RESEARCH PROPOSAL

Exploring the Viability of Widespread Adoption of RISC-V Architecture in Mobile Phones: Prospects and Challenges

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1. Introduction

1.1 Proposal Introduction

This research aims to determine the viability of the widespread adoption of RISC-V instruction set architecture (ISA) in mobile phones. This is important to investors and engineers because they may want to know whether RISC-V mobile will potentially succeed before investing a lot of money and work in RISC-V development. The analysis will focus on the software ecosystem, hardware ecosystem and performance of RISC-V mobile phones. Data will mainly be collected from literature articles, news, industry reports, and technical specification documents. SWOT analysis will be used in the final stage to summarise all the internal and external factors impacting the viability. The evaluation will focus on the data collection and processes, decisions made during the research and the quality of the outcome.

1.2 RISC-V Introduction

RISC-V is an open-source ISA that was innovated by Professor Krste Asanovic and their students in 2010[1]. Unlike the current dominant ISA, x86 and ARM, it is not proprietary and is free to be modified[2]. RISC-V is designed to be modular to provide high flexibility. It consists of one basic instruction set and various optional instruction set extensions. The basic instruction set only contains 47 instructions, but it is strong enough to run operating systems and satisfies many embedded system scenarios[3].

1.3 Current Stage of RISC-V

In 2022, the CEO of RISC-V International announced that there were already 10 billion chips based on RISC-V in the market. They are applied in AI, wearables, the Internet of Things (IoT), etc. [4]. With the increase in the performance of RISC-V chips, applications are also extending from simple embedded systems to high-performance computing (HPC) as shown in Figure 1.

[1] RISC-V, 2023, *About*, RISC-V, viewed 16 April 2023, <https://riscv.org/about/>.
[2] McLellan, B 2022, *The State of the RISC-V Union*, part II, Cadence, viewed 16 April 2023, <https://community.cadence.com/cadence_blogs_8/b/breakfast-bytes/posts/the-state-of-the-risc-v-union-part-ii>.
[3] Wang, C 2021, *RISC-V ISA 介绍*, lecture notes, 循序渐进，学习开发一个 RISC-V 上的操作系统, Institute of Software, Chinese Academy of Sciences, delivered 16 May 2021, viewed 16 April 2023, <https://github.com/plctlab/riscv-operating-system-mooc/tree/main/slides>.
[4] Michell, R 2022, 'Over 10 billion RISC-V cores are in use, but where are they?', *electropages*, viewed 16 April 2023, <https://www.electropages.com/blog/2022/07/over-10-billion-risc-v-cores-are-use-where-are-they>.

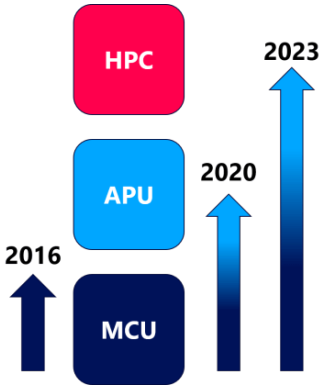

Figure 1: RISC-V processor performance trending[5]

1.4 Case Study: Arm Is Attempting to Change Its Royalty Strategy

Recent news in March 2023 shows that the company Arm, the owner of ARM ISA powering 95% of mobile phones in the market[6], is planning to change its royalty strategy[7]. Currently, when an ARM-based chip is sold, 1-2% of the selling price of the chip is paid to Arm. After the change, the royalty will be based on the device's average price, making devices' royalty different even though their chips are the same. As a result, phone manufacturers like Samsung, who target the high-end market or want to focus on better peripherals than chips, may see the challenge, leading to an increase in prices[8]. Therefore, adopting RISC-V ISA into mobile chips becomes an opportunity to make ARM less monopolistic and benefits customers and manufacturers. However, this requires extensive work, research and ecosystem support, and people may need clarification on whether it is worth doing so.

