) that you used to do the design. Be sure to cite the references, which you can add in the `References.bib` file.

3.2. Design

In this section, you need to capture your design, which should include the following:

- Design rationale, i.e. what your thinking was behind the design.
- References to literature/sources as appropriate [**?**], but preferably in the intro above.
- You can assume the reader is in their third year of their E&E engineering degree, and that they will not need detailed explanations of trivial information (e.g. what a resistor is, or what Ohm's law is).
- Design calculations, for example to determine resistor values and capacitor values, or to check for allowed voltage and current ranges and levels. These calculations should also give expected outputs, which hopefully matches the simulated values.
- Analysis of given or expected input conditions.
- Expected values and ranges based on your design.
- Explain your choice of supply by referring to the advantages and disadvantages of each.

- Circuit diagram like the one in Figure 3.1. I used "print to PDF" from LTSpice, but feel free to use a cropped screengrab if you are PDF-challenged and do not have a PDF printer (there are some free PDF creators online). Also have a look at the demo video on SUNLearn.

For your benefit, here is how to write values with units: 150 mΩ or 199 myUnits, and this is how we write ranges: 2 to 5 kV.

Here is an inline equation $\frac{55}{45+3}$. Here is a numbered equation in Eq. 3.1.

$$a = \frac{55}{45+3}. \tag{3.1}$$

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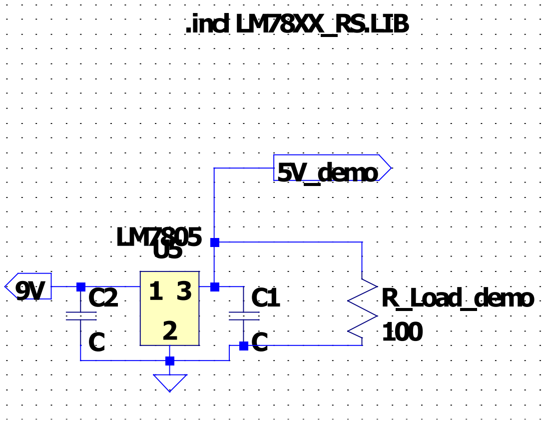
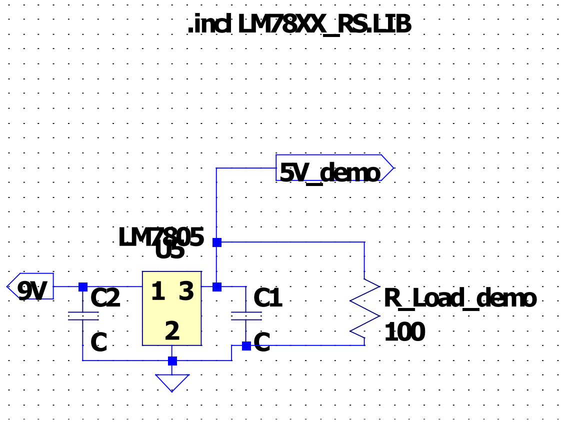
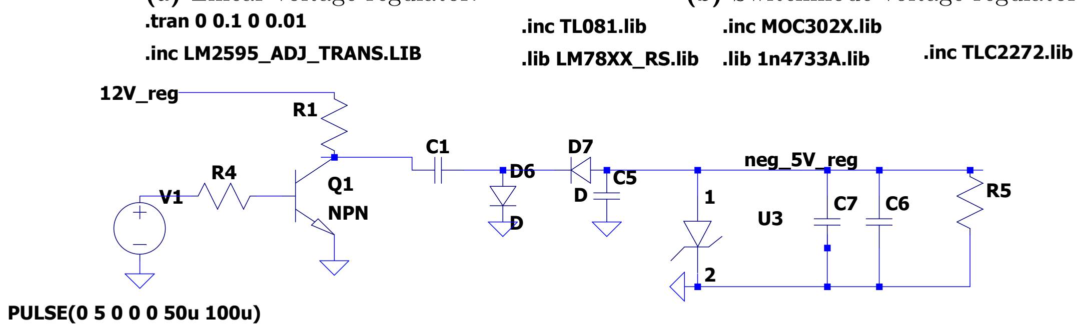


(a) Linear voltage regulator.



(b) Switchmode voltage regulator.



(c) Chargepump voltage regulator.

Figure 3.1: Circuit diagrams of the two voltage regulators, and another irrelevant one

.

3.3. Results

In this section, you want to demonstrate, by means of referring to simulation results, using the designed circuit, how your circuit behaves as you designed it in Section 3.2. Present and report on your simulated results in Figure 3.2. Be absolutely sure that the text and information in your report are readable.

