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E344 Assignment 2

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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.

September 23, 2020

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5. Ek verklaar dat die werk in hierdie skryfstuk vervat, behalwe waar anders aangedui, my eie oorspronklike werk is en dat ek dit nie vantevore in die geheel of gedeeltelik ingehandig het vir bepunting in hierdie module/werkstuk of 'n ander module/werkstuk nie.
   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.

21785155 Studentenommer / *Student number*	Handtekening / *Signature*
D.H. von Eschwege Voorletters en van / *Initials and surname*	September 23, 2020 Datum / *Date*

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Nomenclature

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

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

Chapter 1

System design

1.1. System overview

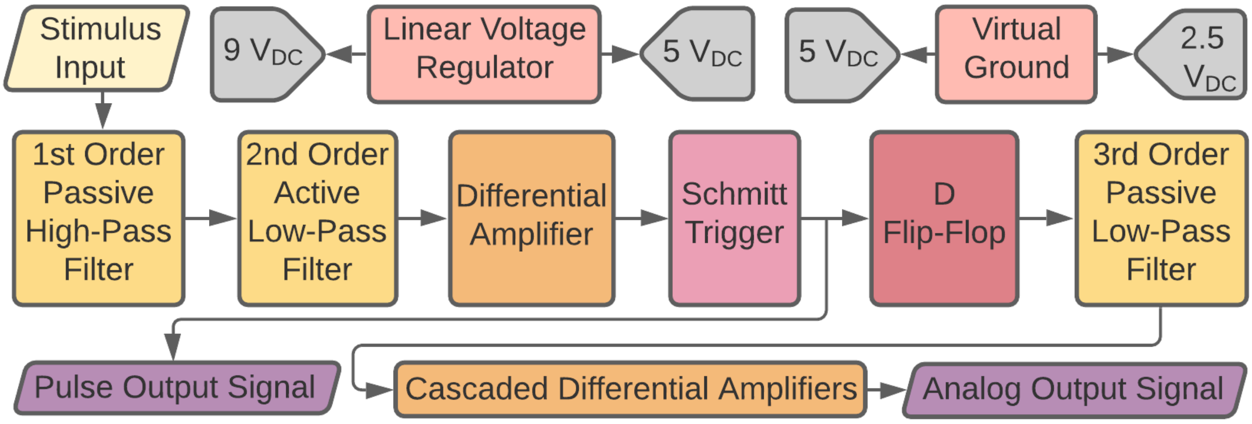


Figure 1.1: System Diagram

A heart-rate sensor is designed to receive an input signal from which pulses and analogue values are generated, corresponding to heart-beats and the heart-rate respectively. The aforementioned is achieved by voltage regulation, signal conditioning, pulse generation and conversion to analogue, as shown in figure 1.1. The circuit is powered by a voltage regulator [1] which can supply 100 mA, of which 12.8 mA is used for the temperature sensor - see E344 Assigment 1 [1] - leaving 87.2 mA at 5 V. The input signal has an amplitude of insufficient magnitude for conversion, and is subject to noise, necessitating signal conditioning: a first order passive high-pass filter and a second order active low-pass filter attenuate both high- and low-frequencies. Chosen with maximal simplicity in mind to reduce cost and complexity, the filters still performing adequately. Thereafter, a differential amplifier produces a signal with a large amplitude and little noise. A Schmitt Trigger then outputs a pulse signal with a frequency corresponding to the heart-rate. The Schmitt Trigger was chosen as it provides a noise margin via hysteresis. An analogue voltage output is required for the microcontroller - filtering and peak detection using diodes was considered but discarded, as non-linear diodes result in extremely slow simulation. Rather, the pulse output signal was converted to a pulse-width modulated signal, where the frequency of the former determines the duty cycle of the latter. This was done as PWM signals lend themselves to conversion-to-analogue by simple filtering. The PWM signal was obtained by using a D Flip-Flop and a RC-circuit (see section **??**). A third order passive RC filter is then used - passive components reduce current usage and simulation time. The filter is of high order as to minimize noise, while meeting the settling time requirement. Finally, the signal was amplified to achieve the required range.

Chapter 2

Heart rate sensor

2.1. Introduction

Circuits pertaining to signal conditioning, pulse signal and analogue output generation will be discussed. Conditioning is done via filtering and amplification; active filters provide high input and low output impedance, and a large Q-factor [2]. A differential amplifier is suitable for amplification, as the gain is referenced against a customizable voltage [3]. A Schmitt Trigger is well-suited for pulse generation, as it provides a noise margin [4]. PWM signals can be converted to analogue using filtering [5].

