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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.

16 August 2021

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W. Viljoen Voorletters en van / *Initials and surname*	16 August 2021 Datum / *Date*

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Nomenclature

Variables and functions

J	Joules
P	Power
W	Watt
V	Voltage/Volts
I	Current
A	Ampere
R	Resistance
Ω	Ohms
Q	Charge
C	Coulomb
t	time
$F.V$	Full Voltage
V_{OC}	Open circuit voltage
I_{SC}	Short circuit current
T_{amb}	Ambient Temperature
T_j	Junction Temperature
V_{sg}	Source to gate voltage
V_{gs}	Gate to source voltage
V_T	Threshold voltage
V_{Supp}	Supply voltage
V_{cc^+}	Positive voltage rail of an op-amp
V_{cc^-}	Negative voltage rail of an op-amp
V_{ref}	Reference voltage of an op-amp
V	Inverting input of an op-amp
V^+	Non-inverting input of an op-amp
R_s	Sense resistance

Acronyms and abbreviations

s.	seconds
e.g.	for example
LED	Light-Emitting Diode
mV	milli Volts
mA	milli Ampere
NMOS	Negative-channel Metal-Oxide Semiconductor
PMOS	Positive-channel Metal-Oxide Semiconductor
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
Temp	temperature
AC	Alternating current
DC	Direct current
op-amp	Operational Amplifier
LTspice	Circuit Simulation Software

Chapter 1

Literature

1.1. Battery

Overview

Batteries are known as energy storage devices, and they act as power sources when their potential chemical energy is being converted to electrical energy this being achieved through an electrochemical process. In lead-acid batteries various electrodes are being submerged in an electrolyte, this is a mixture of water and acid and are used to store the energy. The battery we are using for the model will be a lead-acid battery. Figure 1.1 illustrates, with a picture and a diagram, what is taking place in the inside of the battery.

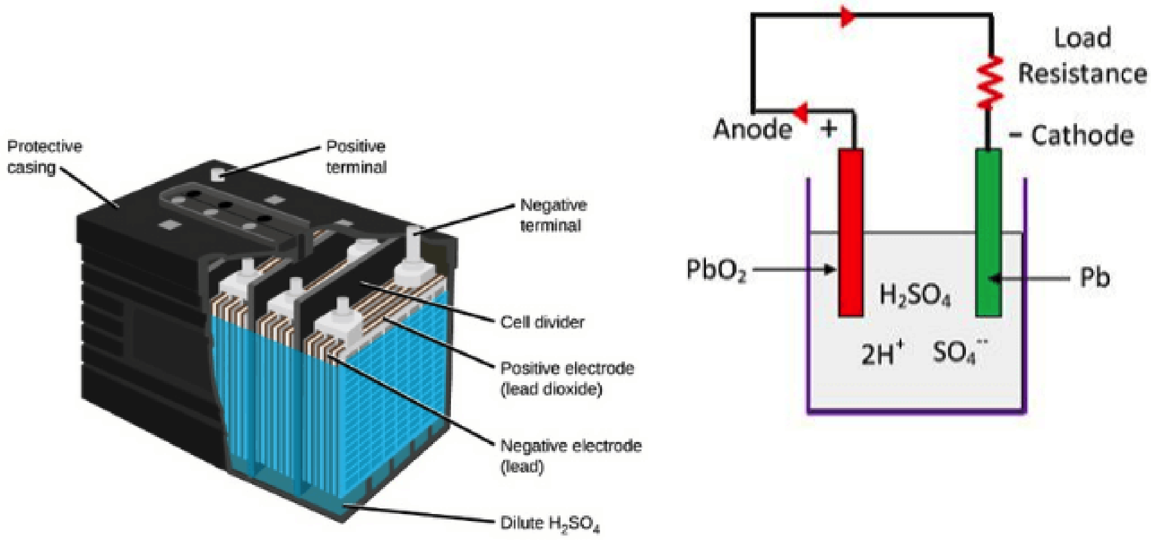


Figure 1.1: Picture and diagram of the inside of a lead-acid battery. [1]

The battery unit consists of a voltage of 6V and has 3 units. Each of the cells consists of a nominal voltage of 2V [5]. When fully charged, the battery possesses an open circuit voltage of 6.4V across the given terminals. It also consists of a rated power of 24Wh.
When the battery is being connected to a load, there will be a small instantaneous drop in the voltage. This drop is due to the internal resistance of the battery. The materials that are making up the battery is opposing the flow of the current. This resistance created, will cause the voltage to drop when current make its way through the battery when a load is connected.