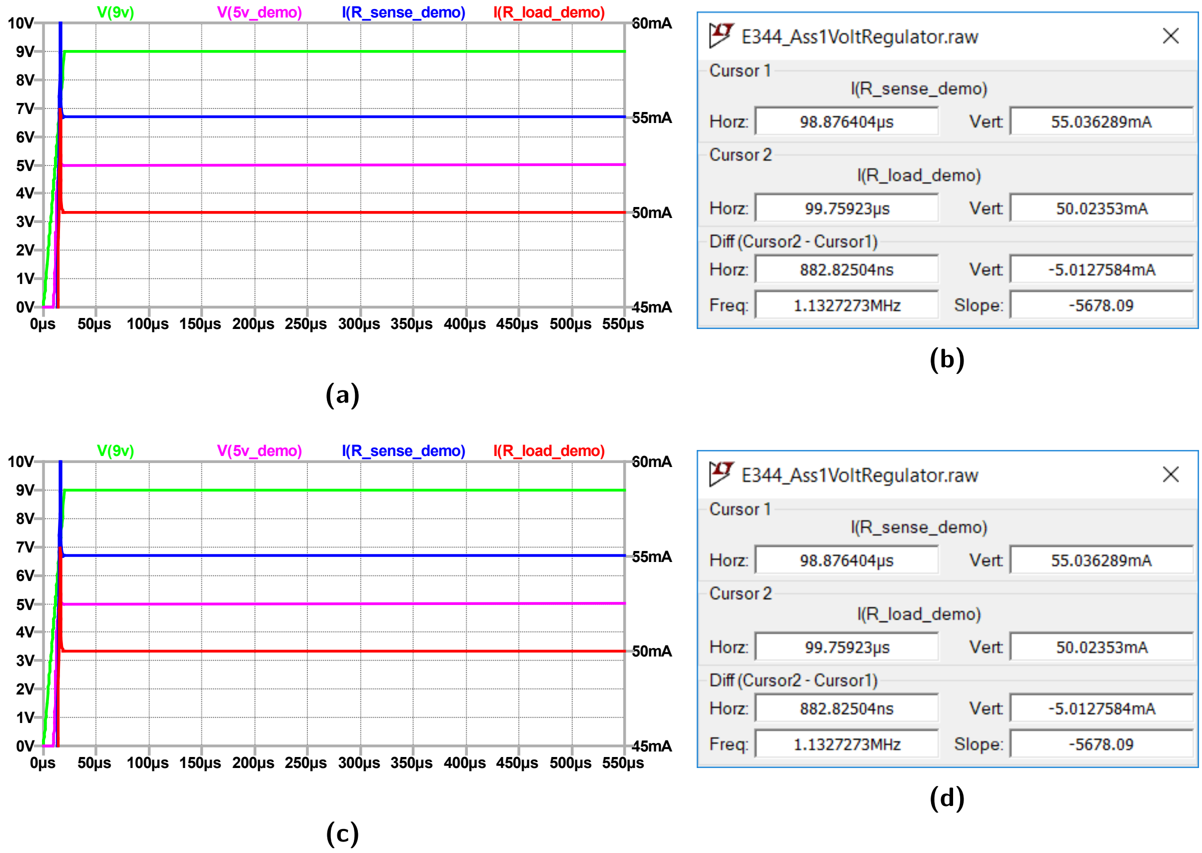


Figure 3.2: Voltage regulation, comparing the linear and switchmode regulators... (a) Blah blah. (b) Blah blah. (c) Blah blah. (d) Blah blah. As far as possible, please put input(s) and output(s) on the same plot rather than on separate plots. Based on the datasheet of XXXX in [**?**].

Table 3.1: Example of a simple table.

	2017	2018	Δ_{Abs}	Δ_{DiD}
A	9,868	10,399	+5	-11
B	10,191	10,590	+4	-12

Table 3.2: Example of another table.

Schools	Total energy used		Change	
	2017 [kWh]	2018 [kWh]	Δ_{Abs} [%]	Δ_{DiD} [%]
A	9,868	10,399	+5	-11
B	10,191	10,590	+4	-12

You can use screengrabs or photos of the oscilloscope, or download the CSVs and plot them as PDFs using Matlab, Excel or similar. You can also use tables, example of which are presented in Tables 3.1 and 3.2.

3.4. Summary

State whether your design performs as expected and what the limitations or things to keep in mind are.

Bibliography

[1] K. S. B. Y. J. D. Bethel Afework, Jordan Hanania. (2018) Photovoltaic cell. https://energyeducation.ca/encyclopedia/Photovoltaic_cell.

