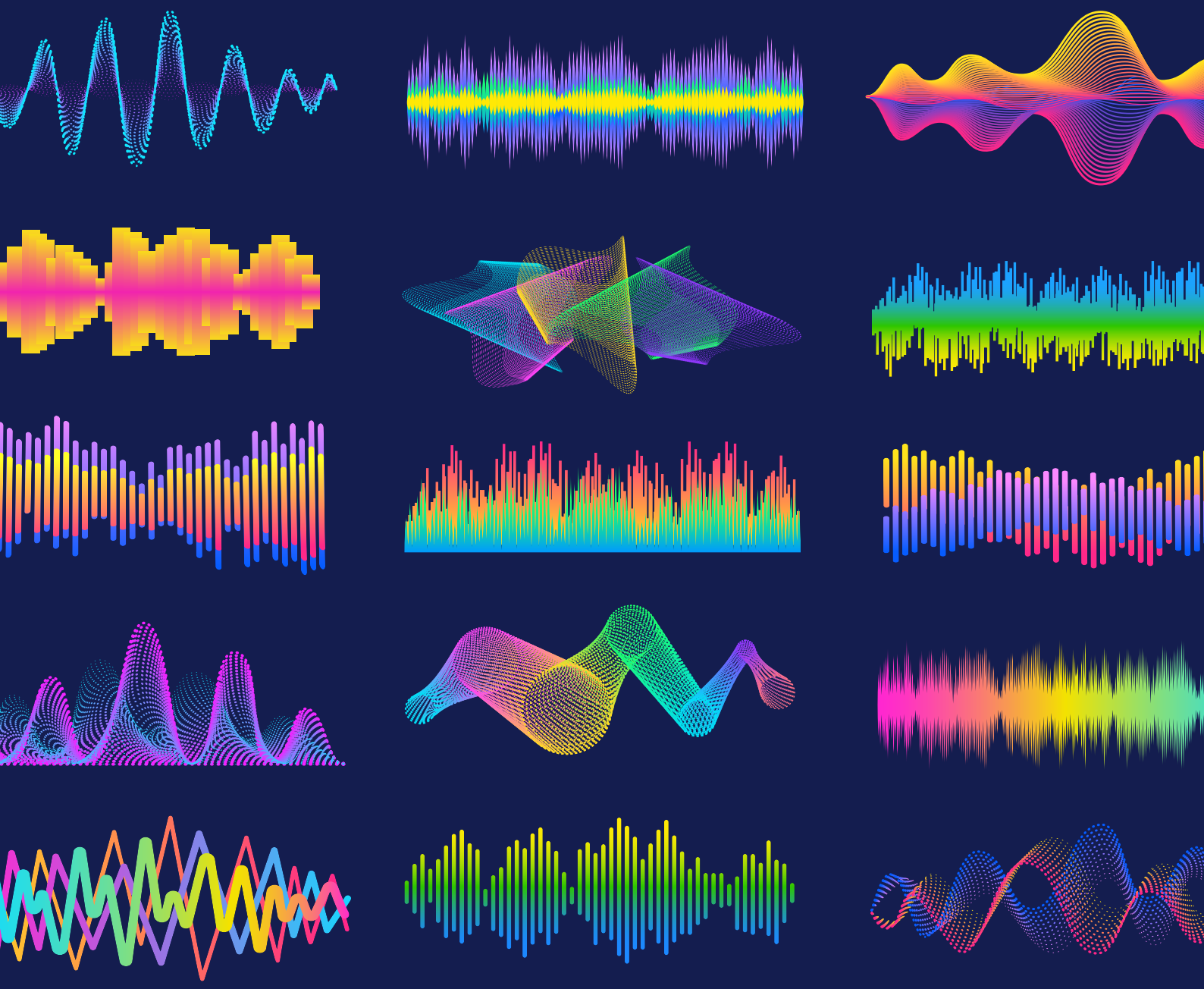
DTU Electrical Engineering
Department of Electrical Engineering
KAIST EE
전기 및 전자공학부

Portable Ultrasound System for Blood Velocity Estimation

Jeppe Hinrichs

Master Thesis



Portable Ultrasound System for Blood Velocity Estimation
Project Report

Master Thesis
April, 2023

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Cover photo: RawPixel, 2022
Published by (1): DTU, Department of Electrical Engineering, Ørsteds Plads, Building 348, 2800 Kgs. Lyngby, Denmark
www.elektro.dtu.dk
Published by (2): KAIST, 전기 및 전자공학부, E3-2, 291 대학로 유성구34141 대전 대한민국
www.ee.kaist.ac.kr
Timespan: Saturday 1st October, 2022—Wednesday 12th April, 2023
Credits: 30 ECTS / 9 credits

Degree: Master of Science
Field: Electrical Engineering

Approval

This thesis has been prepared over six months at the Brain/Biomedical Microsystems Laboratory, School of Electrical Engineering, at the Korean Advanced Institute of Science and Technology, KAIST, and the Department of Electrical Engineering, Technical University of Denmark, DTU. This thesis is in partial fulfilment for the joint-degree Master of Science in Electrical Engineering, MSEE from KAIST and DTU.

