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E344 Assignment 1

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23252162

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 13, 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.

23252162 Studentenommer / *Student number*	 Handtekening / *Signature*
AA. Cilliers Voorletters en van / *Initials and surname*	August 13, 2021 Datum / *Date*

Contents

List of Figures

List of Tables

Nomenclature

Update this list to make it applicable to your project.

Variables and functions

$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.
ε	The Bayes error.
ε_u	The Bhattacharyya bound.
B	The Bhattacharyya distance.
s	An HMM state. A subscript is used to refer to a particular state, e.g. s_i refers to the i^{th} state of an HMM.
$\mathbf{S}$	A set of HMM states.
$\mathbf{F}$	A set of frames.
$\mathbf{o}_f$	Observation (feature) vector associated with frame f.
$\gamma_s(\mathbf{o}_f)$	A posteriori probability of the observation vector $\mathbf{o}_f$ being generated by HMM state s.
μ	Statistical mean vector.
Σ	Statistical covariance matrix.
$L(\mathbf{S})$	Log likelihood of the set of HMM states $\mathbf{S}$ generating the training set observation vectors assigned to the states in that set.
$\mathcal{N}(\mathbf{x}\|\mu, \Sigma)$	Multivariate Gaussian PDF with mean μ and covariance matrix Σ.
a_{ij}	The probability of a transition from HMM state s_i to state s_j.
N	Total number of frames or number of tokens, depending on the context.
D	Number of deletion errors.
I	Number of insertion errors.
S	Number of substitution errors.

Acronyms and abbreviations

Update this list to make it applicable to your project.

PV	Photovoltaic
OC	Open Circuit
NEC	National Electrical Code
STC	Standard Test Conditions
Ah	Amp Hour
Wh	Watt Hour
CCCV	Constant Current Constant Voltage
DoD	Depth of Discharge

Chapter 1

Solar photovoltaic cells and solar modules

Photovoltaic (PV) technology uses a natural source of energy in the form of sunlight and coverts the sunlight into electrical energy. One PV device is called a cell, and are made from semiconductor materials such as silicon. These cells are quite small and only produce around 1-2 watts. In order to increase the power output several cells are connected together to form a module [5] [6]. Ovear the years the efficiency of solar PV modules have greatly improved, however polycrystalline PV modules which are going to be used in this project are not the most efficient type of PV module. Their efficiency is around 13-16% according to an article by Geotherm [7], however a practical study found it to be closer to 11% [8] more detail?

A PV module's performance is judged by its current–voltage (I–V) characteristic curve. As seen in figure 1.1a and figure 1.1b a few interesting points can be seen on the figures, namely the Open Circuit (OC) voltage and the Short Circuit (SC) Current (insert fig here + reference). The open circuit voltage can be defined as the maximum available voltage from one solar cell when no load is connected (this occurs at 0 current). The OC voltage is useful when you want to calculate how many solar modules(panels) you can connect in series which will connect to your inverter or charge controller. SC Current is how much current the solar cell is pulling when the voltage across the cell is 0, this can be measured when the positive and negative terminals are connected directly to each other. This SC current will be the maximum amount of amps that the solar cell will produce and can be used to determine how many amps connected devices can handle by multiplying with a 1.25 times scaling factor according to National Electrical Code (NEC) 80% requirements [9]. Typically a single PV cell has an OC voltage of around 0.5V to 0.6V at room temperature (25°C) [10].

finish 6&7.

6. https://www.victronenergy.com/blog/2020/02/20/pv-panel-output-voltage-shadow-effect/ https://www.alternative-energy-tutorials.com/photovoltaics/solar-cell-i-v-characteristic.html As voltage increases current stays the same until a certain point.