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[6] acdc Dynamics. (2014, Jan.) Maximum power point tracking. https://learn.sun.ac.za/pluginfile.php/2893563/mod_resource/content/0/SLP005-12%20PV%20Module.pdf.

[7] edX, “Maximum power point tracking,” https://www.youtube.com/watch?v=5Us5mM87PU8, 2019.

[8] couleenergy. (2020) Standard test conditions of pv module. https://couleenergy.com/standard-test-conditions-of-pv-module/.

Appendix A

Social contract

Download copy from SUNLearn, sign and include here (replace this one).

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E-design 344 Social Contract

2021

The purpose of this document is to establish commitment between the student and the organisers of E344. Beyond the commitment made here, it is not binding.

In the months preceeding the term, the lecturer (Thinus Booysen) and the Teaching Assistant (Kurt Coetzer) spent countless hours to prepare for E344 to ensure that you get your money's worth and that you are enabled to learn from the module and demonstrate and be assessed on your skills. We commit to prepare the assignments, to set the tests and assessments fairly, to be reasonably available, and to provide feedback and support as best and fast we can. We will work hard to give you the best opportunity to learn from and pass analogue electronic design E344.

I, ... have registered for E344 of my own volition with the intention to learn of and be assessed on the principals of analogue electronic design. Despite the potential publication online of supplementary videos on specific topics, I acknowledge that I am expected to attend the scheduled lectures to make the most of these appointments and learning opportunities. Moreover, I realise I am expected to spend the additional requisite number of hours on E344 as specified in the yearbook.

I acknowledge that E344 is an important part of my journey to becoming a professional engineer, and that my conduct should be reflective thereof. This includes doing and submitting my own work, working hard, starting on time, and assimilating as much information as possible. It also includes showing respect towards the University's equipment, staff, and their time.

Prof. MJ Booysen	Student number: ....
Signature:	Signature: ....
Date: 29 July 2021	Date: ....

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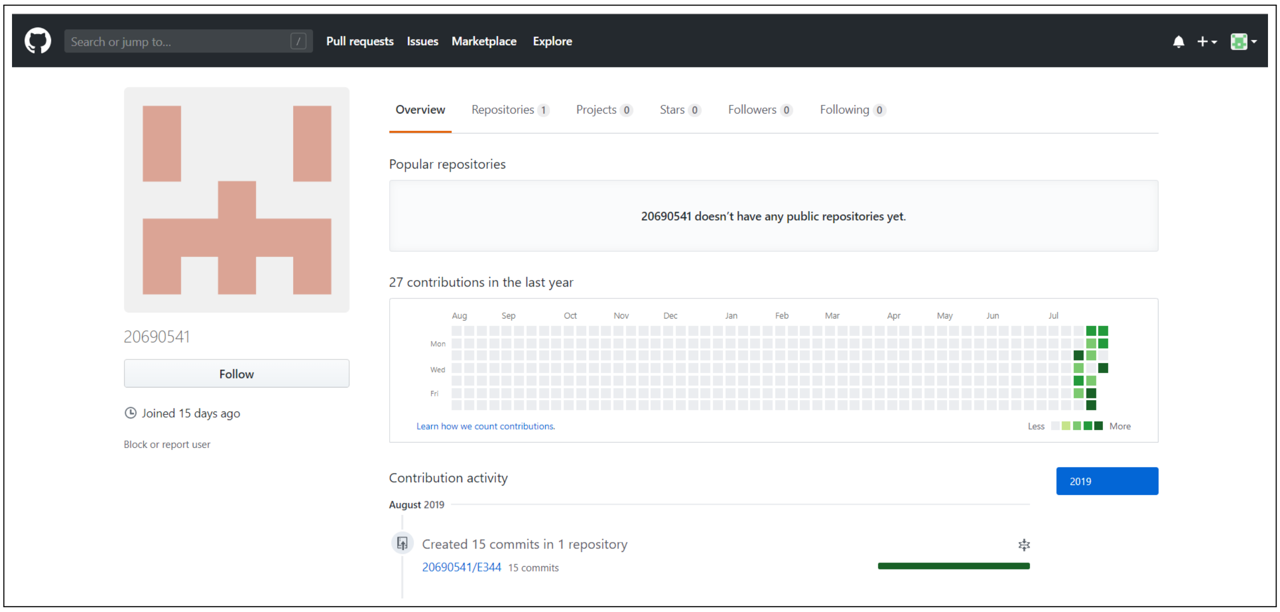
Appendix B

GitHub Activity Heatmap

Take a screenshot of your github version control activity heatmap and insert here.



Appendix C

Stuff you want to include

remove this!!

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