It is assumed that the reader has a basic knowledge in the areas of electrical engineering and circuit analysis.

Jeppe Hinrichs - s163555

.....

Signature

.....

Date

Abstract

Abstract

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Resumé

Hej, her er noget tekst uden mening. Denne tekst skal vise, hvordan en trykt tekst vil se ud på dette sted. Hvis du læser denne tekst, får du ingen information. Virkelig? Er der ingen information? Er der forskel på denne tekst og noget nonsens som "Huardest gefburn"? Kjift – slet ikke! En blindtekst som denne giver dig information om den valgte skrifttype, hvordan bogstaverne er skrevet og et indtryk af udseendet. Denne tekst skal indeholde alle bogstaver i alfabetet, og den skal være skrevet på originalsproget. Der er ikke behov for særligt indhold, men længden af ord skal passe til sproget.

요 약

안녕하세요, 여기 의미 없는 문자가 있습니다. 이 텍스트는 이 플레이스에서 인쇄된 텍스트의 모양을 보여줘야 합니다. 이 텍스트를 읽으면 정보를 얻을 수 없습니다. 정말? 정보가 없나요? 이 텍스트와 "Huardest gefburn"과 같은 말도 안 되는 내용 사이에 차이가 있나요? Kjift – 전혀 그렇지 않습니다! 이와 같은 블라인드 텍스트는 선택한 글꼴, 글자의 작성 방법 및 모양에 대한 정보를 제공합니다. 이 텍스트는 알파벳의 모든 문자를 포함해야 하며 원래 언어로 작성되어야 합니다. 특별한 내용은 필요 없지만, 단어의 길이는 언어와 일치해야 합니다.

Contents

List of Figures

List of Tables

Acronyms

Notation	Description
AC	Alternating Current
DC	Direct Current
EMI	Electromagnetic Interference
GCD	Greatest Common Divisor
LCM	Least Common Multiple
MCU	Microcontroller Unit
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
MRI	Magnetic Resonance Imaging
RVS	Reduced Voltage Switching
SMPS	Switched-Mode Power Supply
SNR	Signal-to-Noise Ratio

Glossary

Notation	Description
HIGH	Logic high voltage level
LOW	Logic low voltage level
SPICE	Electronic circuit simulator

Nomenclature

Category	Name	Unit	Description
Preamplifier	V_{ref}	V	Reference voltage
	C_{hp}	F	High pass filter capacitor
	R_{hp}	Ω	High pass filter resistor
	f_{hp}	Hz	High pass cut-off frequency
	C_{lp}	F	Low pass filter capacitor
	R_{lp}	Ω	Low pass filter resistor
	f_{lp}	Hz	Low pass cut-off frequency
	A_v	1	Amplification factor
Modulator	R_1	Ω	AIM voltage divider resistor
	R_2	Ω	AIM voltage divider resistor
	R_{in}	Ω	AIM input resistor
	R_{fb}	Ω	AIM feedback resistor
	C_1	F	AIM capacitor
	V_{in}	V	Input signal voltage
	V_{span}	V	Voltage range of input signal
	V_{pwm}	V	PWM signal
	V_H	V	V_{pwm} high level voltage
	V_L	V	V_{pwm} low level voltage
	V_{out}	V	V_{pwm} voltage range $(V_H - V_L)$
	V_{hys}	V	Hysteresis voltage
	V_{hw}	V	Hysteresis width
	V_{th_H}	V	Hysteresis threshold upper voltage
	V_{th_L}	V	Hysteresis threshold lower voltage
	V_c	V	PWM carrier voltage
	V_{c_H}	V	PWM carrier upper voltage
	V_{c_L}	V	PWM carrier lower voltage
	f_{sw}	Hz	PWM signal frequency
	D	1	PWM signal duty cycle
	t_H	s	PWM carrier charge time
	t_L	s	PWM carrier discharge time
	τ	1	PWM carrier charge constant
	R_{th}	Ω	PWM carrier thevenin resistance
	f_{idle}	Hz	PWM signal idle switching frequency
	k_2	1	R_{fb}, R_{in} voltage divider
Gate driver	D_{dt}	1	Dead-time circuit diode
	R_{dt}	Ω	Dead-time circuit resistor
	C_{dt}	F	Dead-time circuit capacitor
	V_C	V	Dead-time circuit supply voltage
	V_s	V	IC supply voltage
	t_c	s	Charging circuit time
Power stage	V_{DD}	V	Power supply voltage
	Q_1, Q_2, Q_3, Q_4	1	Power stage switches