1.5 Case Study: Android Will Support RISC-V

In January 2023, Google announced that Android would officially support RISC-V, and Google hopes that RISC-V to be a first-tier architecture of Android[9]. With the giant industry's OS support, the way to RISC-V mobile phones has become brighter. However, it is not the first time Google officially supports a new architecture. In 2015, Google put effort into supporting

[5] Urquhart, R 2021, *Is RISC-V the future?*, Codasip, viewed 16 April, 2023, <https://codasip.com/2021/07/27/is-risc-v-the-future/>.
[6] Arm, 2023, *Smartphones*, Arm, viewed 16 April 2023, <https://www.arm.com/markets/consumer-technologies/smartphones>.
[7] Collins, B 2023, 'New Arm Deal Could Push Up Price Of Android Phones', *Forbes*, viewed 16 April 2023, <https://www.forbes.com/sites/barrycollins/2023/03/23/new-arm-deal-could-push-up-price-of-android-phones/?sh=5ff810b37930>.
[8] Walia, P 2023, 'ARM's new business strategy could drive up prices of Galaxy phones', *Sammobile*, viewed 16 April 2023, <https://www.sammobile.com/news/arms-business-strategy-change-increase-price-galaxy-phones/>.
[9] Simons, H 2023, 'Android will officially support the RISC-V architecture', and that's a big deal, *Android Authority*, viewed 16 April 2023, <https://www.androidauthority.com/android-risc-v-support-3262537/>.

MIPS architecture in Android[10]. Time has demonstrated that MIPS is far less successful than ARM in terms of the market share of ISA. Therefore, it becomes necessary to have a deeper understanding of whether RICS-V can become a popular mobile phones ISA.

1.6 Case Study: SiFive Announced Its Fastest RISC-V Processor, P670

P670 is among the most popular RISC-V processors, announced in November 2022[11]. According to its performance analysis (Figure 2), although it has slightly less overall performance than Arm's Cortex-A76, it halves the size and doubles the compute density. This is good news for achieving RISC-V mobile phones regarding hardware support. However, it is also worth noticing that Cortex-A76 was introduced two years ago, so there is still a gap for RISC-V to catch up with its competitor. Meanwhile, ARM is also doing its anti-strategies. For example, in 2019, Arm made the instruction set for its embedded processors Cortex-M customisable[12]. It is noteworthy that customizability is one of the leading "selling points" of RISC-V.

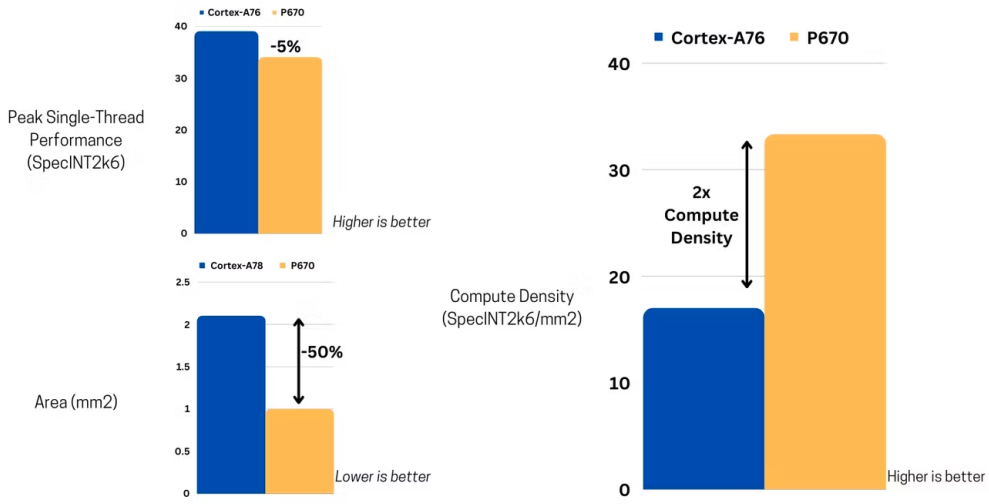

Figure 2: Comparison between P670 and Cortex-A76[13]

[10] Harold, D 2015, 'MIPS CPU Architecture Fully Supported by Google's New Brillo OS for the IoT', *GlobeNewswire*, viewed 16 April 2023, <https://www.globenewswire.com/en/news-release/2015/10/27/780521/10893/en/MIPS-CPU-Architecture-Fully-Supported-by-Google-s-New-Brillo-OS-for-the-IoT.html>.

[11] Maning, J 2022, RISC vs. RISC-V vs. ARM: What Is the Difference?, 'MakeUseOF', viewed 16 April 2023, <https://www.makeuseof.com/risc-vs-arm-what-is-the-difference/>.

[12] Krewell, K 2019, 'Arm enables customized instructions for Cortex-M cores', embedded, viewed 16 April 2023, <https://www.embedded.com/arm-enables-customized-instructions-for-cortex-m-cores/>.

