

Improving the coherence time of superconduct- ing qubits by de- sign

A procedure to cal-
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tion ratios

R.A. Koster

Cover Text

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spanning multiple lines

ISBN 000-00-0000-000-0

Improving the coherence time of superconducting qubits by design

A procedure to calculate participation ratios

by

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to obtain the degree of Bachelor of Science
at the Delft University of Technology,
to be defended publicly on Tuesday January 1, 2013 at 10:00 AM.

Student number:	4110749
Project duration:	March 1, 2012 – January 1, 2013
Thesis committee:	Prof. dr. ir. J. Doe, TU Delft, supervisor
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This thesis is confidential and cannot be made public until December 31, 2013.

An electronic version of this thesis is available at <http://repository.tudelft.nl/>.

Preface

Preface...

R.A. Koster
Delft, January 2016

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Introduction

This document is intended to be both an example of the TU Delft \LaTeX template for reports and theses, as well as a short introduction to its use. It is not intended to be a general introduction to \LaTeX itself,¹ and we will assume the reader to be familiar with the basics of creating and compiling documents.

Instructions on how to use this template under Windows and Linux, and which \LaTeX packages are required, can be found in `README.txt`.

Document Structure

Since a report, and especially a thesis, might be a substantial document, it is convenient to break it up into smaller pieces. In this template we therefore give every chapter its own file. The chapters (and appendices) are gathered together in `report.tex`, which is the master file describing the overall structure of the document. `report.tex` starts with the line

```
\documentclass{tudelft-report}
```

which loads the TU Delft report template. The template is based on the \LaTeX book document class and stored in `tudelft-report.cls`. The document class accepts several comma-separated options. The default language is English, but this can be changed to Dutch (e.g., for bachelor theses) by specifying the `dutch` option:

```
\documentclass[dutch]{tudelft-report}
```

Furthermore, hyperlinks are shown in blue, which is convenient when reading the report on a computer, but can be expensive when printing. They can be turned black with the `print` option. This will also turn the headers black instead of cyan.

If the document becomes large, it is easy to miss warnings about the layout in the \LaTeX output. In order to locate problem areas, add the `draft` option to the `\documentclass` line. This will display a vertical bar in the margins next to the paragraphs that require attention. Finally, the `nativefonts` option can be used to override the automatic font selection (see below).

This template has the option to automatically generate a cover page with the `\makecover` command. See the next section for a detailed description.

The contents of the report are included between the `\begin{document}` and `\end{document}` commands, and split into three parts by

1. `\frontmatter`, which uses Roman numerals for the page numbers and is used for the title page and the table of contents;
2. `\mainmatter`, which uses Arabic numerals for the page numbers and is the style for the chapters;
3. `\appendix`, which uses letters for the chapter numbers, starting with 'A'.

¹We recommend <http://en.wikibooks.org/wiki/LaTeX> as a reference and a starting point for new users.

The title page is defined in a separate file, *e.g.*, `title.tex`, and included verbatim with `\input{title}`.² Additionally, it is possible to include a preface, containing, for example, the acknowledgements. An example can be found in `preface.tex`. The table of contents is generated automatically with the `\tableofcontents` command. Chapters are included after `\mainmatter` and appendices after `\appendix`. For example, `\input{chapter-1}` includes `chapter-1.tex`, which contains this introduction.

The bibliography, finally, is generated automatically with

```
\bibliography{report}
```

from `report.bib`. The bibliography style is specified in `tudelft-report.bst`, which is a modified version of `apsrev4-1.bst` (from REVTeX) designed to also display the titles of referenced articles. The template will automatically generate clickable hyperlinks if a URL or DOI (digital object identifier) is present for the reference. As an example, we cite the paper by Nobel laureate Andrei Geim and his pet hamster [1]. Although it is possible to manage the bibliography by hand, we recommend using EndNote (available from Blackboard) or JabRef (available from <http://jabref.sourceforge.net/>).

Cover and Title Page

This template will automatically generate a cover page if you issue the `\makecover` command. There are two formats for the cover page: one with a page-filling ('bleeding') illustration, with the title(s) and author(s) in large ultrathin typeface, and the other where the illustration fills the lower half of the A4, whereas title(s), author(s) and additional text are set in the standard sans-serif font on a plain background with a color chosen by the user. The last option is selected by the optional key `split`: `\makecover[split]` yields a page with the illustration on the lower half. All illustrations are bleeding, in accordance with the TU Delft style.