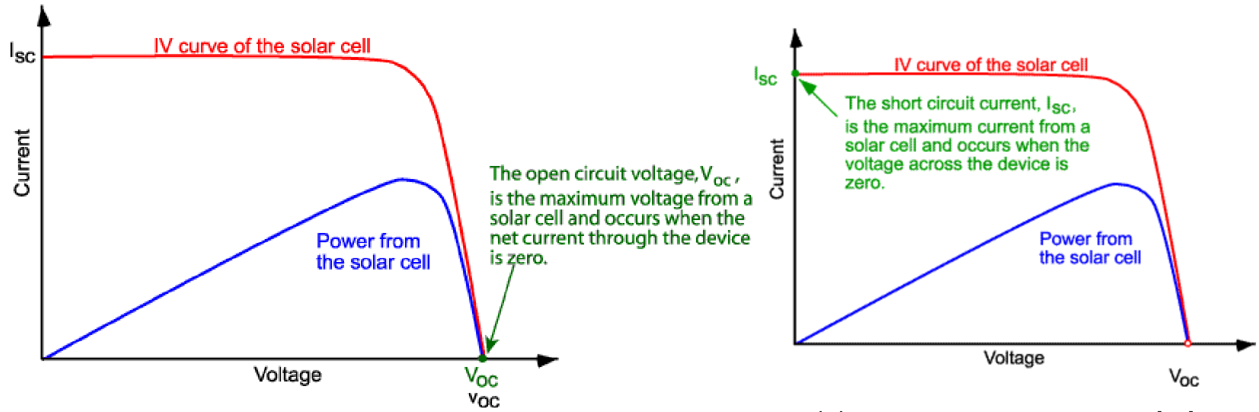
7. The maximum power point is where the product of volts x amps gives the highest wattage possible. $P_{mpp} = V_{mpp} I_{mpp}$

"The point on a power (I-V) curve that has the highest value of the product of its corresponding voltage and current, or the highest power output" ....re phrase

The solar module provided to us has a OC voltage of 21.6V and a SC current of 0.34A according to the ACDC Dynamics datasheet [11]. It appears to have 36? 72 individual solar cells

Solar PV modules are tested at a certain set of standard conditions because voltage and current varies with temperature. This set of criteria are called the Standard Test Conditions (STC), these conditions are: the cell's temperature at 25°C, an irradiance of 1000 W/m^2 and the atmospheric density to be 1.5 . [9] At STC conditions the solar PV module provided to us has a rated power output of 5W.

Still need to do measurements and tabulate.



(a) OC Voltage of Solar Cell [12]

(b) SC Current of Solar Cell [13]

Figure 1.1: OC Voltage and SC Current of Solar Cell

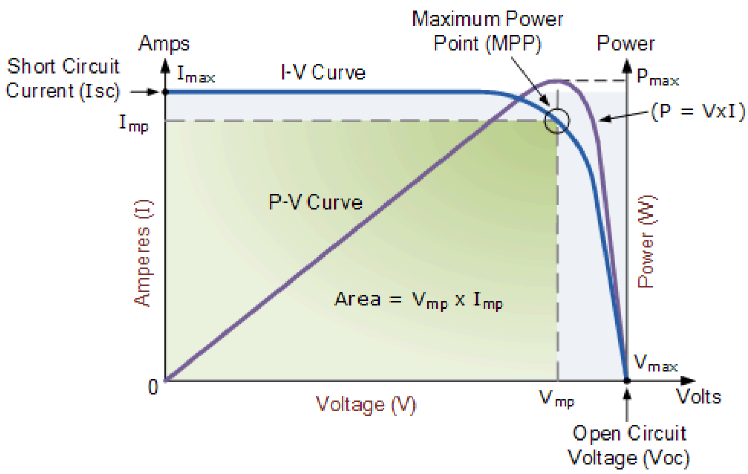


Figure 1.2: Relationship between Current and Voltage Characteristics [1]

The document you submit must not have ANY red text in - the text in red in this template is for information only. Introduce the reader to what you want to present in this chapter. Think carefully of what you want to convey. You want the reader (e.g. another student) to understand the main concepts – they need to understand enough to safely and efficiently **use** and **design for** a solar module, but abstract enough to not get caught up in the minutiae of electrons. The person assessing your report will consider whether you have demonstrated that you were able to find, integrate (absorb), and effectively convey knowledge on this topic. So, write a short summary of information you gathered from literature (papers, web sites, datasheets). Include any references to literature you feel is needed. Be sure to cite all the references, which you can add in the `References.bib` file, using the \{`cite`} command.