Charging the battery

Power are being supplied to the battery and that charges it. The battery consists of different charging stages, shown graphically, in Figure 1.2. Terminal voltage are being adjusted so that the current will be constant, most of the charging phase occurs in this stage, charging to around 80 % of the battery's total capacity. Terminal voltage are being kept at a constant and this allows for final charging of the battery, as the current gradually decreases. Following that a very small terminal voltage will be applied to maintain the battery charging level. Finally, equalisation will occur. This is when the controlled overcharge is being performed rhythmically to increase the batteries longevity and by reversing negative chemical effects.

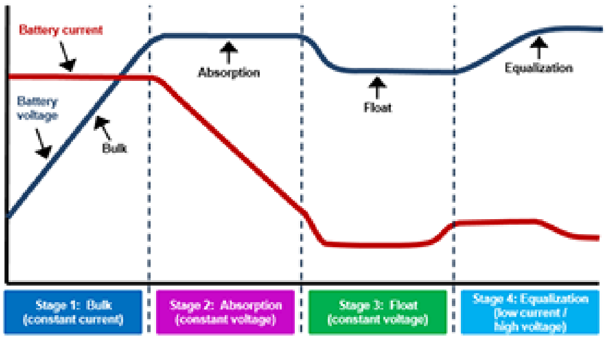


Figure 1.2: The charging stages of a battery. [2]

Discharging the battery

The battery consists of a rated capacity of 4Ah. The rating of these batteries is being measured at 25 °C and at a discharge rate of 1C. This indicates that, at a rated capacity of 4Ah, the battery will successfully provide 4A of current for approximately an hour. This will be achieved because the capacity will be influenced by the rate of the discharge and temperature. Generally, it's suggested to only use roughly 20 % of the battery's capacity to increase its longevity. Moving beyond this point can possibly damage the battery's ability to store energy. From the provided datasheet [5] of the battery, we are able to witness the discharge characteristics (graphically) in Figure 1.3.

The self-discharge ratio is less than 3 % per month at 25 °C. The ratio of the self-discharge expands as temperatures expands. Based on the ratio of the self-discharge, the battery will be able to be stored for a few months without having to recharge. Depth of discharge (DoD) or state of charge (SoC) will be monitored to avoid causing damage to the battery. As mentioned, from the datasheet [5] of the battery you can witness the self-discharge characteristics graphically in Figure 1.4.

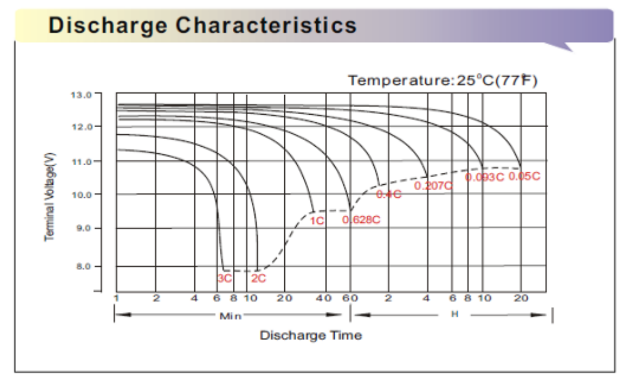


Figure 1.3: Battery datasheet extract 1.

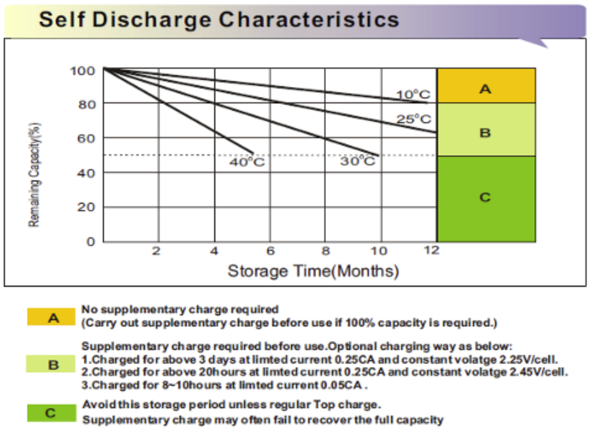


Figure 1.4: Battery datasheet extract 2.

