

Debug Box: Comparative Study of Microcontroller-Based Hardware-Level Debugging Efficiency

Koovum Prashant Joshi, Computer Systems Engineering (BS)

Mentor: Michael Goryll, Associate Professor

School of Electrical, Computer, and Energy Engineering



Research Question and Abstract

Research Question:

How effective are different microcontrollers at performing hardware-level debugging using SWD and JTAG interfaces?

Abstract:

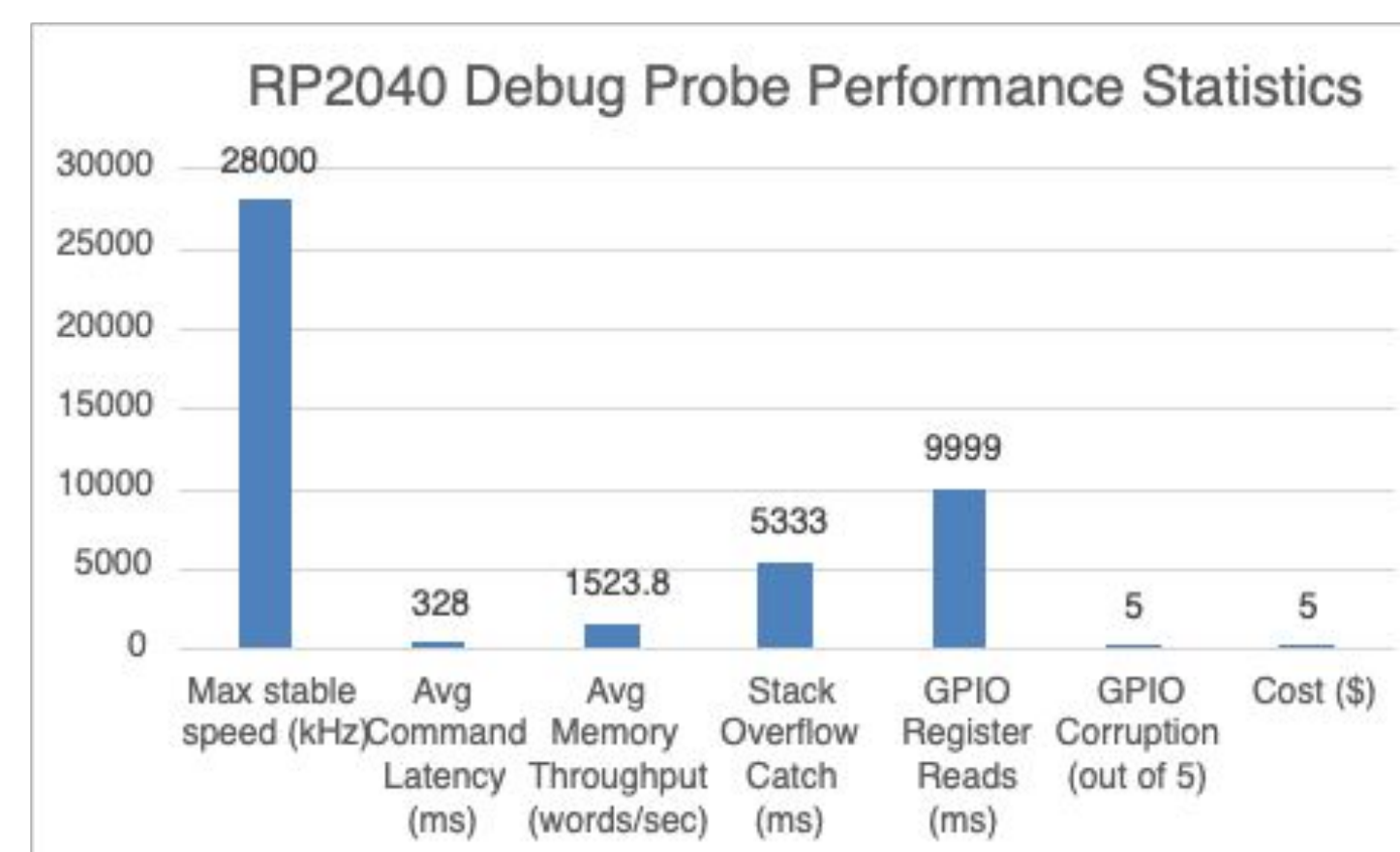
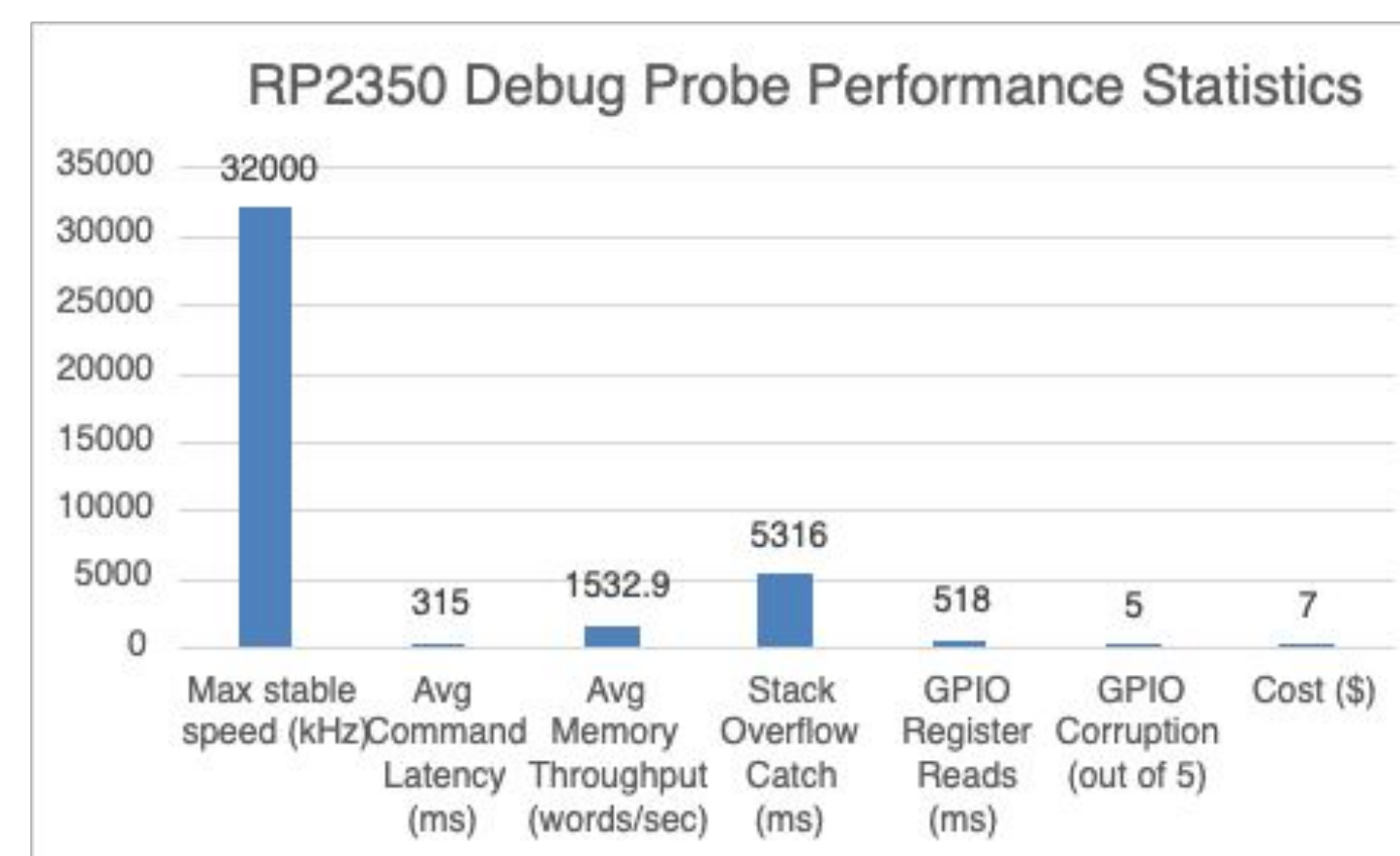
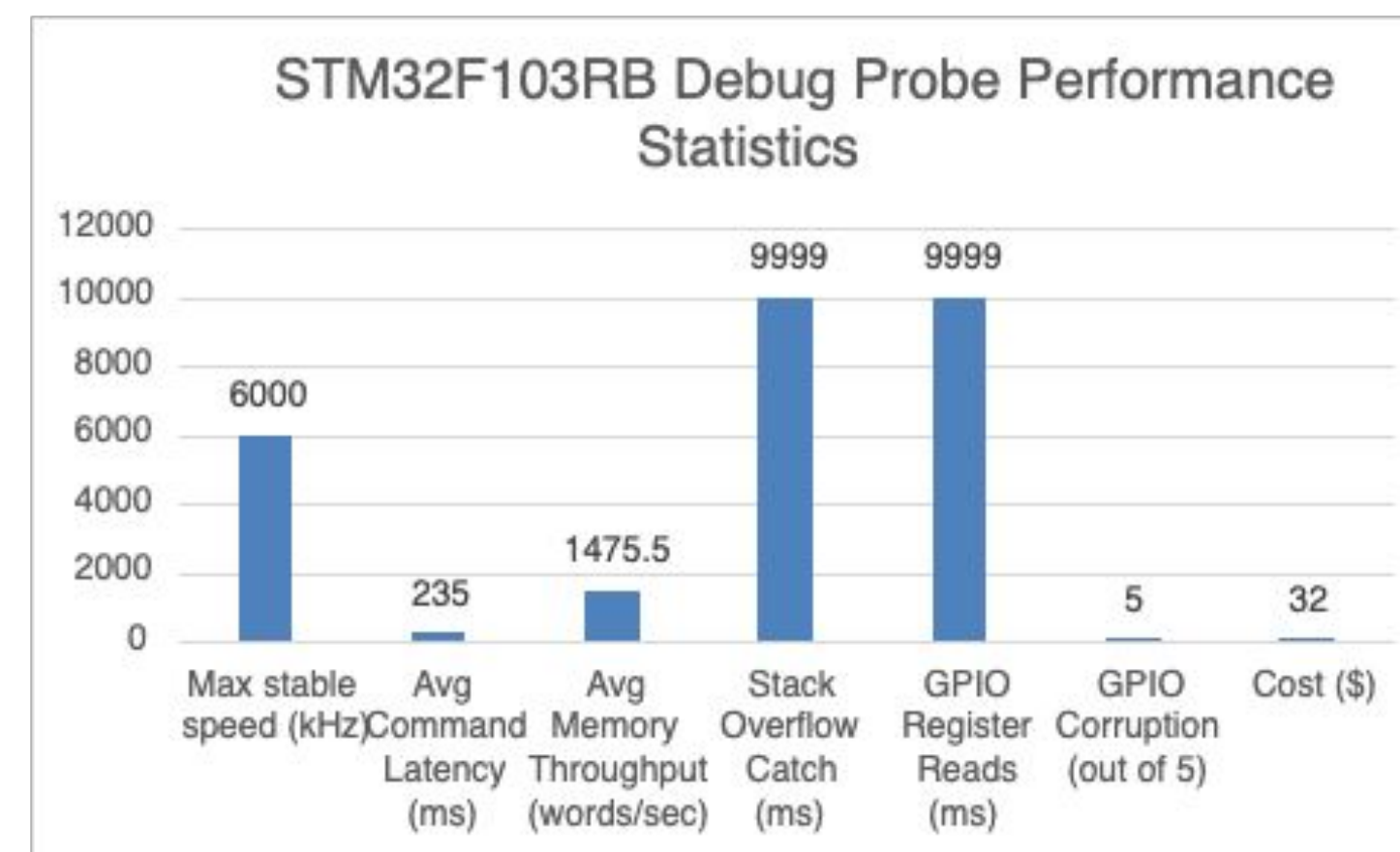
This study evaluates the debugging efficiency of different microcontrollers for CubeSat applications by using a “debugging box” system that links two devices to detect faulty code. It compares latency, reliability, and cost to identify the most effective low-cost option. The goal is to improve accessibility to space technologies.