Some examples of how to cite (all of these have been added in the `References.bib` file): It was stated by [14] that ... . Subsequently, he changed his mind and said in that ... . While [2] claims it to be ... . Figure 1.3 shows a figure, which could paint a thousand words (if it does not, rather use words)! Table 1.1 could capture some of your datasheet and/or measured results.

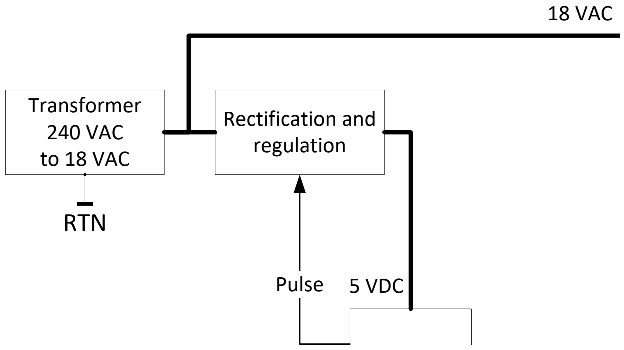


Figure 1.3: This is my caption, make me descriptive! And cite if you borrow figures [2].

Table 1.1: Example of a simple table.

	V_{OC} [V]	I_{CC} [A]	V_{pmax} [V]
Theroretical per cell	1.0	1.0	1.0
Datasheet per module	1.0	1.0	1.0
Measured dark 1.0	1.0	1.0	
Measured upside-down 1.0	1.0	1.0	
Measured oblique 1.0	1.0	1.0	
Measured facing 1.0	1.0	1.0	

Chapter 2

Lead acid batteries

Lead acid batteries are the most common battery type that is used in PV solar systems. They are low cost, have a very long lifetime and have well documented and researched technology for recharging [15].add more general info on lead acid batteries Batteries are given a rating based on the nominal voltage of the battery, in the case of the lead acid battery provided to us it is rated at 6V. A lead acid battery is constructed of a few individual cells connected in series. The nominal voltage of a single cell is 2V, thus our battery has a total of 3 cells. The most common way to measure the storage capacity of a battery is in amp hours (Ah), which is define as the total number of hours at which a battery can provide the same amount of current equal to the discharge rate at the nominal voltage of the battery [16]. However, there is another measure called watt hour (Wh), which is determined by multiplying the Ah capacity with the nominal voltage of the battery. Our battery has an advertised capacity of 4Ah, thus the expected Wh capacity is $4Ah \times 6V = 24Wh$. This rated capacity is rated according to discharge rate and temperature of the specific battery, because the capacity is greatly affected by the discharge rate and temperature of the battery. As shown in figure 2.1 we can see that the battery capacity falls by roughly 1% per degree when the temperature of the battery is below 20°. Too high temperatures are not good for the battery either as this can make the battery age faster or self-discharge [3].

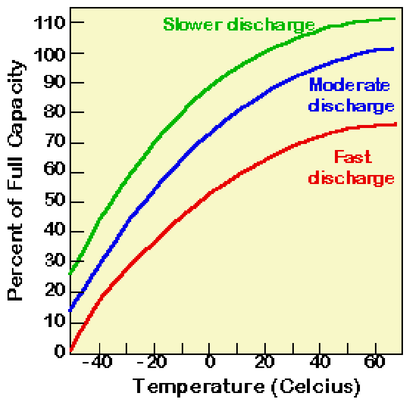


Figure 2.1: Relationship between Battery Capacity, Temperature and Discharge Rate [3]

Testing the OC voltage of the lead acid battery provided to us gives a result of 6.39V, if a load is connected to the battery, the battery will begin to discharge and the voltage of the battery will slowly begin to drop. However there will also be an instantaneous drop in voltage across the terminals of the battery, this is due to the internal resistance of the battery. Internal resistance is the resistance on the inside of the battery and determines the maximum discharge current of a battery [17].