Category	Name	Unit	Description
	V_g	V	Gate driver signal
	V_o	V	Output voltage
	I_o	A	Output current
	R_{BTL}	Ω	Speaker equivalent load resistance
Output filter	R_f	Ω	Output filter single-ended load
	C_{BTL}	F	Output filter differential capacitance
	C_f	F	Output filter single-ended capacitance
	L_f	H	Output filter inductance
	ΔI_L	A	Output filter ripple current
	Q	1	Output filter quality factor
	f_c	Hz	Output filter cut-off frequency
	ω_n	$\mathrm{rad\,s^{-1}}$	Output filter natural frequency
	ζ	1	Output filter damping ratio
Shunt regulator	R_{sh}	Ω	Shunt current limiting resistor
	I_K	A	Shunt cathode current
	$I_{K_{\max}}$	A	Shunt maximum cathode current
	$I_{K_{\min}}$	A	Shunt minimum cathode current
	I_{su}	A	Shunt supply current
	R_{A1}	Ω	Shunt adjust resistor 1
	R_{A2}	Ω	Shunt adjust resistor 2
	C_L	F	Shunt load capacitance
	$V_{\mathrm{ref_{IC}}}$	V	Shunt internal reference voltage

1 Introduction

The progress of imaging internal organs has advanced significantly during the 20th century. Three major technologies used are X-ray, Magnetic Resonance Imaging (MRI), and ultrasound. Each of the technologies have distinct advantages and disadvantages in biomedical imaging, thus are still relevant for modern medicine. With x-rays, an important drawback is that patients are exposed to ionizing radiation [1], [4], [5], [7] [3], [6] This template complies with the DTU Design Guide https://www.designguide.dtu.dk/. DTU holds all rights to the design program including all copyrights. It is intended for two-sided printing. The `\cleardoublepage` command can be used to ensure that new sections and the table of contents begins on a right-hand page. The back page always ends as an odd page. [2]

All document settings have been collected in Setup/Settings.tex. These are global settings, meaning the settings will affect the whole document. Defining the title for example will change the title on the front page, the copyright page, and the footer. A watermark can be enabled or disabled in Setup/Premeable.tex. You can edit the watermark to display draft, review, approve, confidential, or anything else. By default, the watermark is printed on top of the document's contents and has a transparent gray color. Here I am just testing the synchronization functionality of Overleaf and Github. Now, that the first synchronization finished successfully, I want to test that the reverse direction process is also functional. Hopefully, this will end up on Overleaf.

1.1 This is a section

Every chapter is numbered and the sections inherit the chapter number followed by a dot and a section number. Figures, equations, tables, etc. also inherit the chapter numbering.

1.1.1 This is a sub section

Sub-sections are also numbered. In general, try not to use a deep hierarchy of sub-sections (`\paragraph{}` and the like). The document will become segmented, which will make the document appear less coherent.

This is a sub sub section

And those are not numbered. It is possible to adjust the deep hierarchy of numbering sections in Setup/Settings.tex.

The front and back cover has been made to replicate the examples in the design guide https://www.designguide.dtu.dk/#stnd-printmedia. The name of department heading is omitted because it is located in the top right corner (no need to write it twice). Take a look at https://www.inside.dtu.dk/en/medarbejder/om-dtu-campus-og-bygninger/kommunikation-og-design/skabeloner/rapporter if you want to make your cover separately.

Citing is done with the `biblatex` package [3]. Cross referencing (figures, tables, etc.) is taken care by the `cleveref` package. Just insert the name of the label in `\cref{}` and it will automatically format the cross-reference. For example, writing the `cleveref` command `\cref{fig:groupedcolumn}` will output "fig. 3.3". Using `\Cref{}` will capitalize the first letter and `\crefrange{}{}` will make a reference range. An example: Figure 3.2 is an example of a stacked bar chart and figs. 3.1 to 3.3 are three consecutive figures.