[13] Maning, J 2022, RISC vs. RISC-V vs. ARM: What Is the Difference?, 'MakeUseOF', viewed 16 April 2023, <https://www.makeuseof.com/risc-vs-arm-what-is-the-difference/>.

2. Research Problem

2.1 Significance of the Research Problem

As discussed in the previous section, although there has been some positive news regarding adopting RISC-V in mobile phones, the future of RISC-V mobile phones is still unclear. Although running Android on RISC-V mobile phones has been experimentally achieved by Alibaba's T-Head as early as 2020[14], other factors, such as performance and software and hardware ecosystem for RISC-V mobile phones, are also essential for widespread adoption. For now, RISC-V mobile phones have yet to be commercially available. Since adopting RISC-V in mobile phones is difficult, engineers and investors may need some good references to decide whether it is worth it before delving deeper into RISC-V. Therefore, the research problem "**To what extent is the widespread adoption of RISC-V architecture in mobile phones viable?**" is raised.

2.2 Research Sub-questions

Three main aspects will be considered to solve the main problem. This includes the overall performance, software ecosystem and hardware ecosystem. The market competition between RISC-V and ARM is also worth studying alone. However, this research will mainly focus on the technical parts. Some findings, such as the performance differences between ARM and RICS-V with the same price, may indicate some competitive advantages for further study.

2.2.1 Overall Performance

- What are the fastest RISC-V chips for mobile phones, and how do they perform compared to the latest ARM chips?
- Do they gain any advantage in performance vs. power and performance vs. price compared to ARM chips?
- Regarding the internal property of RISC-V ISA, what are the potential benefits and limitations of RISC-V chips to achieve high performance?

2.2.2 Software Ecosystem

- How do the current compilers support RISC-V?
- How does Android support RISC-V?
- How are current development tools designed for mobile phone development?

[14] Hafacree, G 2020, Alibaba's T-Head Releases Open Source Android 10 Port for RISC-V Chips, hackster.io, viewed 16 April 2023, <https://www.hackster.io/news/alibaba-s-t-head-releases-open-source-android-10-port-for-risc-v-chips-1b3265755785>.

- Are the leading software developers starting or planning to develop apps for RISC-V mobile phones?
- How challenging is it to port existing ARM-based apps into RISC-V, and are there any good translators or emulators for RISC-V to run ARM-based apps during the transition?

2.2.3 Hardware Ecosystem

- How do the available RISC-V processors or SoC support mobile phones regarding performance, power efficiency, assessable features, etc.?
- What is the level of support from the semiconductor industries in making RISC-V chips?
- How standardised are the RISC-V chips for mobile phones? Since RISC-V is highly customisable, different manufacturers implement different variations of RISC-V, leading to the problem of fragmentation. As a result, it is hard to design software for general RISC-V processors.

2.3 Target Audiences

2.3.1 Investors

Adopting RISC-V in mobiles requires considerable funding support, especially for developing RISC-V chips. However, investors may have limited time or domain knowledge to delve into the topic. Therefore, this research aims to provide a clear but thoughtful analysis of the potential of RISC-V mobile phones to investors.

2.3.2 Engineers

While exploring the viability, the strengths and weaknesses of RISC-V when being implemented into mobiles are also summarised. This may provide some guidance when making their software or hardware product to maximise the advantage of using RISC-V.

2.3.3 Researchers

Specific research is still required in the performance and software and hardware ecosystem areas to achieve RISC-V mobile phones. For example, this may include developing a new RISC-V compiler supporting more features before researchers investigate a deeper area in RISC-V mobile phones. This research can be a good starting point as it is from the perspective of the RISC-V mobile phones topic. The research outcome may indicate some research gaps and tell whether this topic is worth further research.

2.4 Outcome Presentation

The outcome of this research is planned to present as a journal article. The sections of the article will be generally aligned with the research sub-questions about performance and software and hardware ecosystem. However, the software ecosystem will be the focus if time and resources are limited.

2.5 Research Done in the Relevant Field

For now, few journal articles directly focus on the prospect of RISC-V architecture in mobile phones, and I am still looking for one. There is an article written by Samuel Greengard focusing on a more general concept of whether RISC-V revolutionises computing [15]. The article concludes with a highly positive outlook for RISC-V architecture to supplant ARM and x86, which includes the mobile phone area. Other resources explicitly discussing RISC-V mobile phones prospect are mostly blogs article or personal videos. Therefore, this area requires further academic study. There is research on different areas of RISC-V other than mobile phones. Although they are not directly related, many findings can be shared. For example, Waterman's energy efficiency and code size reduction research helps me understand the possible optimisation available for RISC-V processors and therefore find out the potential advantage of RISC-V mobiles phones[16].