Lead acid batteries are charged using the constant current constant voltage (CCCV) charge method. With this method the battery is charged as shown in figure 2.2 in 3 stages: constant current charge, topping charge and float charge. The constant current charge is where the current is kept at a constant rate and the main portion (70%) of the charging is done and the voltage rises to the peak voltage. The topping charge stage slowly decreases the current, but the voltage stays at the same level. The float charge lower the voltage to the float charge level in order to compensate for the loss caused by self-discharge. The battery is considered fully charged when the current drops below a certain set level (around 3-5% of the Ah rating) [4]. According to the datasheet provided by RS Pro [18] the maximum constant current rate at which our battery should be charged is 1.2A when using the constant voltage method. nmr 3.? Our battery is fully charged at a float voltage of between 6.75V and 6.9V

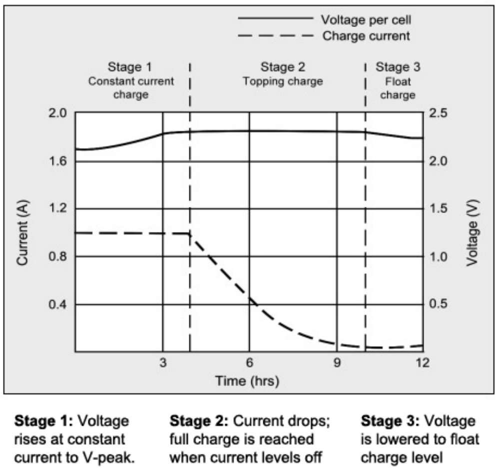


Figure 2.2: Charge States of Lead Acid Battery [4]

After being charged the lead acid battery is now ready to be discharged,however there are some important points to consider about discharging a lead acid battery. The amount that a battery has been discharged is measured by the depth of discharge (DoD), which is expressed as a percentage relative to the total capacity of the battery. Discharging a battery to 100% DoD is not recommended as this will decrease the lifetime of the battery. The recommended DoD for longevity is determined by whether your battery is a shallow-cycle or deep-cycle battery. A shallow-cycle battery will get the most cycles with a DoD of 50% and a deep-cycle battery can be discharged to a DoD of 80%. According to the datasheet provided by RS Pro [18] the maximum burst discharge current that our battery can provide is 60A for 5s.3. resistor added would start discharging battery. 4&5

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 [2], 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.

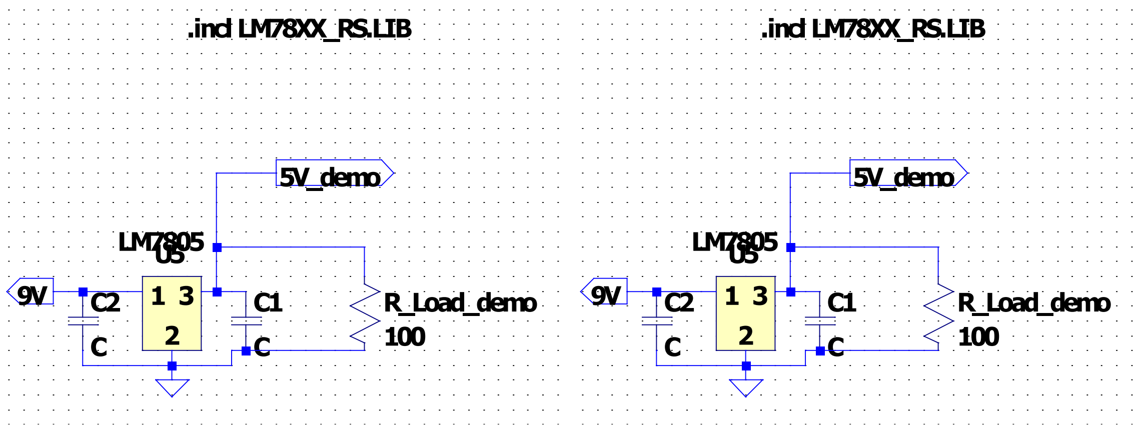
- Circuit diagram like the one in Figure 3.1. I used “print to PDF” from LTSpice, but feel free to use a cropped screengrab if you are PDF-challenged and do not have a PDF printer (there are some free PDF creators online). Also have a look at the demo video on SUNLearn.