1.2 Font and symbols test

Symbols can be written directly in the document, meaning that there is no need for special commands to write special characters. I love to write special characters like æøå inside my TEX document. Also á, à, ü, û, ë, ê, î, ï could be nice. So what about the "£" character. What about ř é ő † ě ü | œ ‘ @ ö ä ň ń ľ SS ł ⋯ ç ñ ţ ů ą “ č ™ [ ] ’. Some dashes - – —, and the latex form - – —

This is a font test
Arial Regular

MRI, Signal-to-Noise Ratio (SNR), Switched-Mode Power Supply (SMPS), Reduced Voltage Switching (RVS), Alternating Current (AC), Direct Current (DC), Electromagnetic Interference (EMI), Greatest Common Divisor (GCD), Least Common Multiple (LCM)
HIGH, LOW, SPICE

I want to talk about SPICE, HIGH and LOW. These are all DC and AC electric principles. I want to mention that Metal-Oxide-Semiconductor Field-Effect Transistor devices can be called MOSFET.

1.3 Tikz Test

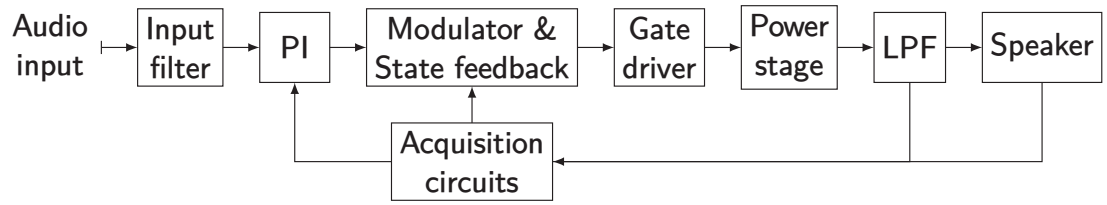

Figure 1.1: Simple overview of the system

I like to talk about logic systems and their binary states. Such as HIGH and LOW. These are also important in SPICE simulation systems.

I like to explain abbreviations such as MOSFET. This abbreviation stands for Metal-Oxide-Semiconductor Field-Effect Transistor. I like this paper [11]. Two datasheets [8], [9]

2 Colours

The design guide define 3 primary colours (dtured, white and black) and 10 secondary colours https://www.designguide.dtu.dk/#stnd-colours. Below are codes for the various colour modes. RGB is used for web and Office Programmes. CMYK is used for print. HTML is used for HTML-coding. If you know anything about colour codes you might notice that the RGB codes are ranging from 0-1 instead of the usual 0-255.

color	rgb	cmyk	HTML
dtured	0.77 0 0.05	0 0.91 0.72 0.23	C4000D
white	1 1 1	0 0 0 0	FFFFFF
black	0 0 0	0 0 0 1	000000
blue	0.12 0.24 1	0.88 0.76 0 0	1F3DFF
brightgreen	0.31 1 0.34	0.69 0 0.66 0	4FFF57
navyblue	0 0 0.4	1 0.9 0 0.6	000066
yellow	0.95 0.83 0.18	0.05 0.17 0.82 0	F2D42E
orange	1 0.35 0.14	0 0.65 0.86 0	FF5924
pink	1 0.65 0.74	0 0.35 0.26 0	FFA6BD
red	1 0.14 0.35	0 0.86 0.65 0	FF2459
green	0 0.78 0	0.89 0.05 1 0.17	00C700
purple	0.33 0.04 1	0.67 0.96 0 0	540AFF

The default colour mode for this template is cmyk. The current colour model is cmyk which is also illustrated by the underlined numbers in the colour test table above. If you which to change the colour model to rgb go to Setup/Settings.tex and change `targetcolourmodel` to rgb. In Setup/Settings.tex it is also possible to change the background colour of the front and back page. The colours are primarily used for diagrams (the plotcyclelist DTU) and the front and back page.

Lighter colours can be achieved as written in the LaTeX code below. For example to get a tint of 50% you would write colourname!50.

Normal dtured 80% dtured 70% dtured 60% dtured 50% dtured

For more information about colours in LaTeX read the `xcolor` manual. I want to use the MCU [10] for the MCU part of the project. Microcontroller Unit (MCU)

3 Examples of figures, tables, equations and listings

In the following a bunch of examples of figures and tables have been made. There are advantages to using `tikZ` diagrams over excel diagrams. 1) the font and font size perfectly matches the document 2) the styling and colours are pre-defined to follow the design guide 3) the plots uses vector graphics which reduces the file size, reduces the compile time and looks sharp when zooming in. The possibilities are endless, look at the `pgfplots` gallery for inspiration: http://pgfplots.sourceforge.net/gallery.html. However there are still cases where I would recommend to insert a plot as a picture. For example if the plot contains a lot of data: a line graph with 1000 points takes a long time to compile.

Some tips if you want good looking diagrams or graphs which will be inserted as pictures (e.g. in a figure environment with \includegraphics): The main font is Arial. Use DTU colours as described in chapter 2. Use high quality pictures. Try to scale the diagram (picture) so the text size of the axis legends match the text size in this document.