1.2. Solar Module

Solar PV cell

Device that transforms the energy of light into electricity, and this is being done with the photovoltaic effect and it can be arranged in a specific way to form solar modules and arrays.

Structure

A PV cell is embodied of a pn-junction which is bordering the positive and negative doped semiconductor sectors and electrodes which controls the charge in the given regions and allows for the current to flow, anti-reflection coating and protective layers. A realistic and applicable example can be seen in Figure 1.5

Operation

Photons in sunlight can be soaked up, reflected or it can pass directly through a PV cell. When light is being absorbed, a solar module will be created by successfully connecting a P-type semiconductor and a N-type semiconductor with each other. Overabundance electrons in N-type will infuse the holes in the P-type (around the junction). This will carry on until equilibrium is achieved. A tiny region encircling the junction will have the opposite polarity to their doped regions. This will then create an electric field combating the flow of the current

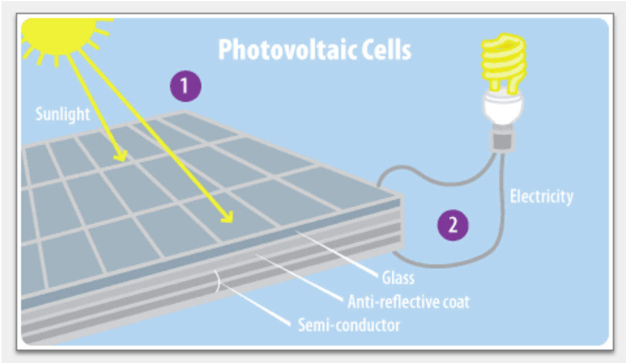


Figure 1.5: Simple solar panel model. [3]

(acting as a switch), this is called the depletions region. When photons from the sunlight hit the pn-junction it will energize the electrons and allow them to move cross the depletion region. The current will begin to flow.

Efficiency of a polycrystalline PV module

When we convert solar energy (irradiance) to electrical energy there will be a little bit loss of energy. With regards to *Geotherm* [6], the module's cells consists of an efficiency of around 13-16 %.

Power characteristics of the solar PV module

With regards to the open circuit analysis the prospective difference was taken over the terminals when no current was drawn, thus leading to a maximum voltage over the terminals. Regarding a short circuit analysis, the terminals at the output are being connected, therefore there appears to be zero voltage over the terminals, leading to maximum currents being drawn. Polycrystalline silicon solar cells (in commercial modules) appear to commonly have open-circuit voltages of roughly 0,6V. Cells are being connected in series to supply and achieve a higher voltage and deliver more power. The solar module we use for our design has a V_{OC} of 21.6V and a I_{OC} of 0.34 A. We know that the maximum power point (MPP) is the highest output power that the device is able to deliver. Power can be displayed as $P = V \times I$. MPP can be achieved by the I-V curve 1.6. Drawing a graph of the product and including every voltage and its corresponding current is helpful. This will provide you with the supplied power since it's an active device. This highest value seen on this graph will be the value of the MPP. We know that there are 36 cells in the solar module and each of these cells individually has an open circuit voltage of 0.6V. The rated output power of the solar PV, Pmax is 5W. Readings were done on the solar module and can be viewed in Table 1.7.

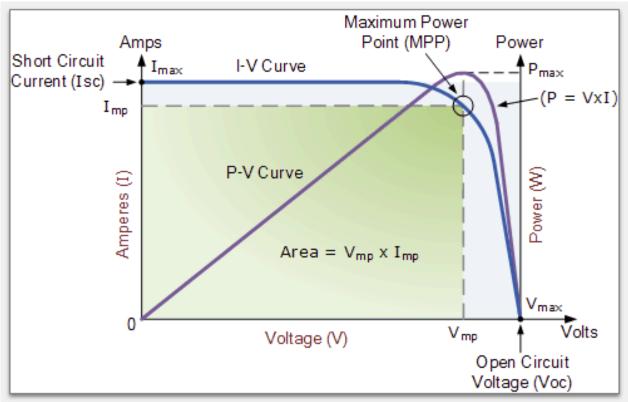


Figure 1.6: I-V curve. [4]

Tests	Isc	Voc
Dark (covered)	0 A	0 V
Indoors	495 mA	4.7 V
Ambient light	10.72 A	15.41 V
Oblique sunlight	139 A	20.46 V
Perpendicular sunlight	219 A	21.26 V

Figure 1.7: Readings done on solar module.