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.

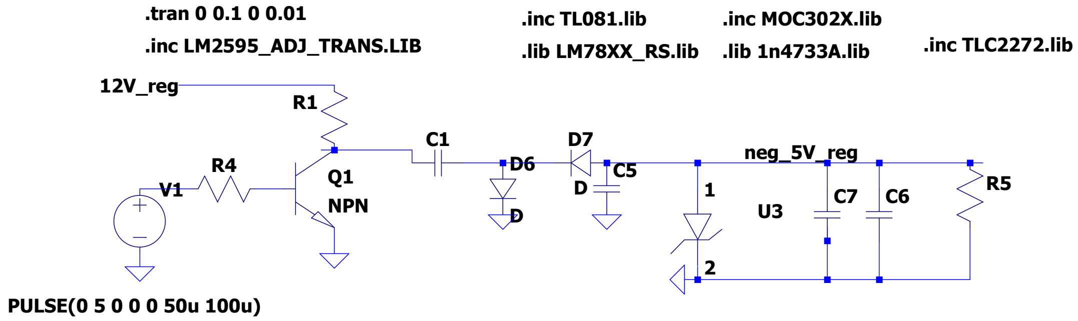
Here is an inline equation $\frac{55}{45+3}$. Here is a numbered equation in Eq. 3.1.

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

.



(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.