Before generating the cover, you need to provide the information to put on it. This can be done with the following commands:

- `\title[Optional Color]{Title}`
This command is used to provide the title of the document. The title title is also printed on the spine. If you use a title page (see below), this information will be used there as well. As the title, subtitle and author name are printed directly over the cover photo, it will often be necessary to adjust the print color in order to have sufficient contrast between the text and the background. The optional color argument is used for this.
- `\title[Optional Color]{Subtitle}`
This command is used to provide a subtitle for the document. If you use a title page (see below), this information will be used there as well. It possible to adjust the print color in order to have sufficient contrast between the text and the background – the optional color argument is used for this.
- `\author{J. Random Author}`
This command specifies the author. The default color is `tudelft-white`, but this may be adjusted in the same way as the titles.
- `\affiliation{Technische Universiteit Delft}`
The affiliation is the text printed vertically on the front cover. It can be the affiliation, such as the university or department name, or be used for the document type (*e.g.*, Master's thesis). The default color is again `tudelft-white`, adjustable through the color option.
- `\coverimage{cover.jpg}`
With this command you can specify the filename of the cover image. The image is stretched to fill the full width of the front cover (including the spine if a back cover is present).
- `\covertext{Cover Text}`
If a back cover is present, the cover text is printed on the back. Internally, this text box is created using the \LaTeX minipage environment, so it supports line breaks.
- `\titleoffsetx{OffsetX}, \titleoffsety{OffsetY}` If the cover page contains a page-filling picture (*i.e.*, `split` is not specified with the `makecover` command, the best position of the title depends

²Note that it is not necessary to specify the file extension.

a lot on the picture chosen for it. The lower left corner of the minipage containing title, subtitle and author is specified by these two commands. The offsets are measured from the top left corner of the page.

- `\afiloffsetx{AfilX}`, `\afiloffsety{AfilY}` specifies the lower left corner of the text containing the affiliation, measured from the top left corner of the page.

In addition to `[split]`, the `\makecover` command accepts several additional options for customizing the layout of the cover. The most important of these is `back`. Supplying this option will generate a back cover as well as a front, including the spine. Since this requires a page size slightly larger than twice A4 (to make room for the spine), and \LaTeX does not support different page sizes within the same document, it is wise to create a separate file for the cover. `cover.tex` contains an example. The recommended page size for the full cover can be set with

```
\geometry{papersize={1226bp,851bp}}
```

after the document class and before `\begin{document}`.

The other options `\makecover` accepts are

- `nospine`
If a back cover is generated, the title will also be printed in a black box on the spine. However, for smaller documents the spine might not be wide enough. Specifying this option disables printing the title on the spine.
- `frontbottom`
By default the black box on the front is situated above the blue box. Specifying this option will place the black box below the blue one.
- `spinewidth`
If a back cover is present, this option can be used to set the width of the spine. The default is `spinewidth=1cm`.
- `frontboxwidth`, `frontboxheight`, `backboxwidth`, `backboxheight`
As their names suggest, these options are used to set the width and height of the front (black) and back (blue) boxes. The default widths and heights are `4.375in` and `2.1875in`, respectively.
- `x`, `y`
The blue and black boxes touch each other in a corner. The location of this corner can be set with these options. It is defined with respect to the top left corner of the front cover. The default values are `x=0.8125in` and `y=3in`.
- `margin`
This option sets the margin between the borders of the boxes and their text. The default value is `12pt`.

For a thesis it is desirable to have a title page within the document, containing information like the thesis committee members. To give you greater flexibility over the layout of this page, it is not generated by a command like `\makecover`, but instead described in the file `title.tex`. Modify this file according to your needs. The example text is in English, but Dutch translations are provided in the comments. Note that for a thesis, the title page is subject to requirements which differ by faculty. Make sure to check these requirements before printing.

Chapters

Each chapter has its own file. For example, the \LaTeX source of this chapter can be found in `chapter-1.tex`. A chapter starts with the command

```
\chapter{Chapter title}
```

This starts a new page, prints the chapter number and title and adds a link in the table of contents. If the title is very long, it may be desirable to use a shorter version in the page headers and the table of contents. This can be achieved by specifying the short title in brackets:

```
\chapter[Short title]{Very long title with many words which could not possibly
fit on one line}
```

Unnumbered chapters, such as the preface, can be created with `\chapter*{Chapter title}`. Such a chapter will not show up in the table of contents or in the page header. To create a table of contents entry anyway, add

```
\addcontentsline{toc}{chapter}{Chapter title}
```

after the `\chapter` command. To print the chapter title in the page header, add

```
\setheader{Chapter title}
```

Chapters are subdivided into sections, subsections, subsubsections, and, optionally, paragraphs and subparagraphs. All can have a title, but only sections and subsections are numbered. As with chapters, the numbering can be turned off by using `\section*{...}` instead of `\section{...}`, and similarly for the subsection.

