The case for using QEMU[7] on the Cloud-V[4] platform for RV64GC over current RISC-V hardware using SPECCPU2017[10] as a benchmark

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Abstract

This paper evaluates whether using virtual machines such as the QEMU emulator for RISC-V in 2024 may be more performant than the current RISC-V hardware available for correctness and performance.

Keywords: RISC-V, QEMU, Benchmarks, Single Board Computers, SBCs, performance, correctness

1. Introduction

In the rapidly evolving landscape of the semiconductor industry, RISC-V[6], an open-source Instruction Set Architecture (ISA), has gained substantial attention. A lot of the hardware being made is for very specific software use cases and the general purpose computer hardware optimization for RISC-V is still behind in performance as compared to other architectures like ARM & x86. The parallel development of RISC-V software lags behind due to inherent challenges such as the low availability of hardware in the market, fast changes in the RISC-V specification extensions as well as the delayed application processor profiles for RISC-V. Accessible hardware and streamlined development environments remain scarce, impeding a true evaluation of RISC-V performance and correctness. We will evaluate whether using virtual machines like QEMU are a viable alternative for development of RISC-V software as compared to scarcely available hardware.

2. Cloud-V: Benchmarking Environment

Cloud-V is a cloud-based platform that provides software developers with access to RISC-V real and emulated hardware, and a stable development environment with a rich set of languages, tools and libraries. As vendor-neutral platform, Cloud-V provides access to the listed hardware in Table 1. For QEMU user mode, this benchmark is run on qemu-riscv64 version 8.2.1 running on ubuntu 22.04 LTS on x86. The environment is an LXC container which is allocated 4 cores of AMD EPYC™ 7713, 8GB of memory, and 2GB of swap.

3. Evaluating SPECCPU2017

SPEC CPU2017 provides various benchmark suites & is divided into specrate & specspeed tests. Specrate measures the throughput (or work-per-unit-time) of the device under test by running multiple concurrent copies of each benchmark. Specspeed measures the total time needed to run the benchmark &

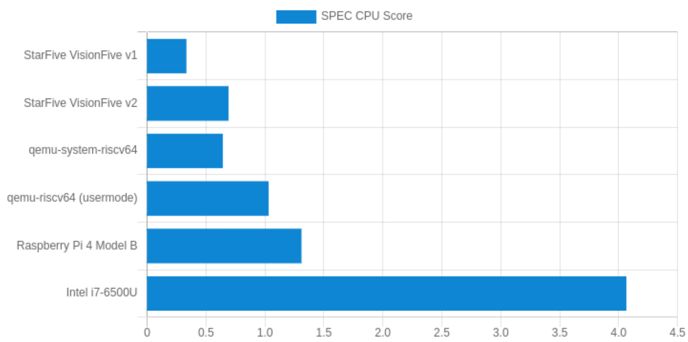

Figure 1: SPECintrate Single-Core

the performance score is calculated based on the time taken to execute the benchmark. A higher score means less time was needed to run the benchmark. Specspeed & Specrate is further divided into integer & floating point tests called intrate, fprate, intspeed, fpspeed. Each of the intrate, fprate, intspeed, & fpspeed are further divided into base & peak benchmarks. The difference between base & peak benchmarks is only of compiler options used. Options allowed under the base rules are a subset of those allowed under the peak rules. This paper will be limited to **intrate** and **fprate** point benchmarks of SPEC CPU2017 with base and peak rules. The SPECCPU2017 software is provided as an ISO image and the version used here is *cpu2017-1.1.9.iso*. See Figure 1-4 for quick overview of the results in single-core and multi-core score. A detailed breakdown available on Cloud-V's[3] website.

4. Results

The results in Table 2 show us that that qemu-riscv64 user mode emulator is 95% faster than VisionFive 2 in multi-core with comparable results in single-core fprate. It is also 49% faster in single-core intrate and 152% faster in multi-core. Overall, this makes the RISC-V software development

