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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 16, 2020

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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.

21564027 Studentenommer / *Student number*	Handtekening / *Signature*
T. Colley Voorletters en van / *Initials and surname*	August 16, 2020 Datum / *Date*

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Nomenclature

Variables and functions

I_{in}	Current drawn from the 9 VDC supply.
P_{in}	Power supplied by the 9 VDC supply.
P_{out}	Power supplied by the 5 VDC regulator.
$\%_{eff}$	Percentage regulator efficiency.
ΔP	Power dissipation.
$V_{I_{max}}$	Maximum rated input voltage.
V_D	Rated dropout voltage.
$P_{D_{max}}$	Maximum rated power dissipation.
$///$	
$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.
ε	The Bayes error.
ε_u	The Bhattacharyya bound.
$\mathbf{S}$	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.
S	Number of substitution errors.

Acronyms and abbreviations

AE	Afrikaans English
AID	accent identification
ASR	automatic speech recognition
AST	African Speech Technology
CE	Cape Flats English
DCD	dialect-context-dependent
DNN	deep neural network
G2P	grapheme-to-phoneme
GMM	Gaussian mixture model
HMM	hidden Markov model
HTK	Hidden Markov Model Toolkit
IE	Indian South African English
IPA	International Phonetic Alphabet
LM	language model
LMS	language model scaling factor
MFCC	Mel-frequency cepstral coefficient
MLLR	maximum likelihood linear regression
OOV	out-of-vocabulary
PD	pronunciation dictionary
PDF	probability density function
SAE	South African English
SAMPA	Speech Assessment Methods Phonetic Alphabet
///	
VDC	direct-current voltage

Chapter 1

System design

1.1. System overview

The block diagram for a temperature sensor conditioning system is shown in Fig. 1.1. The system is supplied by a 9 VDC battery, and performs conditioning of the temperature sensor data to produce an output signal which can be more easily interpreted by the user, in accordance with the specifications in [1]. Any measured temperature between 34°C and 42°C generates a defined output signal.

1.2. Rationale

An inverting op-amp with unity gain is used to remove an offset level from the temperature sensor stimulus signal. Thereafter, a differential op-amp amplifies the signal to achieve the desired range of output values. A low-pass filter removes any noise from the amplified signal. In order to supply the required 5 VDC to each op-amp, a linear voltage regulator is used to step down from the 9 VDC provided by the battery. Separate voltage dividers are also used to provide 0.69 VDC and 0.21 VDC bias voltages to the inverting and differential op-amps respectively.