Background Information

Single Wire Debug (SWD) - An electrical interface for debugging and programming microcontrollers, used as a space-saving alternative to JTAG

JTAG (Joint Action Test Group) - an industry-standard interface (IEEE 1149.1) used for debugging

Microcontroller - a compact, self-contained computer on a single integrated circuit, designed to manage specific, embedded tasks



Procedure

1. Design scripts to test Stack Overflow, Race Conditions, and GPIO Corruption
2. Test the 3 selected microcontroller’s ability to discover these errors
3. Compile data and compare latency, cost, and ability to discover errors
4. Compare test points to find the microcontroller best suited for low-resource projects

Conclusion

Based on the results of this study, the RP2350 demonstrates the strongest overall performance as a microcontroller debug setup for low-cost CubeSat systems. It exhibits a favorable balance of cost and performance, ranking second in price while achieving the highest observed maximum debugging speed among the tested devices. In addition, the RP2350 shows superior reliability in handling a broad range of error conditions. Overall, the findings indicate that the RP2350 is the most suitable option for low-cost CubeSat debugging applications within the scope of this evaluation.

Future Research

Future work will expand the scope of this study by evaluating additional microcontroller families, specifically the ESP32 series and STM32 4/5xx series. Further investigation will also explore alternative debugging software environments. While this study primarily utilized OpenOCD and Black Magic Probe, assessing other debugging tools may provide additional insight into performance differences, compatibility, and overall debugging efficiency across platforms.

Acknowledgement(s)

I would like to express my sincere gratitude to my advisor, Professor Michael Goryll, for his guidance and support throughout this project. I would also like to thank the Sun Devil Satellite Laboratory (SDSL) and the Interplanetary Laboratory (IPL) for providing access to their facilities and workspace.

References

1. Christof, N. (2013). *Debugging of embedded systems* (Bachelor’s thesis, University of Applied Sciences Technikum Wien, Degree Program in Business & Electronics, supervised by MSc Roman Beneder). https://www.academia.edu/17436529/Debugging_of_Embedded_Systems
2. Eisele, M., Ebert, D., Huth, C., & Zeller, A. (2023). Fuzzing embedded systems using debug interfaces. In *Proceedings of the 32nd ACM SIGSOFT International Symposium on Software Testing and Analysis (ISSTA '23)* (pp. 829–841). Association for Computing Machinery. <https://doi.org/10.1145/3597926.3598115>