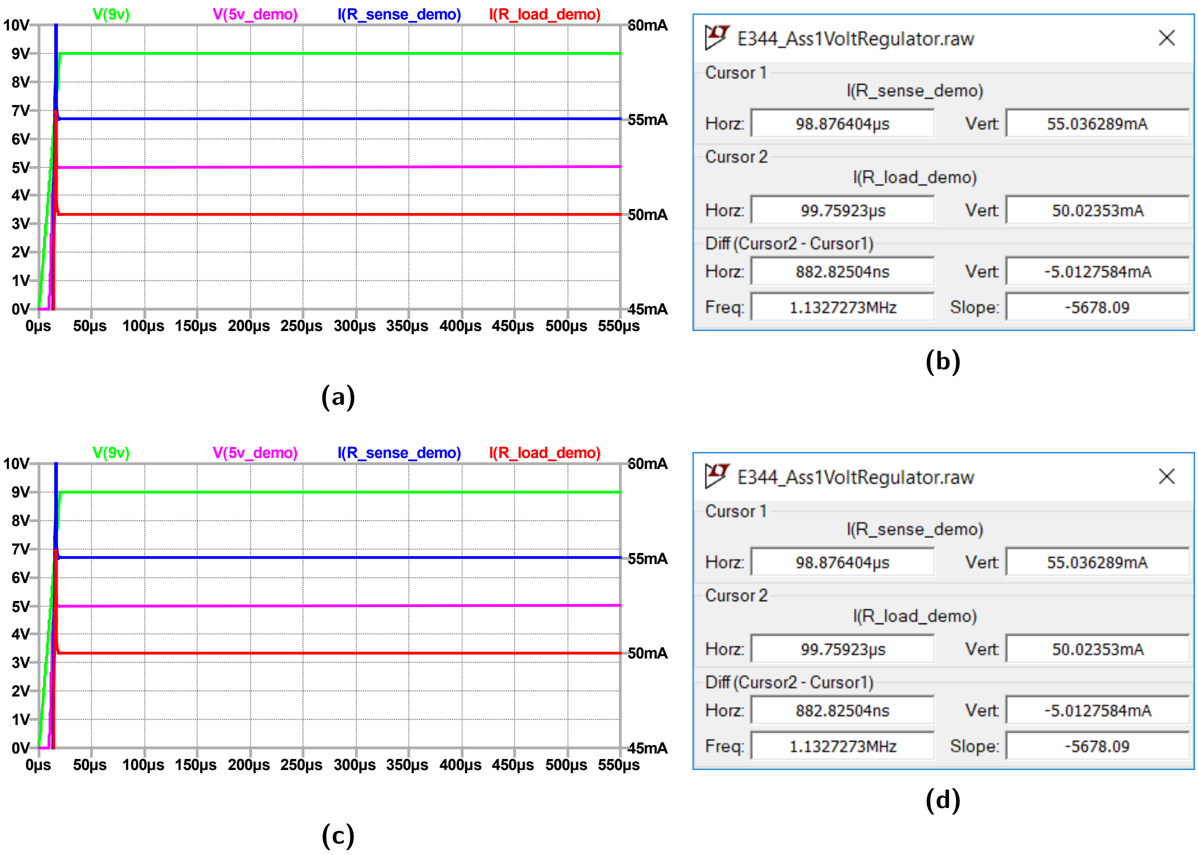


Figure 3.2: Voltage regulation, comparing the linear and switchmode regulators... (a) Blah blah. (b) Blah blah. (c) Blah blah. (d) Blah blah. As far as possible, please put input(s) and output(s) on the same plot rather than on separate plots. Based on the datasheet of XXXX in [2].

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] A. E. Tutorials, "Solar cell i-v characteristic," https://www.alternative-energy-tutorials.com/photovoltaics/solar-cell-i-v-characteristic.html, 2016.

[2] BBC, "How to make opamps amp op," 2018. [Online]. Available: www.electronics-tutorials.ws

[3] C. Honsberg and S. Bowden, "Battery characteristics," https://www.pveducation.org/pvcdrom/lead-acid-batteries/characteristics-of-lead-acid-batteries, 2020.

[4] B. University, "Bu-403: Charging lead acid," https://batteryuniversity.com/article/bu-403-charging-lead-acid, Nov. 2019.

[5] U. D. of Energy, "Solar photovoltaic cell basics," https://www.energy.gov/eere/solar/solar-photovoltaic-cell-basics.

[6] ——, "Solar photovoltaic technology basics," https://www.energy.gov/eere/solar/solar-photovoltaic-technology-basics.

[7] Geotherm, "Polycrystalline solar cells vs monocrystalline: Which is better?" https://geothermhvac.com/mono-vs-poly-better/#:~:text=Polycrystalline%20panels%20have%20lower%20effi%ciency,less%20power%20per%20square%20foot.

[8] Kurpaska, Slawomir, Knaga, Jaroslaw, Latala, Hubert, Sikora, Jakub, and Tomczyk, Wieslaw, "Efficiency of solar radiation conversion in photovoltaic panels," *BIO Web Conf.*, vol. 10, p. 02014, 2018.

[9] A. Beaudet, "How do i read the solar panel specifications?" https://www.altestore.com/blog/2016/04/how-do-i-read-specifications-of-my-solar-panel/, Apr. 2016.

[10] A. E. Tutorials, "Solar photovoltaic panel," https://www.alternative-energy-tutorials.com/photovoltaics/photovoltaic-panel.html, 2014.

[11] *SLP005-12 PV Module Product Specification Sheet*, SLP005-12 PV Module datasheet, ACDC Dynamics.

[12] C. Honsberg and S. Bowden, "Open-circuit voltage," pveducation.org/pvcdrom/solar-cell-operation/open-circuit-voltage, 2020.