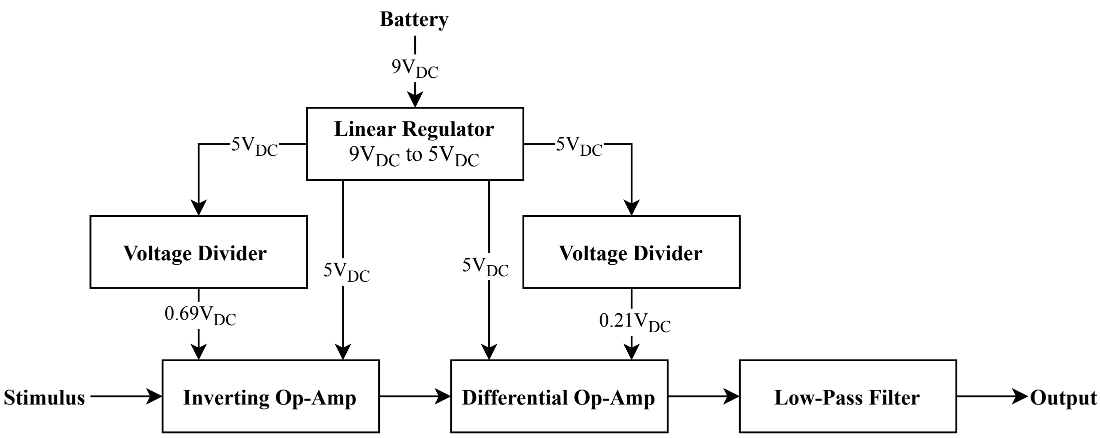


Figure 1.1: System diagram

Chapter 2

Voltage regulation

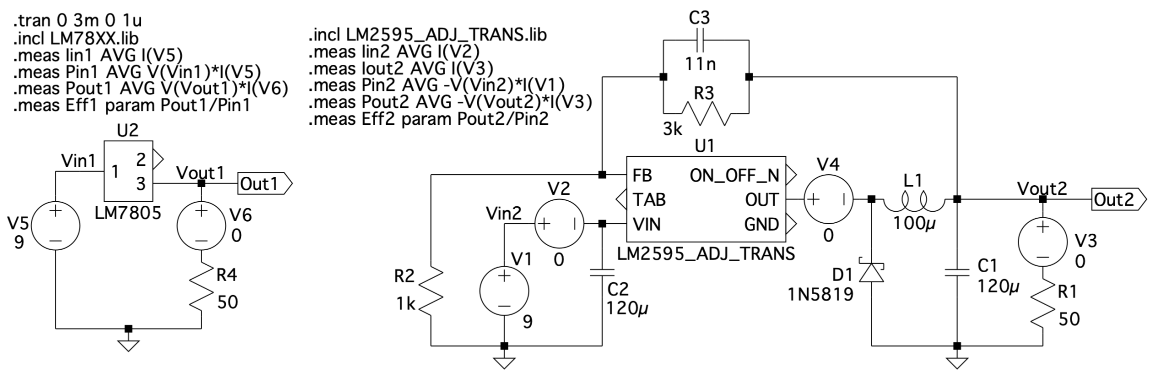
2.1. Introduction

Both a linear and switch-mode regulator were considered as voltage regulation solutions for the system. Identical scenarios were simulated on LTSpice to compare various aspects of the functionality of each regulator. The component limitations, in [2] and [3], and the simulation results were compared, and the more suitable regulator was chosen for the system design.

As per the system requirements [1], 9 VDC needs to be regulated down to 5 VDC in order to supply the positive input voltages for the amplification stage of the system. A minimum current draw of 100 mA is allowed, and there are various accuracy requirements for the system. A 50 kΩ load is connected to the regulator for testing purposes. The aforementioned, as well as the power usage, are taken into consideration when choosing an appropriate regulator.

2.2. Design

Figure 2.1 shows the LTSpice models used to compare the regulators.



(a) Linear voltage regulator.

(b) Switch-mode voltage regulator.

Figure 2.1: Circuit diagrams of the two voltage regulators.

The following values are of interest, in accordance with the system requirements [1]:

- Current I_{in} drawn from the 9 VDC supply.
- Power $P_{in} = \frac{I_{in}}{V_{9VDC}}$ supplied by the 9 VDC supply.
- Power $P_{out} = \frac{I_{out}}{V_{5VDC}}$ supplied by the 5 VDC regulator.

- Regulator efficiency $\%_{eff} = \frac{P_{out}}{P_{in}} \times 100$.
- Power dissipation $\Delta P = P_{in} - P_{out}$ of the regulator.
- Maximum rated input voltage $V_{I_{max}}$ of the regulator.
- Rated dropout voltage V_D of the regulator.
- Maximum rated power dissipation $P_{D_{max}}$ of the regulator.

The LM7805 linear regulator requires no additional design components to achieve the desired output, whereas the LM2595 switch-mode regulator requires an additional network of resistors, capacitors and inductors. This can be seen in Figure 2.1b. The switch-mode circuit was designed in accordance with Figure 35 from [3], and using Equations 2.1 and 2.2.

$$V_{out} = V_{REF}\left(1 + \frac{R_3}{R_2}\right). \tag{2.1}$$

$$R_3 \approx 3\,\mathrm{k\Omega}$$

$$C_3 = \frac{1}{31 \times 10^3 \times R_3}. \tag{2.2}$$

$$C_3 \approx 11\,\mathrm{nF}$$

2.3. Results

Table 2.1 summarises the values of interest obtained via simulation, or from the datasheets [2] and [3], for the regulators. It is clear that the LM7805 linear regulator has a higher power efficiency than the LM2595 switch-mode regulator. It also remains well below the maximum rated power dissipation $P_{D_{max}} = 750\,\mathrm{mW}$, as its power dissipation ΔP is only 446 mW.

Table 2.1: Comparison of linear and switch-mode regulators.

	LM7805 linear regulator	LM2595 switch-mode regulator	
I_{in}	105,06	101,44	mA
P_{in}	946	913,05	mW
P_{out}	500	348,15	mW
$\%_{eff}$	52,85	38,13	%
ΔP	446	528,91	mW
$V_{I_{max}}$	30 [2]	45 [3]	V
V_D	1,7 [2]	0.8 [3]	V
$P_{D_{max}}$	750 [2]	internally limited [3]	mW

Figure 2.2 compares the output voltages obtained from the linear and switch-mode regulators after each was simulated in LTSpice. The LM7805 regulator produces a near-perfect expected 5 VDC output, shown in Figures 2.2a and 2.2b. The LM2595 regulator produces a less satisfying output closer to 4.9 VDC, seen in Figures 2.2c and 2.2d, and has a considerable amount more noise than the linear output, as noted in Figure 2.2e.