`\section{...}`

`\subsection{...}`

`\subsubsection{...}`

`\paragraph{...}` Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

Fonts and Colors

The fonts used by this template depend on which version of \TeX you use. Regular \TeX , *i.e.*, if you compile your document with `latex`, `pslatex` or `pdflatex`, will use Utopia for text, Fourier for math and Latin Modern for sans-serif and monospaced text. However, if you want to adhere to the TU Delft house style, you will need to use \XeTeX , as it supports TrueType and OpenType fonts. Compiling with `xelatex` will use Arial for most titles and text, Courier New for monospace and Cambria for math. If you want to have a sans-serif font for the main text, while using `latex`, `pslatex` or `pdflatex`, you can use the option `noroman` in the report style: `\usepackage[... ,noroman]{tudelft-report}`. For document and part titles, TU Delft Ultra Light is used. For quotes, columns and text in boxes, you use Georgia. If you want to use \XeTeX , but do not want to use the TU Delft house style fonts, you can add the `nativefonts` option to the document class. This will still use TU Delft Ultra Light and Arial on the cover, but not for the body of the document. If you need to use these fonts for certain sections in the main text, they are available via `\tudrmfamily` (Georgia) and `\tudtitlefamily` (TU Delft Ultra Light).

You have to learn the rules of the game. And then you have to play better than anyone else.

Albert Einstein

The corporate colors of the TU Delft are cyan, black and white, available via `\color{tudelft-cyan}`, `\color{tudelft-black}` (which differs slightly from the default `\color{black}`) and `\color{tudelft-white}`, respectively. Apart from these three, the house style defines the basic colors `tudelft-sea-green`, `tudelft-green`, `tudelft-dark-blue`, `tudelft-purple`, `tudelft-turquoise` and `tudelft-sky-blue`, as well as the accent colors `tudelft-lavendel`, `tudelft-orange`, `tudelft-warm-purple`, `tudelft-fuchsia`, `tudelft-bright-green` and `tudelft-yellow`.

2

Theory

The quantum bit

A quantum bit, often called qubit, is...

The transmon qubit

The qubit under investigation during this project is the so called transmon qubit.

LC-circuits

The transmon qubit can be treated as a simple LC-circuit.

Energy in an LC-circuit

The total energy stored in an LC-circuit at any time can be calculated as follows:

$$W = \frac{1}{2} CV^2 \quad (2.1)$$

Electric fields

Perfect Electric Conductor

As the qubit is supercooled to temperatures of only a few mK, the metal in the qubit is treated as a Perfect Electric Conductor (PEC).

Continuity rules

Stored energy

The energy stored in the Electric field in a material can be calculated using equation (2.2)

$$W = \frac{\epsilon}{2} \int |E|^2 dV \quad (2.2)$$

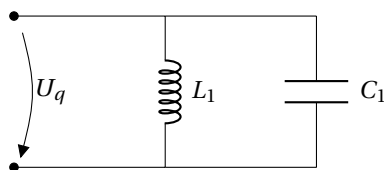


Figure 2.1: A simple parallel LC-circuit

Sources of decoherence

In order for the qubit to be coherent . . . The source in question during this project is the layers of lossy material in the system.

Lossy materials

During production of qubits, different procedures introduce lossy materials to the structure.

Two-Level Systems

The participation ratio

In order to determine what kind of structure design may improve coherence time the participation ratio of lossy layers can be calculated. If the assumption is made that the Electric field remains constant inside the lossy layer equation (2.2) can be rewritten as follows:

$$W = \frac{\epsilon}{2} t \int |E|^2 dA \quad (2.3)$$

Where ϵ is the permittivity of the material and t is the thickness of the lossy layer. Furthermore, A is the surface area of the lossy layer.

Bibliography

- [1] A. K. Geim and H. A. M. S. ter Tisha. Detection of earth rotation with a diamagnetically levitating gyroscope. *Physica B: Condensed Matter*, 294–295:736–739, 2001. doi: 10.1016/S0921-4526(00)00753-5.