[13] ——, "Short-circuit current," https://www.pveducation.org/pvcdrom/solar-cell-operation/short-circuit-current, 2020.

[14] M. J. Booysen, S. J. Andersen, and A. S. Zeeman, "Informal public transport in Sub-Saharan Africa as a vessel for novel Intelligent Transport Systems," in *16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013)*, Oct 2013, pp. 767–772.

[15] C. Honsberg and S. Bowden, "Lead acid batteries," https://www.pveducation.org/pvcdrom/batteries/lead-acid-batteries, 2020.

[16] ——, "Battery capacity," https://www.pveducation.org/pvcdrom/battery-characteristics/battery-capacity, 2020.

[17] ——, "Other electrical battery parameters," https://www.pveducation.org/pvcdrom/battery-characteristics/other-electrical-battery-parameters, 2020.

[18] *Sealed Lead-Acid Battery General Purpose Specification*, Sealed Lead-Acid Battery 537-5422(6V4.0Ah) datasheet, RS Pro.

Appendix A

Social contract

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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, Abraham Albertus Cilliers .... 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.

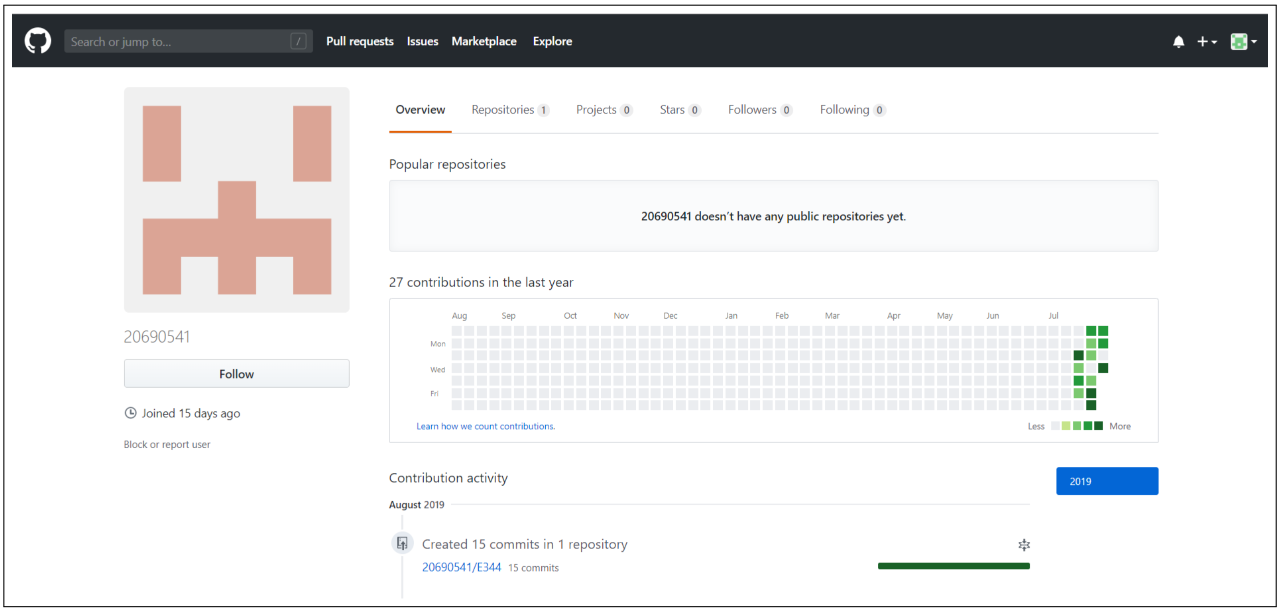
Prof. MJ Booysen	Student number: 23252162
Signature: Digitally signed by MJ BOOYSEN Date: 2021.08.04 22:12:45 +02'00'	Signature: Cilliers
Date: 4 Aug 2021	Date: 10 Aug 2021

1

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!!

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

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Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

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