Chapter 2

Design

2.1. High Side Switch

2.1.1. Overview

The high side switch is used to switch the supply on or cut it off and is triggered with a control signal. This circuit is constructed with the use of 2 MOSFETs, resistors and a diode. The MOSFETs that we can use is the IRF9Z24NPBF PMOS and the 2N7000 NMOS. The Schottky diode is used to eliminate opposite voltage polarity, to insure no current flows into the supply source. With the use of the MOSFETs in the circuit we want to understand the requirements when they should allow or prevent current to flow. For the NMOS, the close switch state conditions are that the gate to source voltage, should be greater than the threshold voltage, which is 2.1V. For the PMOS to allow current to flow, the source to gate voltage, must be less than the threshold voltage, which is 2V. a Pull down resistor is required at the node which connects the control signal to the NMOS. Another resistor is added to scale down the switch on voltage of the PMOS which then allows current to flow through. When die control signal is set low, the NMOS wil by in the closed switch state to connect the supply to ground and no current will flow. The circuit is shown in Figure2.1.

2.1.2. Circuit

The circuit I built and measured is shown Figure2.1, the measurements confirmed the results seen in the simulation shown by Figure2.2.

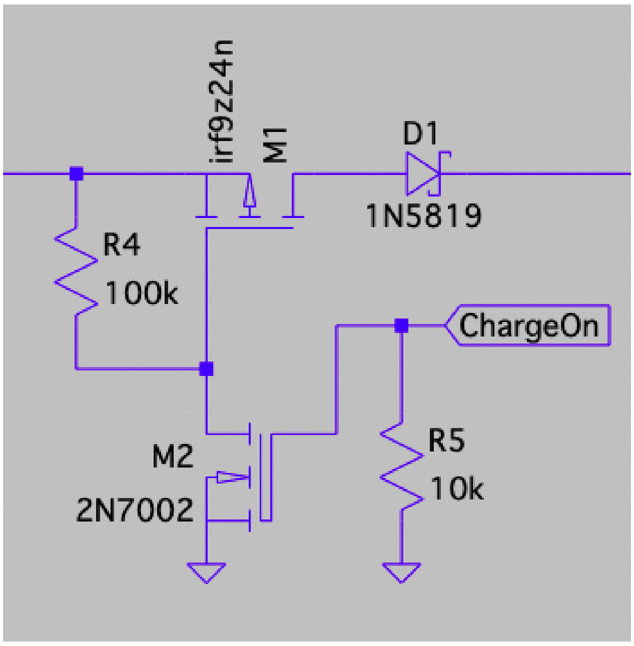


Figure 2.1: High-side Switch on supply side.

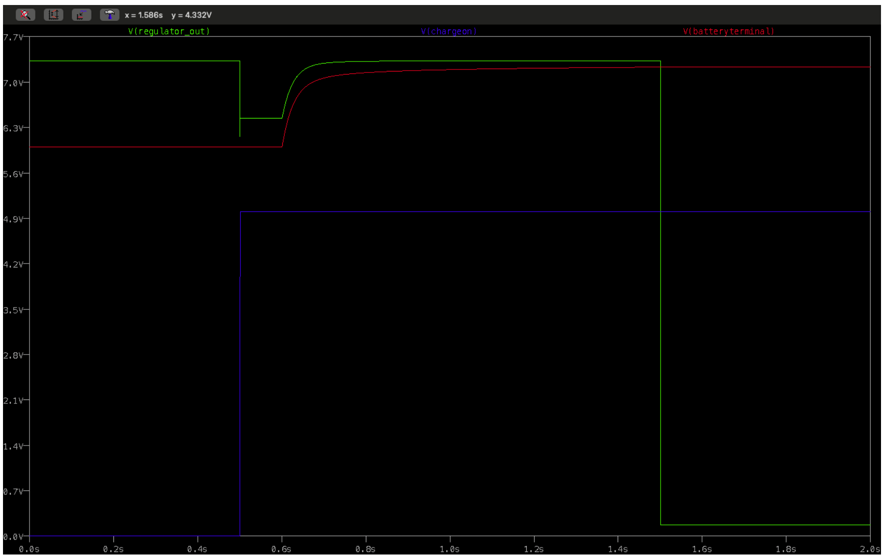


Figure 2.2: High-side Switch Simulation.