3. Methodology

3.1 General Methodology

As this research aims to evaluate the feasibility of the widespread adoption of RISC-V mobile phones, it is more or less similar to a feasibility study. A feasibility study is a study of a project's **technical, economic, legal, operational and schedule** feasibility[17]. Although RISC-V mobile is a general concept instead of a product or project, some ideas can be applied. As mentioned in Section Two, this research will focus on analysing performance and software and hardware ecosystems. The **performance** analysis can deduce **technical feasibility**, such as whether RISC-V mobile phone is powerful enough to meet the daily use requirement and **economic feasibility** when comparing their price with ARM mobile phone. The software and hardware ecosystem analysis can deduce **technical feasibility**, such as how hard it is to build RISC-V compilers or processors and **operational feasibility** when considering how well software and

[15] Greengard, S 2020, 'Will RISC-V Revolutionize Computing?', *Communications of the ACM*, vol. 63, no. 5, pp. 30-32, viewed 16 April 2023, <https://dl.acm.org/doi/pdf/10.1145/3386377>.
[16] Waterman, A 2011, 'Improving Energy Efficiency and Reducing Code Size with RISC-V Compressed', thesis, EECS Department University of California, Berkeley, viewed 16 April 2023, <https://people.eecs.berkeley.edu/~krste/papers/waterman-ms.pdf>.
[17] Simplileran, 2023, Feasibility Study and Its Importance in Project Management, simplilearn, viewed 16 April 2023, <https://www.simplilearn.com/feasibility-study-article>.

hardware producers support RISC-V in the long term. As RISC-V is an open-source ISA, the widespread of it is less likely to be impacted by legal challenges. Schedule feasibility is used originally to measure how a project fits the deadline, but there is generally no time limit for the widespread adoption of RISC-V mobile phones. Therefore, this research will cover most areas required for a feasibility study, including technical, economic, and operational feasibility.

3.2 Methods to Study Software Ecosystem

3.2.1 Literature Review

I plan to conduct an extensive literature review on RISC-V compilers, libraries, OS, and software. This will give me a general concept of how well the RISC-V software ecosystem is developed and how close it can be used in practice. More importantly, some articles will highlight the challenges and opportunities associated. When reviewing these articles, I should focus on and draw out the relevant parts of the ecosystem of RISC-V mobile phones.

3.2.2 Case Study

I plan to conduct a case study on the leading companies relevant to RISC-V mobile phones, such as Google, Huawei and Alibaba and find out the prospect and challenges of their OS product, such as the RISC-V version of Android and HarmonyOS. I will also explore how the development tools support these OS so that developers are able to develop RISC-V apps. I will pay attention to some mainstream software vendors to understand whether they intend to adapt their software to RISC-V mobile phones in the future. This part will allow me to access the activity level among RISC-V software developers to see if a vibrant software ecosystem will be created in the future. The data for this part is usually obtained from news articles and the RISC-V Summit and specification documents.

3.2.3 Comparative Analysis

I will compare the RISC-V OS, development tool support and app support to the current dominant ARM software ecosystem. I will evaluate the similarities, differences and potential advantages of RISC-V mobile phones that can beat ARM phones. The comparative analysis is essential because the spread of RISC-V mobile phones also means that many people and manufacturers will give up ARM mobile phones. To achieve this, RISC-V mobile phones should have their highlights.

3.2.4 Surveys and Interviews

A good software ecosystem is inseparable from the support of customers. Conducting a survey gives me a general understanding of how the public thinks about RISC-V phones. However, doing a survey requires a lot of preparation, including ethical considerations. It may not be undertaken for a short research period, which is one **limitation**. Similarly, the viewpoints of

domain experts are also valuable to the research. The interview people can be the professors of computing and economics in the university or people in the RISC-V development industry. Using secondary data may also be a good starting point for this part.

3.3 Methods to Study Hardware Ecosystem and Performance

3.3.1 Case Study

I will conduct case studies on the leading companies that produce RISC-V SoC, such as SiFive and look for their performance, power efficiency, and other relevant metrics to identify the challenges and advantages when they are used in mobile phones. It is important to know how many RISC-V chips produced by companies on the market or in the future can be used in mobile phones to create a robust hardware ecosystem. The ideal way is to obtain RISC-V mobile phones and do benchmarking. However, there are few commercially available RISC-V mobile phones or OS, so the data from this part will mostly be secondary, usually from reports, news articles, and literature articles about specific RISC-V chips.