Remember to change the label of your figures so there are no duplicate labels. A label should be placed below a caption or after a heading (fx after a \chapter).

3.1 Graphs and charts

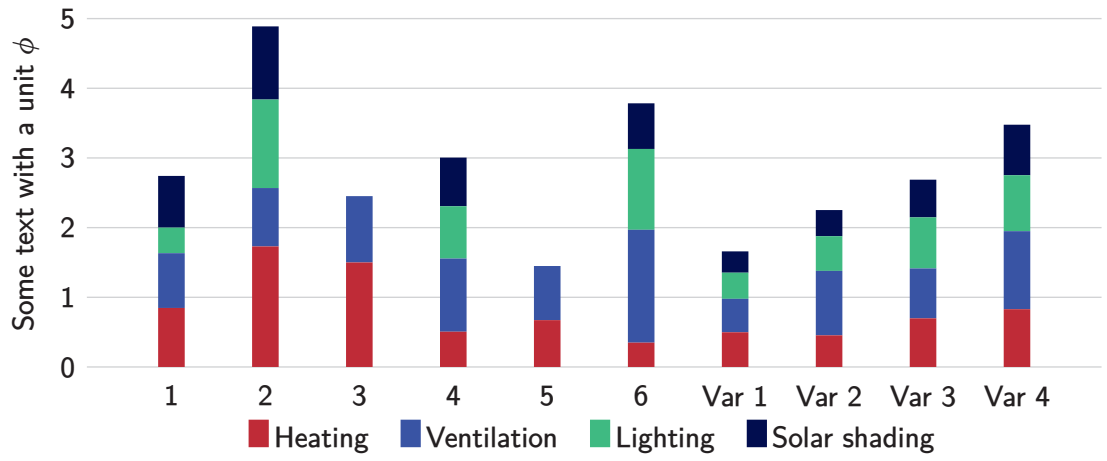

Figure 3.1: Stacked column chart

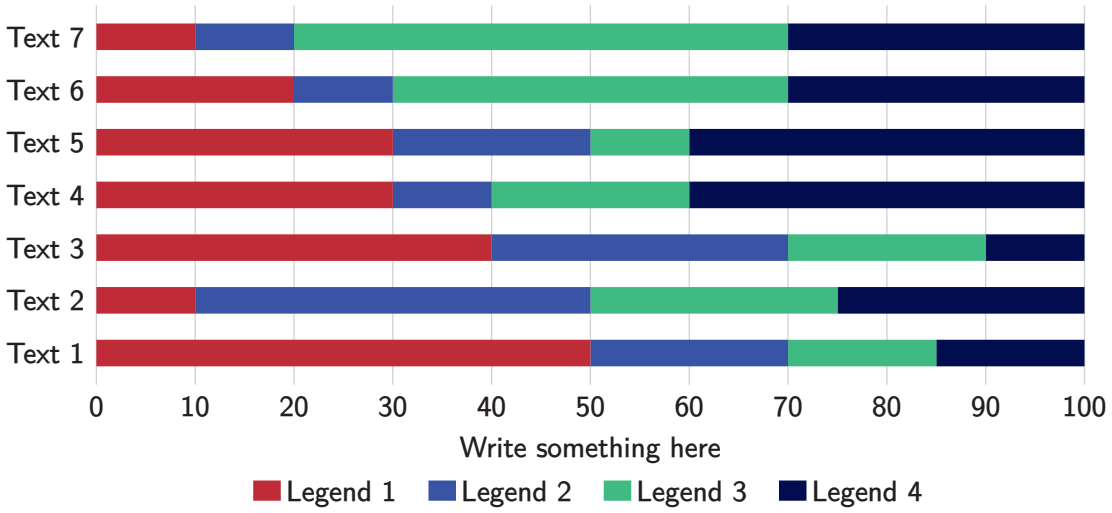

Figure 3.2: Stacked bar chart

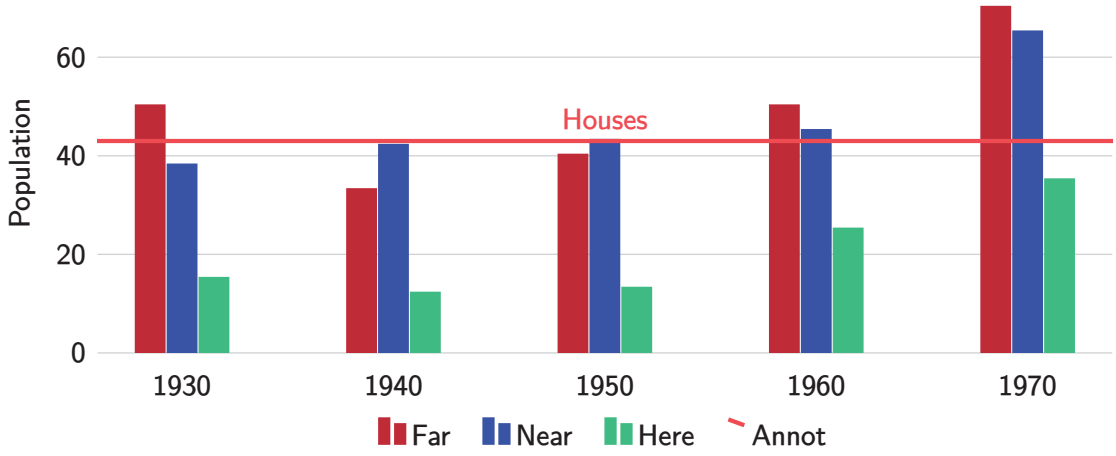

Figure 3.3: Grouped column chart

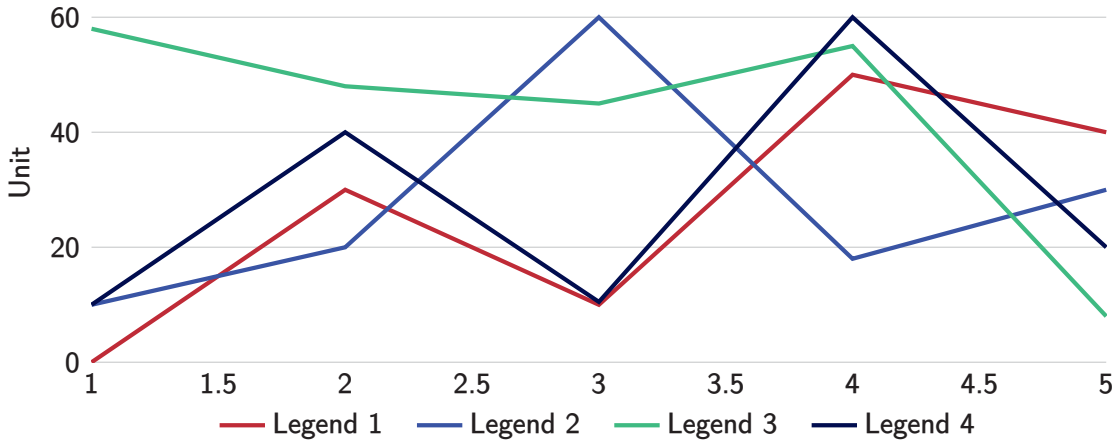

Figure 3.4: Line graph

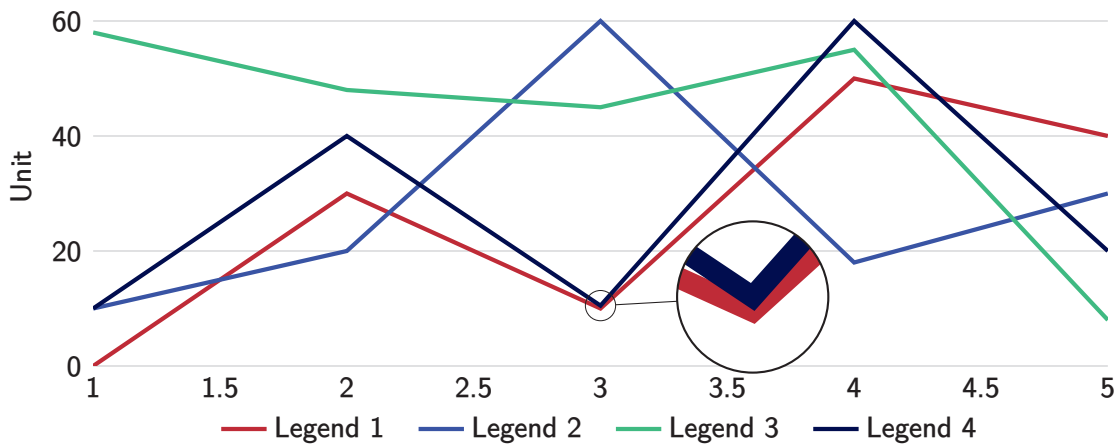