2.2. Design

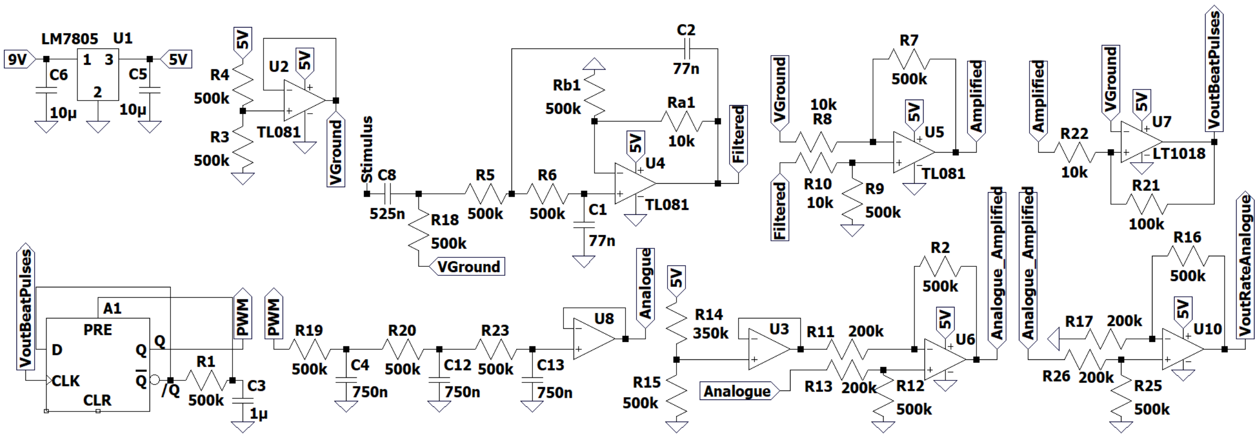


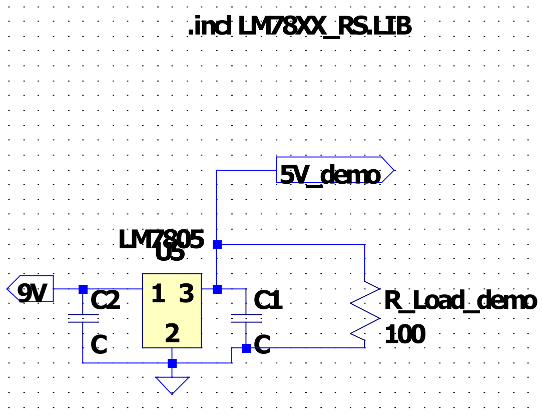
Figure 2.1: Complete Circuit **enlarge this**

The complete circuit is shown upfront in figure 2.1 in order to aid with explanation. Note that when resistor values are selected at random, the largest resistor in the sub-circuit is always chosen to be 500 kΩ, as to reduce current usage. The design process now follows.