3.3.2 Comparison Analysis

I will compare the hardware ecosystem of RISC-V with ARM to see what challenges RISC-V needs to overcome if it wants to surpass ARM in the future. The comparison includes availability, performance, and power efficiency.

3.4 SWOT Analysis

SWOT analysis is a common way to analyse a technology adoption. After obtaining data from performance, software, and hardware ecosystem perspectives, I will draw out the key points and do a SWOT analysis. This will give me a summative view of external and internal factors that possibly impact the feasibility of adopting RISC-V in mobile phones.

3.5 Brief Schedule

Week	Actions
7	• **Finish reading the RISC-V specification document** (about 250 pages) to better understand RISC-V. • Literature article about RISC-V (2)
8	• Lectures on RISC-V OS development by Wang Chen to build up the base knowledge to research on software ecosystem • Literature article about RISC-V (2)
9	• Literature article about RISC-V (8)

	• An extensive search of news and survey research articles to discover and analyse currently or potentially available RISV-V SoC and personal devices.
10	• Literature article about RISC-V (8) • An extensive search of news and survey research articles to discover and analyse currently or potentially available RISV-V OS.
11	• Start a literature • Literature article about RISC-V (6)
12	• Summarise Research Data and finish the literature review
After Semester One	• After the Semester One • Review articles for ARM, especially those including the comparison with RISC-V. • Literature article about RISC-V • Keep following news about RISC-V • Survey

4. Evaluation Criteria

4.1 General Evaluation Criteria

The outcome is about viability/feasibility, so it is qualitative. The evaluation of qualitative research should follow the five main criteria, credibility, dependability, confirmability, transferability, and reflexivity[18]. Credibility is about whether the outcome is plausible, which highly depends on how to collect and analyse data. Dependability is about if the redo of the research will find out the same level of feasibility of RISC-V mobile phones. Confirmability is about how strongly the data collected is linked to the finding. Transferability is the research finding applicable to other contexts and times. For example, the research may become outdated with the change of RISC-V mobile phones. Reflexibility is about indicating the role of the research because the outcome is influenced by personal assumption, experience, and belief[19].

4.2 Evaluation of Research Processes Used

I will evaluate my research process, including **how to collect and analyse my data**. The research data will be collected from journal articles, news articles, industry reports, market analyses, and technical specification documents about RISC-V. Since further analysis and

[18] Stenfors, T & Kajamaa, A & Bennett, D 2020, How to … assess the quality of qualitative research, Wiley Online Library, viewed 16 April 2023, <https://onlinelibrary.wiley.com/doi/full/10.1111/tct.13242>.
[19] The University of Melbourne, n.d., *Reflexivity*, viewed 16 April 2023, <https://medicine.unimelb.edu.au/school-structure/medical-education/research/qualitative-journey/themes/reflexivity>.

outcome will be built on top of them, the reliability and creditability and whether they are unbiased will directly affect the quality of my research. I will also evaluate the **depth of my knowledge** of the RISC-V topic. This is because exploring the viability of RISC-V mobile requires the consideration of many factors, and the deeper the knowledge, the more factors I will be able to cover in my research or mention in my limitation. Next, I will evaluate how I analyse my data. This includes if my analysis tools used are formal enough and if my analysis is unbiased.

4.3 Evaluation of Decision Made

I will evaluate the decision made during the research, further narrowing down of research area, changes in research methods, and strategies to overcome expected challenges. The evaluation of decisions made keeps the research transparent and rigour and has the same quality as the decision made in the research proposal.

4.4 Evaluation of Outcome

The evaluation of the outcome includes evaluating how much **contribution the research made**. Will the research outcome be referred to in the future? I will evaluate the format of my outcome to see if it is presented professionally. Whether the conclusion on the feasibility of RISC-V mobile phones is drawn from enough reported evidence, and is it objective? Whether I have indicated all the limitations, such as the factors that may impact the feasibility but not included in the research. Peer feedback is also important during the research and after the outcome is presented. They can help ensure that the research is rigour and valid. [20]

[20] Throughout the proposal, Grammarly and ChatGPT is used to polish my writing. ChatGPT is also used as a search tool help me find out the general concept on how to research methodology and evaluation criteria.