Figure 3.5: Line graph with magnifying glass

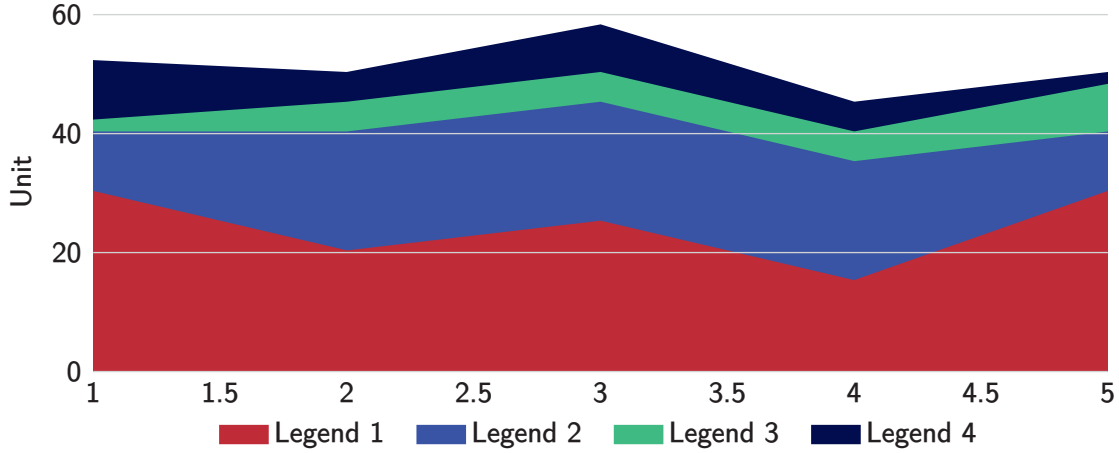

Figure 3.6: Area graph

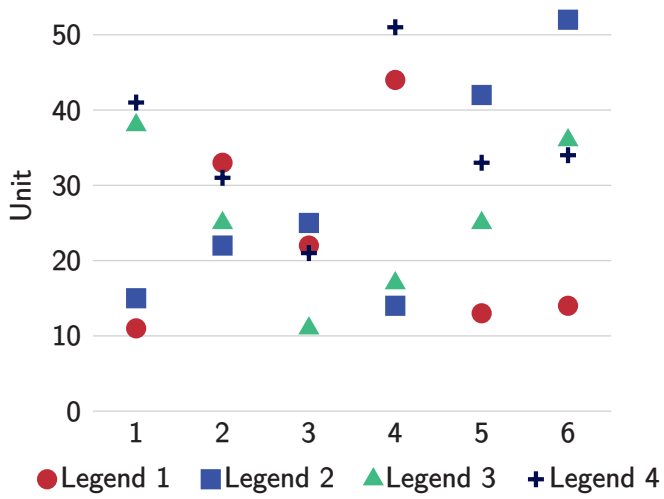

Figure 3.7: Scatter plot

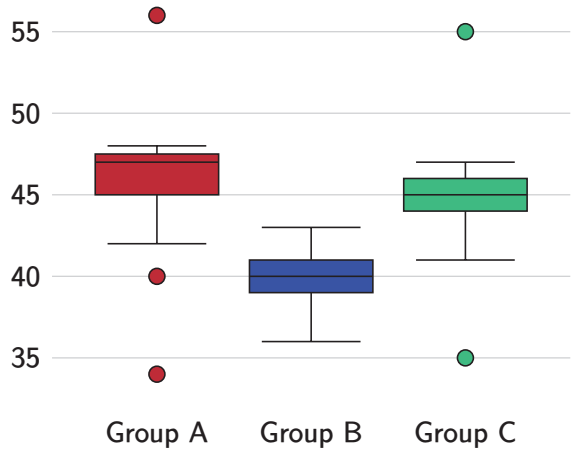

Figure 3.8: Boxplot

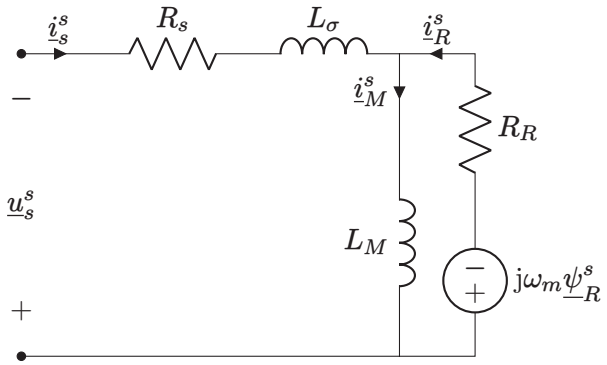

Figure 3.9: The nodes short, V, R and L are presented here, but there a lot more

3.2 Tables and figures

Table 3.1: This is a `booktabs` table

Animal	Description	Price ($)
Gnat	per gram	13.65
	each	0.01
Gnu	stuffed	92.50
Emu	stuffed	33.33
Armadillo	frozen	8.99

`Booktabs` tables don't use any vertical lines. Only horizontal lines are used. Table 3.1 begins with a `\toprule`, ends with a `\bottomrule` with `\midrule` in between. The table has 3 columns formatted as `@{}llS@{}`. `@{}` is cropping the horizontal lines of the table to fit the content (removes column spacing at the left and right edges). `l` aligns the column to the left and `S` aligns the column according to the decimal point (`siunitx` package). You can of course also use `r` to align right or `c` to center the contents of the column.