SoC & Vendor	CPU Core	Frequency [GHz]	Cores/Threads	Memory [GiB]	Storage [GiB]	ISA Extensions [RV, ARM, x86]	Operating System [Linux]
StarFive VisionFive 1 JH7100[11]	SiFive U74 SiFive E24 (Dbg)	1.5	2/2 1/1	8	64	RV64IMAFC RV32IMAFC	Debian 10 Buster
StarFive VisionFive 2 JH7110[12]	SiFive U74 MC SiFive E24 (Dbg)	1.5	4/4 1/1	8	64	RV64IMAFC RV32IMAFC	Debian 12 Bookworm
SiFive HiFive Unleashed Freedom U540[9]	SiFive U54 SiFive S51 (Dbg)	1.5	2/2 1/1	8	64	RV64IMAFC RV64IMAC	Ubuntu 20.04.6 LTS
Raspberry pi 4 Model B Broadcom BCM2711[8]	Cortex-A72	1.8	4/4	8	64	ARMv8	Debian 10 Buster
Intel i7	6500U[1]	2.5-3.1	4/8	8	64	RV64IMFADC	Ubuntu 22.04 LTS
QEMU User	AMD EPYC 7713[2]	2-3.67	4/4	8	64	RV64IMFADC	Ubuntu 22.04 LTS
QEMU System	AMD EPYC 7713	2-3.67	4/4	8	64	RV64IMFADC	Ubuntu 22.04 LTS

Table 1: Details of the physical and virtual hardware that was tested.

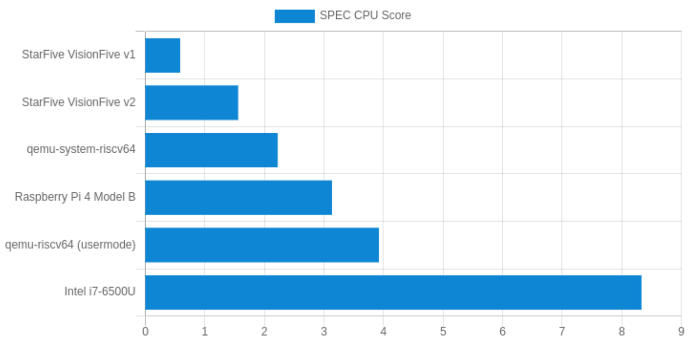

Figure 2: SPECintrate Multi-Core

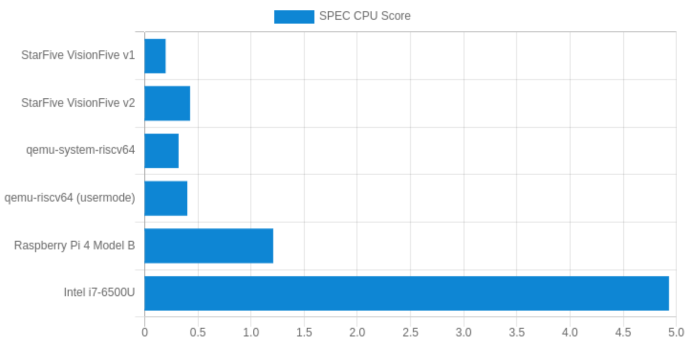

Figure 3: SPECfprate Single-Core

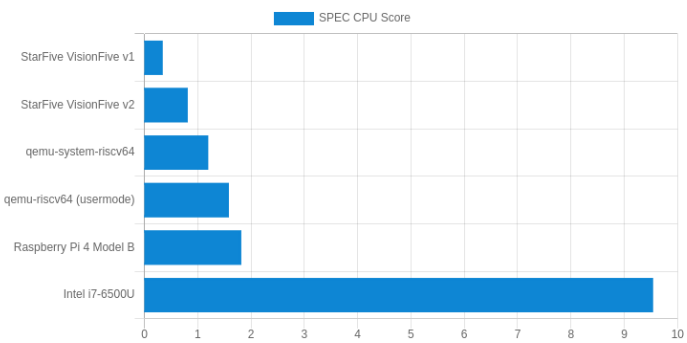

Figure 4: SPECfprate Multi-Core

Ratio Desc.	sc fprate	mc fprate	sc intrate	mc intrate
QEMU-sys/vf2	0.75	1.47	0.93	1.43
QEMU-user/vf2	0.94	1.95	1.49	2.52

Table 2: Resulting performance ratios relative to VisionFive 2.

for RV64GC faster on emulated RISC-V compute instances as compared to other RISC-V SBCs with similar specifications for RV64GC, especially since emulated instances can scale to a much higher core count.

5. Future Work

There are a number of ways this work can be extended, indeed Cloud-V is working further on 3 major avenues. First, the types of benchmarks should be increased to include common other workloads and benchmarks such as coremark[5] and other benchmarks for general purpose computing. Secondly, different types of CPUs such as Intel 14th generation and AMD 4th generation Zen with higher frequencies and IPC should be tested to allow for better real world evaluation. Lastly, other virtualization tools can also be evaluated other then QEMU to give a more holistic view of virtualization performance.

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