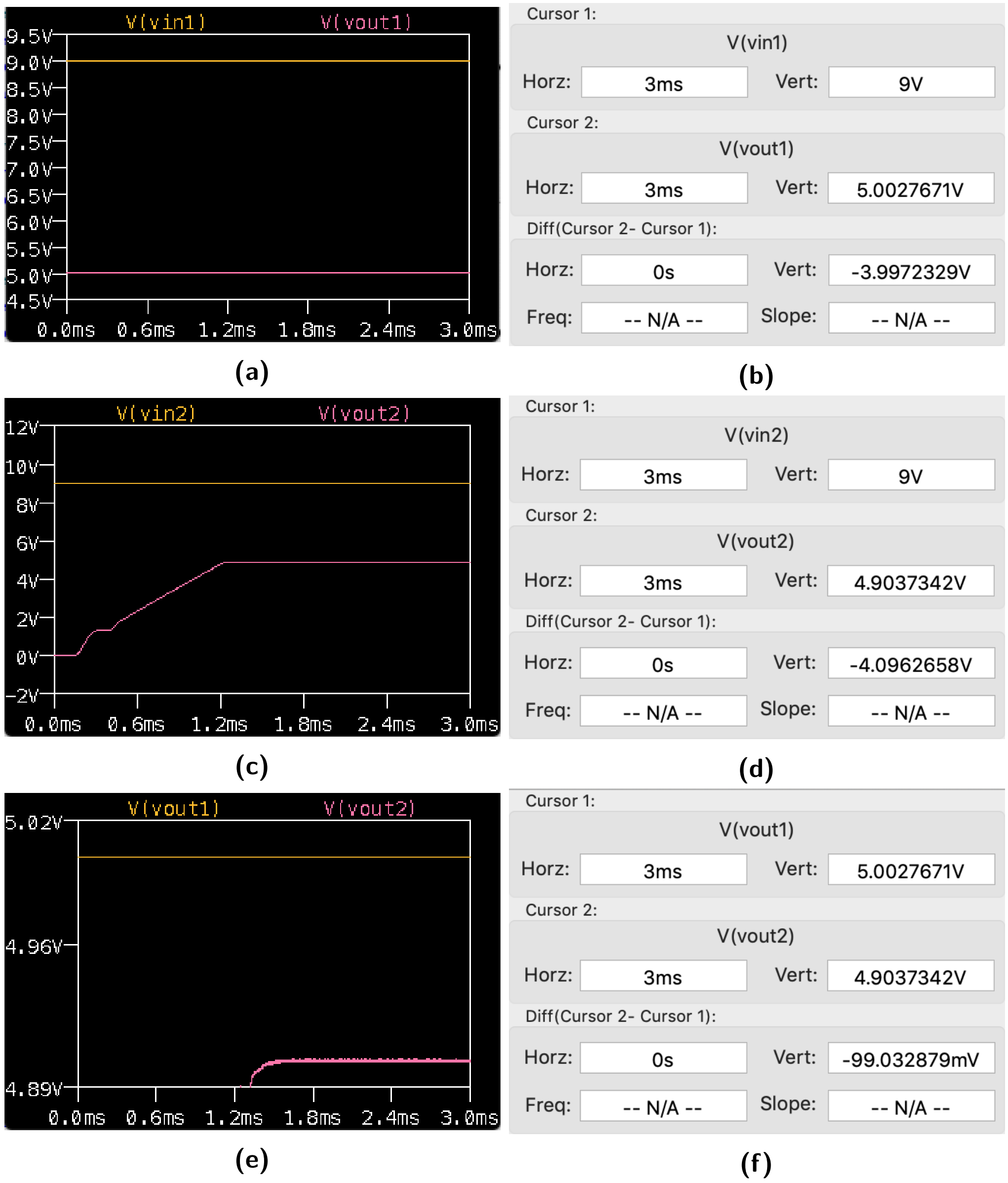


Figure 2.2: Comparing the linear and switch-mode regulators (a) and (b) LM7805 linear regulator input vs. output signals. (c) and (d) LM2595 switch-mode regulator input vs. output signals. (e) and (f) Linear regulator output vs. switch-mode regulator output.

2.4. Summary

As seen in Figure 2.2, the LM7805 linear regulator performs as expected and produces a useful 5 VDC voltage, with no additional cost or design complexity. Any power limitations of the regulator, as stipulated in [2], will not affect the operation of the greater system.