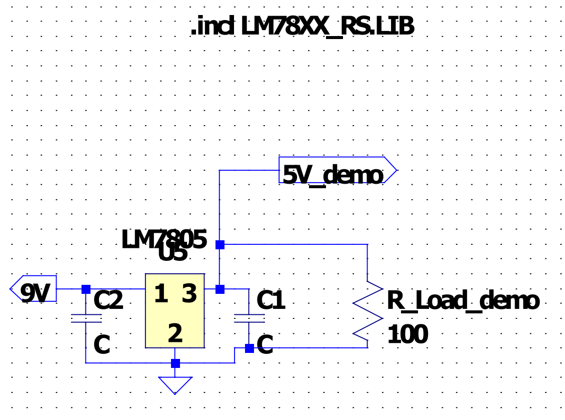
The stimulus input signal contains noise at 0.25 Hz and at 5 Hz and higher. The information in the signal resides between 0.8 to 2.5 Hz, corresponding to 50 and 150 BPM respectively. Noise results in distorted square wave output, thus necessitating filtering. A first order passive high-pass filter, cutoff frequency 0.606 Hz, attenuates the low frequency noise. With R18 = 500 kΩ, C8 = 525 nF according to $f_c = \frac{1}{2\pi RC}$. The capacitor is connected to a virtual ground of 2.5 V, thus centering the signal around 2.5 V. A second order active low-pass filter, cutoff frequency 4.1 Hz, filters out high frequency noise. R5 = R6 = 500 kΩ, C1 = C2 = 77 nF - see aforementioned formula. Cutoff frequencies were selected to remove noise maximally while minimally affecting heart-rate data. The signal should reside slightly above 2.5 V to facilitate amplification (to be discussed). Thus, Rb1 = 500 kΩ and Ra1 = 10 kΩ since $A_v = 1 + \frac{R_A}{R_B}$ [?]. The TL081 op-amp is used, as it is less expensive than the TLC2272 [?]. A filter output with DC offset slightly above 2.5 V allows for the use of a differential amplifier with the existing virtual ground connected to the negative input, thus removing the need for additional circuitry otherwise required to provide a voltage level at the negative input. The signal is amplified according to $\mathrm{V_{OUT}} = \frac{\mathrm{R}_a}{\mathrm{R}_b}(\mathrm{V_2} - \mathrm{V_1})$ [3], where $\mathrm{R_a}$ corresponds to R7 and R9, and $\mathrm{R_b}$ to R8 and R10. The gain of 50 was selected to again provide a DC offset of 2.5 V, as it facilitates implementation of the comparator (to be discussed). Since the amplified signal has an amplitude of only 1.66 V, the inexpensive TL081 was chosen despite having a smaller output range. Next, the signal is fed into a Schmitt Trigger comparator, which produces 5 V if the input exceeds the upper trip point (UTP) and 0 V if the input falls below the lower trip point (LTP) [4]. The range between the UTP and LTP is referred to as the hysteresis width and serves as a noise margin [4] around the reference voltage, $\mathrm{V_{REF}}$. The hysteresis width was chosen as 0.5 V as to be an order of magnitude larger than the highest levels of noise present on the signal serving as input to the comparator. As mentioned previously, the amplified signal has a DC offset of 2.5 V, which was chosen as to require $\mathrm{V_{REF}} = 2.5$ V, once again allowing for the use of the existing virtual ground (instead of additional circuitry) at the negative input of the LT1018 comparator. UTP = 2.75 V, LTP = 2.25 V, UTP = $V_{REF} + \beta Vcc$ and LTP = $V_{REF} - \beta Vcc$, thus $\beta = 0.05$ [4]. Further, $\beta = \frac{\mathrm{R_{22}}}{\mathrm{R_{22}+R_{21}}}$. Thus R21 = 190 kΩ and R22 = 10 kΩ. (R21 was later adjusted to 100 kΩ to account for loading effects). All of the aforementioned thus produces a square wave output, where the frequency of the pulses directly relate to the heart-rate.

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

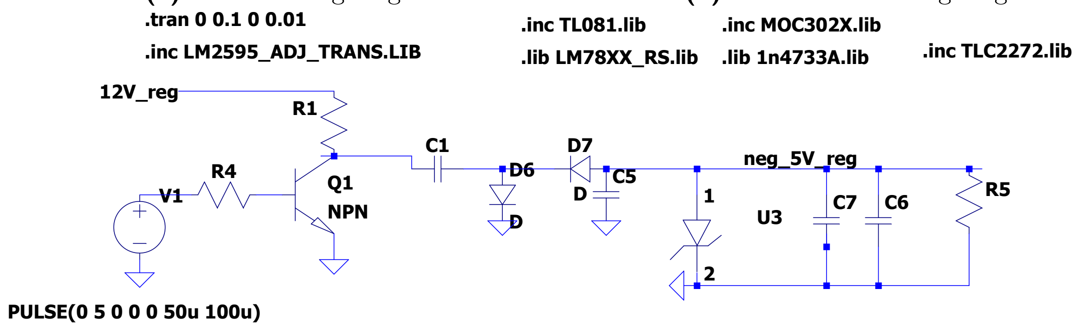
- Design rationale, i.e. what your thinking was behind the design. For example, explain that you had to first analyse the heart beat signals before you could design the filtering.
- References to literature/sources as appropriate [?].
- You can assume the reader has an E&E degree, and will not need detail 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. Importantly, they are based on maths, and not on simulation - there is a difference.
- 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.



(a) Linear voltage regulator.



(b) Switchmode voltage regulator.



(c) Chargepump voltage regulator.

Figure 2.2: Circuit diagrams of the two voltage regulators, and another irrelevant one
.

- Circuit diagram like the one in Figure 2.2. 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.

