

Single Core Design Space Exploration

ECE 568: Advanced Microprocessor Architecture, Spring 2016

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ABSTRACT

This paper seeks to find the best single core superscalar architecture for a given benchmark application by experimenting with different architectures for branch prediction, memory systems, functional units, data path, and other areas. The metrics used to define the “best” architecture are *performance* as instructions per cycle (IPC) and *performance-energy* as the energy delay product (EDP).

1. INTRODUCTION

This study evaluates a single core superscalar architecture using the SimpleScalar simulator suite, seeking the best configuration for the **eeg** benchmark application. A base architecture was given, and design modifications were then made in four groups, branch prediction, memory system, functional units, and data path. In the first phase of design space exploration, tuning one parameter at a time. In the second stage, closely related parameters within the same groups are tuned together. Finally, the best configurations across groups are combined to formulate the best found architecture. For each configuration we observe performance (IPC) and performance-energy (EDP), calculated as $(CPI * energy/cycle) * CPI$. The “best” configuration seeks to maximize performance, and minimize performance-energy.

2. SIMULATION

Simulations of the **eeg** application benchmark were performed using **sim-outorder**. The base configuration had performance of 1.5226 IPC, and a performance-energy product of 219.68. While many parameter changes were tested, unless otherwise noted, all graphs that follow show only configurations that outperformed the base configuration in at least one of these metrics.

To gain some direction in performance tuning, the instruction profile for the benchmark was first evaluated using **sim-profile**. As shown in table 1, the benchmark is primarily an integer program. Given this instruction breakdown, most

Table 1: Instruction Profile for eeg

Type	Count	Percent
load	171,182,879	20.30
store	84,069,724	9.97
uncond branch	60,740,822	7.20
cond branch	59,922,458	7.11
int computation	335,861,146	39.84
fp computation	131,306,086	15.57
trap	1,035	0.00

of the performance tuning was focused on branch prediction and the memory system.

2.1 Branch Prediction

btb-128-2 wins.

2.2 Type Changes and *Special Characters*

We have already seen several typeface changes in this sample. You can indicate italicized words or phrases in your text with the command `\textit`; emboldening with the command `\textbf` and typewriter-style (for instance, for computer code) with `\texttt`. But remember, you do not have to indicate typestyle changes when such changes are part of the *structural* elements of your article; for instance, the heading of this subsection will be in a sans serif¹ typeface, but that is handled by the document class file. Take care with the use of² the curly braces in typeface changes; they mark the beginning and end of the text that is to be in the different typeface.

You can use whatever symbols, accented characters, or non-English characters you need anywhere in your document; you can find a complete list of what is available in the *L^AT_EX User's Guide*[?].

2.3 Math Equations

You may want to display math equations in three distinct styles: inline, numbered or non-numbered display. Each of the three are discussed in the next sections.

2.3.1 *Inline (In-text) Equations*

A formula that appears in the running text is called an inline or in-text formula. It is produced by the **math** environment, which can be invoked with the usual `\begin`. .

¹A third footnote, here. Let's make this a rather short one to see how it looks.

²A fourth, and last, footnote.

.\end construction or with the short form \$. . . \$. You can use any of the symbols and structures, from α to ω , available in L^AT_EX[?]; this section will simply show a few examples of in-text equations in context. Notice how this equation: $\lim_{n \rightarrow \infty} x = 0$, set here in in-line math style, looks slightly different when set in display style. (See next section).

2.3.2 Display Equations

A numbered display equation – one set off by vertical space from the text and centered horizontally – is produced by the **equation** environment. An unnumbered display equation is produced by the **displaymath** environment.

Again, in either environment, you can use any of the symbols and structures available in L^AT_EX; this section will just give a couple of examples of display equations in context. First, consider the equation, shown as an inline equation above:

$$\lim_{n \rightarrow \infty} x = 0 \quad (1)$$

Notice how it is formatted somewhat differently in the **displaymath** environment. Now, we'll enter an unnumbered equation:

$$\sum_{i=0}^{\infty} x + 1$$

and follow it with another numbered equation:

$$\sum_{i=0}^{\infty} x_i = \int_0^{\pi+2} f \quad (2)$$

just to demonstrate L^AT_EX's able handling of numbering.

2.4 Citations

Citations to articles [?, ?, ?, ?], conference proceedings [?] or books [?, ?] listed in the Bibliography section of your article will occur throughout the text of your article. You should use BibTeX to automatically produce this bibliography; you simply need to insert one of several citation commands with a key of the item cited in the proper location in the .tex file [?]. The key is a short reference you invent to uniquely identify each work; in this sample document, the key is the first author's surname and a word from the title. This identifying key is included with each item in the .bib file for your article.

The details of the construction of the .bib file are beyond the scope of this sample document, but more information can be found in the *Author's Guide*, and exhaustive details in the *L^AT_EX User's Guide*[?].

This article shows only the plainest form of the citation command, using \cite. This is what is stipulated in the SIGS style specifications. No other citation format is endorsed or supported.

2.5 Tables

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper “floating” placement of tables, use the environment **table** to enclose the table's contents and the table caption. The contents of the table itself must go in the **tabular** environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules. Again, detailed instructions on **tabular** material is found in the *L^AT_EX User's Guide*.

Table 2: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
\$	4 in 5	Used in business
Ψ ₁ ²	1 in 40,000	Unexplained usage

Immediately following this sentence is the point at which Table 1 is included in the input file; compare the placement of the table here with the table in the printed dvi output of this document.