The LM2595 switch-mode regulator produces an output voltage slightly lower than desired, around 4.9 VDC. It also requires numerous additional components, which increases the overall cost and design complexity of the power supply. Most considerably, the switch-mode regulated signal is far noisier than the linearly regulated signal, seen in Figure 2.2e.

For the above reasons, the LM7805 linear regulator is the chosen solution for the remainder of the system design.

Chapter 3

Temperature sensor conditioning circuit

3.1. Intro

/// Introduce the reader to what you want to present in this chapter. Include any references to literature you feel is needed. In this section, you put a very short summary of infromation you gatherered from literature (papers, web sites, datasheets) that you used to do the design. Be sure to include the references, which you can add in the `References.bib` file.

Some examples of how to cite (all in `References.bib`): It was stated by [4] that ... . Subsequently, he changed his mind and said in [5] that ... . While [6] claims it to be ... .

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 [6].
- You can assume the reader has an E&E degree, and will not need detail 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 buy referring to the advantages and disadvantages of each.
- Circuit diagram like the one in Figure 2.1. 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.

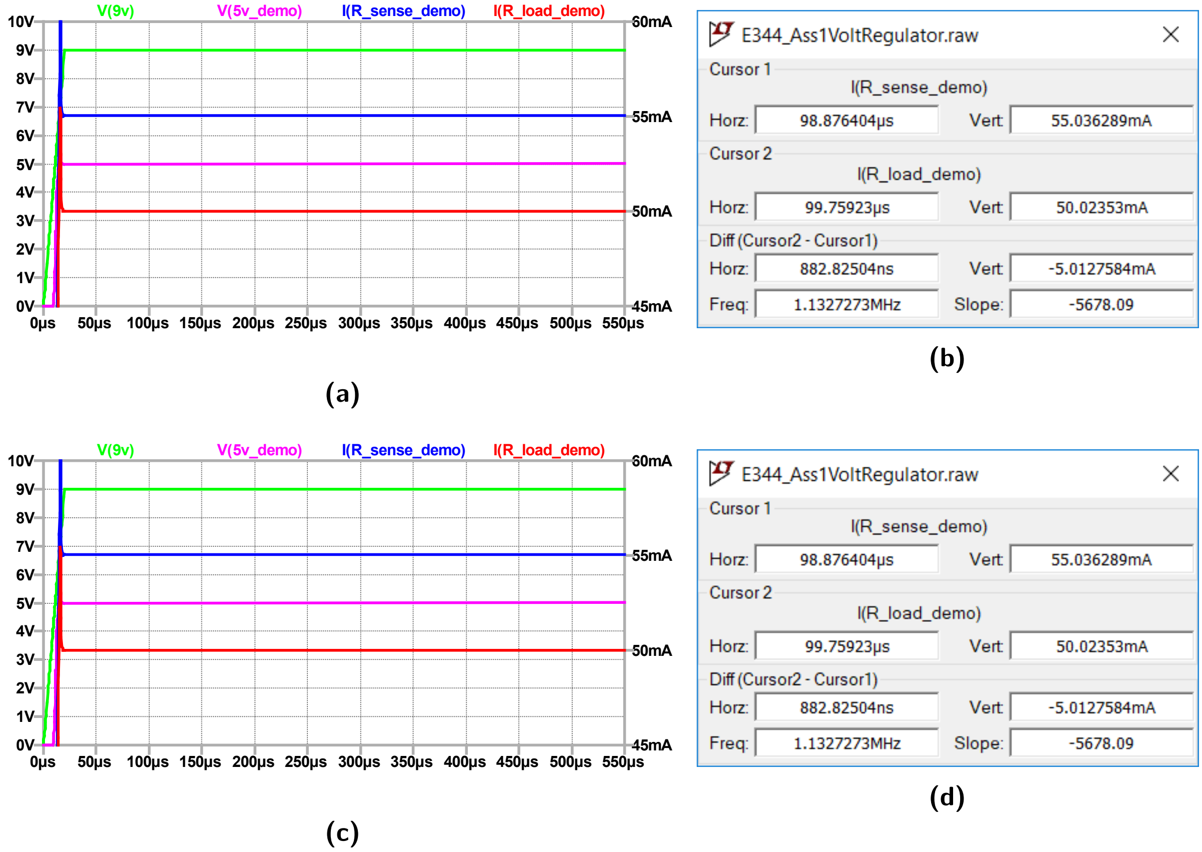


Figure 3.1: Voltage regulation, comparing the linear and switchmode regulators... (a) Blah blah. (b) Blah blah. (c) Blah blah. (d) Blah blah. As far as possible, please put input(s) and output(s) on the same plot rather than on separate plots. Based on the datasheet of XXXX in [6]

For your benefit, here is how to write values with units: 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.