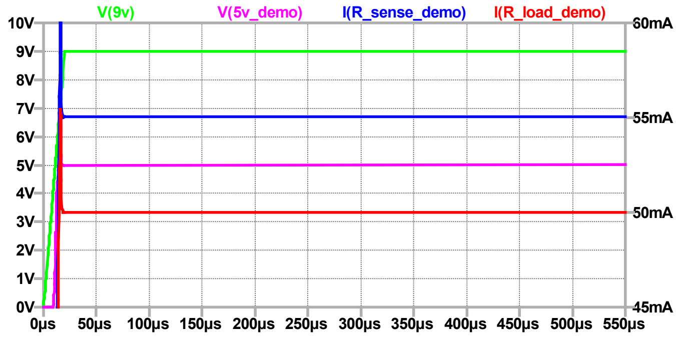
For your benefit, here is how to write values with units: 150 mΩ or 199 myUnits, and this is how we write ranges: 2 to 5 kV.
Here is an inline equation $\frac{55}{45+3}$. Here is a numbered equation in Eq. 2.1.

$$a = \frac{55}{45+3}. \tag{2.1}$$

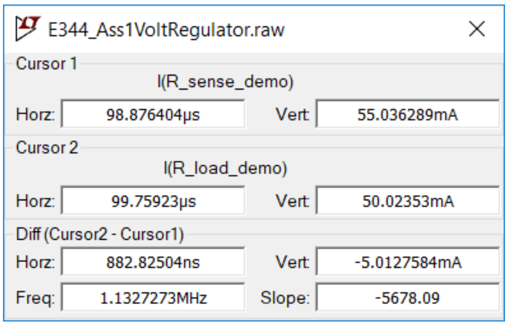
.

2.3. Results

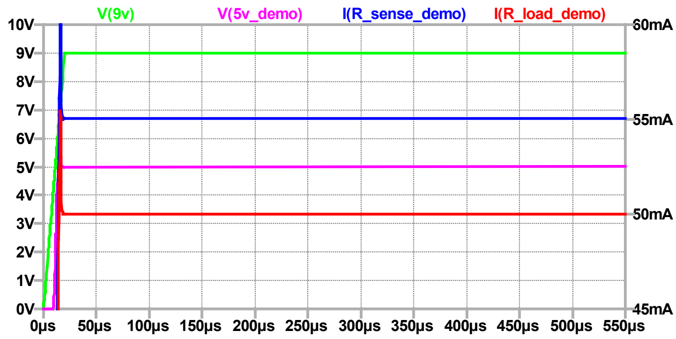
In this section, you want to demonstrate, by means of referring to simulation results, using the designed circuit, how your circuit behaves as you designed it in Section 2.2. Present and report on your simulated results in Figure 2.3. Be absolutely sure that the text and information in your report are readable.
You can use screengrabs or photos of the oscilloscope, or download the CSVs and plot them as



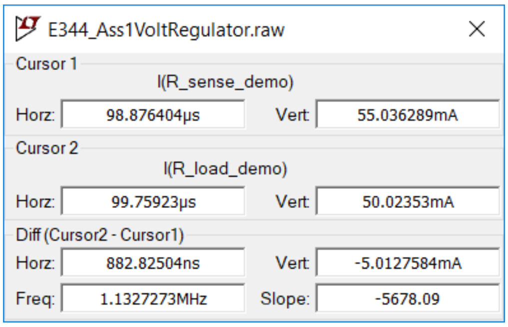
(a)



(b)



(c)



(d)

Figure 2.3: 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 2.1: 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 2.2: 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

PDFs using Matlab, Excel or similar. You can also use tables, example of which are presented in Tables 2.1 and 2.2.

2.4. Summary

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

Chapter 3

System and conclusion

3.1. System

Report on the "so what" or the take-away of the ciruit you designed in this report. Report on noise levels and how the Heart rate 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).

3.2. Lessons learnt

Write down at least three of the most important things you have learnt in Assignment 2, and state what you would have done differently if you had another chance.

Bibliography

[1] "E344 assignment 1."

[2] "Difference between active and passive filter."

[3] W. Storr, "Operational amplifiers," 2018. [Online]. Available: https://www.electronics-tutorials.ws/opamp

[4] ——, "Op-amp comparator," 2018. [Online]. Available: https://www.electronics-tutorials.ws/opamp/op-amp-comparator.html

[5] "Analog output - convert pwm to voltage."

Appendix A

Social contract

Sign and inlcude.

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