Bibliography

[1] Electrical4U, "Working of lead acid battery," 2020. [Online]. Available: https://www.electrical4u.com/working-of-lead-acid-battery-lead-acid-secondary-storage-battery/

[2] ChargeTek, "Battery charger basics," 2015. [Online]. Available: https://chargetek.com/basic-information.html

[3] Global Climate Change, "Solar enery," 2017. [Online]. Available: https://archive.epa.gov/climatechange/kids/solutions/technologies/solar.html

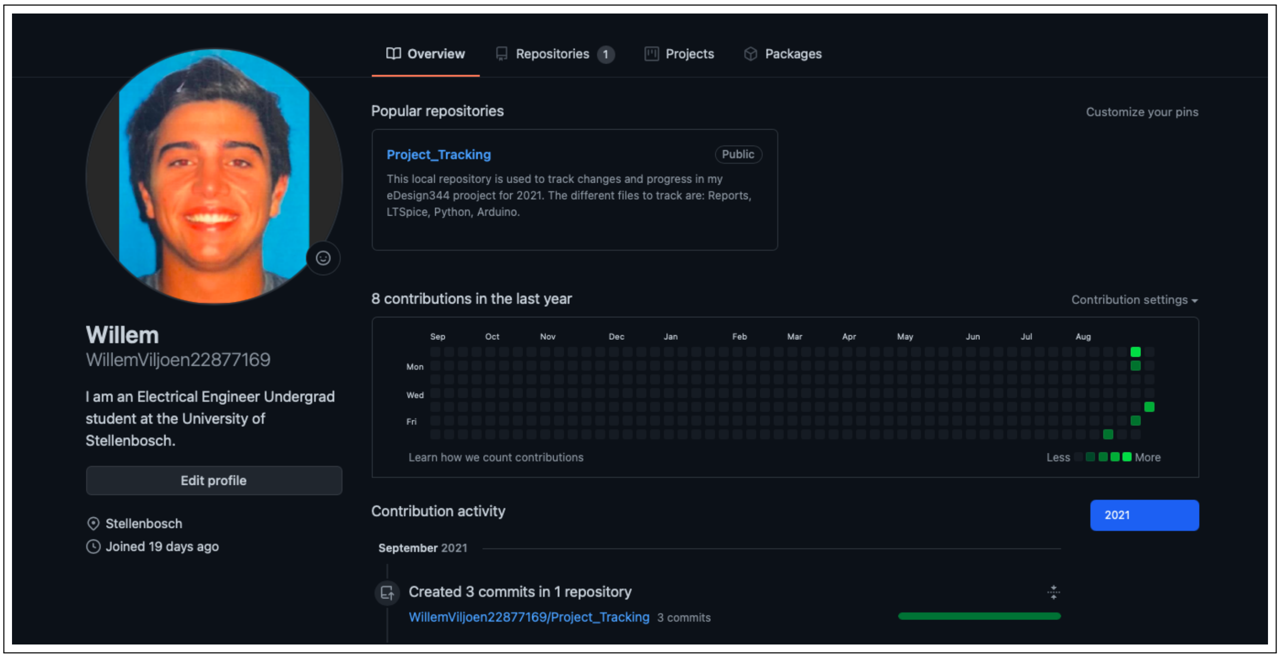
[4] Alternitavie Energy Tutorials, "Solar cell i-v characteristic," 2010. [Online]. Available: https://www.alternative-energy-tutorials.com/photovoltaics/solar-cell-i-v-characteristic.html

[5] RS PRO, "6v 4ah lead-acid battery datasheet," 2009. [Online]. Available: https://docs.rs-online.com/ce41/0900766b81580e4e.pdf

[6] Geotherm, "Polycrystalline silicon solar cells," 2021. [Online]. Available: https://geothermhvac.com/mono-vs-poly-better/

Appendix A

GitHub Activity Heatmap



Appendix B

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, ...Willem Viljoen...................... 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

Signature: .... Digitally signed by MJ BOOYSEN Date: 2021.08.04 22:12:45 +02'00'

Date: 4 Aug 2021

Student number: ....22877169................

Signature: ....

Date: ....16 Aug 2021..........................

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