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

.

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 2.2. Present and report on your simulated results in Figure 2.2 Be absolutely sure that the text and information in your report are readable.

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 **??** and 3.1.

Table 3.1: 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

3.4. Summary

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

Chapter 4

System and conclusion

4.1. System

Report on the integration of the voltage regulator and temperature sensing circuitry. Report on noise levels and how the temperature sensor will fit into the system (E.g. what the calibration will look like and what the the measurement error will be given the range, quantisation error and noise).

4.2. Lessons learnt

Write down at least three of the most important things you have learnt in Assignment 1.

Bibliography

[1] M. J. Booysen, "E-design 344 assignment 1 2020," July 2020. [Online]. Available: https://learn.sun.ac.za/pluginfile.php/2304150/mod_resource/content/3/E344_Ass1.pdf

[2] F. S. Corporation, *MC78LXXA/LM78LXXA 3-Terminal 0.1 A Positive Voltage Regulator*, March 2013. [Online]. Available: www.fairchildsemi.com

[3] T. I. Incorporated, *LM2595 SIMPLE SWITCHER (TM) Power Converter*, May 2016. [Online]. Available: www.ti.com

[4] 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.

[5] S. Gerber, A. J. Rix, and M. J. Booysen, "Combining grid-tied PV and intelligent water heater control to reduce the energy costs at schools in South Africa," *Energy for Sustainable Development*, vol. 50, pp. 117 – 125, 2019.

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

Appendix A

Social contract

Sign and inlcude.

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E-design 344 Social Contract

2020

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 (Michael Ritchie) 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 for the module, 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.

Signature: .... Date: 13 July 2020 ....

....

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 of supplementary videos on specific topics, I acknowledge that I am expected to attend the lectures and lab sessions 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.

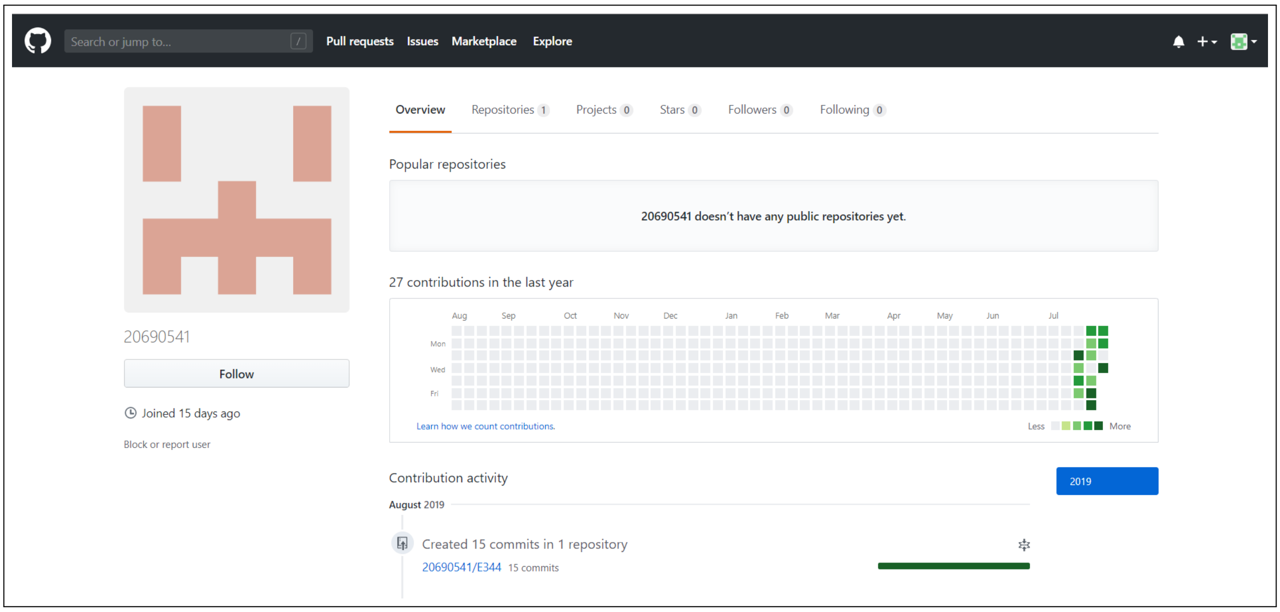
Signature: .... Date: ....

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

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