To set a wider table, which takes up the whole width of the page's live area, use the environment **table*** to enclose the table's contents and the table caption. As with a single-column table, this wide table will “float” to a location deemed more desirable. Immediately following this sentence is the point at which Table 2 is included in the input file; again, it is instructive to compare the placement of the table here with the table in the printed dvi output of this document.

2.6 Figures

Like tables, figures cannot be split across pages; the best placement for them is typically the top or the bottom of the page nearest their initial cite. To ensure this proper “floating” placement of figures, use the environment **figure** to enclose the figure and its caption.

This sample document contains examples of .eps files to be displayable with L^AT_EX. If you work with pdfL^AT_EX, use files in the .pdf format. Note that most modern T_EX system will convert .eps to .pdf for you on the fly. More details on each of these is found in the *Author's Guide*.

2.7 Theorem-like Constructs

Other common constructs that may occur in your article are the forms for logical constructs like theorems, axioms, corollaries and proofs. There are two forms, one produced by the command \newtheorem and the other by the command \newdef; perhaps the clearest and easiest way to distinguish them is to compare the two in the output of this sample document:

This uses the **theorem** environment, created by the \newtheorem command:

THEOREM 1. *Let f be continuous on $[a, b]$. If G is an antiderivative for f on $[a, b]$, then*

$$\int_a^b f(t)dt = G(b) - G(a).$$

The other uses the **definition** environment, created by the \newdef command:

Definition 1. If z is irrational, then by e^z we mean the unique number which has logarithm z :

$$\log e^z = z$$

Two lists of constructs that use one of these forms is given in the *Author's Guidelines*.

There is one other similar construct environment, which is already set up for you; i.e. you must *not* use a \newdef command to create it: the **proof** environment. Here is a example of its use:

Table 3: Some Typical Commands

Command	A Number	Comments
<code>\alignauthor</code>	100	Author alignment
<code>\numberofauthors</code>	200	Author enumeration
<code>\table</code>	300	For tables
<code>\table*</code>	400	For wider tables

PROOF. Suppose on the contrary there exists a real number L such that

$$\lim_{x \rightarrow \infty} \frac{f(x)}{g(x)} = L.$$

Then

$$l = \lim_{x \rightarrow c} f(x) = \lim_{x \rightarrow c} \left[g(x) \cdot \frac{f(x)}{g(x)} \right] = \lim_{x \rightarrow c} g(x) \cdot \lim_{x \rightarrow c} \frac{f(x)}{g(x)} = 0 \cdot L = 0,$$

which contradicts our assumption that $l \neq 0$. \square

Complete rules about using these environments and using the two different creation commands are in the *Author's Guide*; please consult it for more detailed instructions. If you need to use another construct, not listed therein, which you want to have the same formatting as the Theorem or the Definition[?] shown above, use the `\newtheorem` or the `\newdef` command, respectively, to create it.

A Caveat for the T_EX Expert

Because you have just been given permission to use the `\newdef` command to create a new form, you might think you can use T_EX's `\def` to create a new command: *Please refrain from doing this!* Remember that your L^AT_EX source code is primarily intended to create camera-ready copy, but may be converted to other forms – e.g. HTML. If you inadvertently omit some or all of the `\defs` recompilation will be, to say the least, problematic.

3. CONCLUSIONS

This paragraph will end the body of this sample document. Remember that you might still have Acknowledgments or Appendices; brief samples of these follow. There is still the Bibliography to deal with; and we will make a disclaimer about that here: with the exception of the reference to the L^AT_EX book, the citations in this paper are to articles which have nothing to do with the present subject and are used as examples only.

4. ACKNOWLEDGMENTS

This section is optional; it is a location for you to acknowledge grants, funding, editing assistance and what have you. In the present case, for example, the authors would like to thank Gerald Murray of ACM for his help in codifying this *Author's Guide* and the `.cls` and `.tex` files that it describes.

APPENDIX

A. HEADINGS IN APPENDICES

The rules about hierarchical headings discussed above for the body of the article are different in the appendices. In the **appendix** environment, the command **section** is used to indicate the start of each Appendix, with alphabetic order designation (i.e. the first is A, the second B, etc.) and a title

(if you include one). So, if you need hierarchical structure *within* an Appendix, start with **subsection** as the highest level. Here is an outline of the body of this document in Appendix-appropriate form:

A.1 Introduction

A.2 The Body of the Paper

A.2.1 Type Changes and Special Characters

A.2.2 Math Equations

Inline (In-text) Equations.

Display Equations.

A.2.3 Citations

A.2.4 Tables

A.2.5 Figures

A.2.6 Theorem-like Constructs

A Caveat for the T_EX Expert

A.3 Conclusions

A.4 Acknowledgments

A.5 Additional Authors

This section is inserted by L^AT_EX; you do not insert it. You just add the names and information in the `\addition-alauthors` command at the start of the document.

A.6 References

Generated by bibtex from your `.bib` file. Run latex, then bibtex, then latex twice (to resolve references) to create the `.bbl` file. Insert that `.bbl` file into the `.tex` source file and comment out the command `\thebibliography`.

B. MORE HELP FOR THE HARDY

The sig-alternate.cls file itself is chock-full of succinct and helpful comments. If you consider yourself a moderately experienced to expert user of L^AT_EX, you may find reading it useful but please remember not to change it.