Table 3.2: Wrongly formatted table

	Voltage V	Current A	Power W
Transformer input	234.4	0.50	117.4
Transformer output	25.86	2.72	70.3
Efficiency			60%

Table 3.3: Correctly formatted table

	Voltage V	Current A	Power W
Transformer input	234.4	0.50	117.4
Transformer output	25.86	2.72	70.3
Efficiency			60 %

Table 3.2 and table 3.3 have the same comtents but there are some subtle differences in formatting which makes table 3.3 the superior table of the two. The most obvious change is removing the midrule between the transformer input and output rows. The efficency row is the odd man out and a midrule has been used to emphasise the difference between the transformer rows and the efficiency row. The delimiters in the voltage, current and power columns are aligned. The horizontal lines (rules) fits to the content and instead of protruding. The spacing between 60 and the percentage sign is correctly adjusted.

Figure 3.10: Just a normal figure

(a) A subfigure

(b) A subfigure

Figure 3.11: A figure with two subfigures

(a) A subfigure

(b) A subfigure

(c) A subfigure

(d) A subfigure

Figure 3.12: A figure with four subfigures

Referring to the figure as a whole fig. 3.12 or to an individual sub figure fig. 3.12a is done the normal way with `\cref{}` commands.

3.3 Equations

In-line math is easy. Anything surrounded by dollar signs becomes a math field. Here is an example: $f(x) = 2x - 1$. Also anything inside the "\begin{equation}" and "\end{equation}" environment is also a math field. Examples are shown below.

All equations use the default latex font. Some might say it looks weird with a serif font for equations and a sans-serif font for the body text. However, it is very unpractical to change the math font in latex which is the exactly the reason why this has not been done. One benefit of the serif style math font is the clear distinction between symbols (variables) and units.

On the subject of units, those are all taken care of by the `siunitx` package. Whenever there is a number followed by a unit one should write \SI{number}{unit}. Note this command is case sensitive. If a unit should follow a variable use the command \si{unit} (also case sensitive).

The ideal gas law is shown in eq. (3.1).

$$p \cdot V = n \cdot R \cdot T \tag{3.1}$$

$$\frac{\partial}{\partial t} \int_0^\delta U dy = -\delta \frac{1}{\rho} \frac{\partial P}{\partial x} - U_f(t)^2 \tag{3.2}$$

$$d_{step} = \sqrt{\frac{\delta}{\frac{dw}{dp_v}} \cdot t} = \sqrt{\frac{1.0 \times 10^{-11}\,\mathrm{kg/(m\,s\,Pa)}}{\frac{5.4\,\mathrm{kg/m^3}}{233.82\,\mathrm{Pa}}} \cdot 7200\,\mathrm{s}} = 0.001\,766\,\mathrm{m} = 1.766\,\mathrm{mm} \tag{3.3}$$

$$x = \mathrm{x}, \mathrm{x}, \mathrm{x}, x_{1_{2_{3_4}}}^{1^{2^{3^4}}} \cdot hello * \text{hello world} \cdot \text{equation without number}$$

Notice how the `aligned` environment can be used to align the equilibrium arrows in eq. (3.4). Only one equation number is generated using this method. Alternatively if you want an equation number for each line see eqs. (3.5) to (3.6).

$$\begin{aligned} CH_3COOH + OH^- &\rightleftharpoons CH_3COO^- + H_2O \\ H_2O &\rightleftharpoons H^+_{(aq)} + OH^-_{(aq)} \end{aligned} \tag{3.4}$$

$$f(x) = 1 + x - 3x^2 \tag{3.5}$$

$$g(x) + y = 3x - \frac{1}{2}x^3 \tag{3.6}$$

3.4 Listings (code)

Listing 3.1 is a nicely formatted block of code. A listing will automatically continue on the next page if it encounters a page break. Many different programming languages can be highlighted. Check the `listings` package documentation for a list of supported programming languages.

```
%% Monte Carlo simulation, estimation of pi
m=1E7;

x=rand(m,1);
y=rand(m,1);

g = x.^2+y.^2-1;

%dots outside
Pf = sum((g)<=0)/m

pi = 4*Pf
```

Listing 3.1: Monte Carlo simulation to estimate the value of π

Bibliography

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A Title

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