Comparing RISC and CISC Computing Architectures in Commercial Devices

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Abstract

In this study, the CPU performance of the CISC and RISC architectures were compared to one another. A low-end CISC and a high-end RISC machine were tested with a CPU benchmarking suite called Phoronix test suite to determine which architecture would better serve the needs of the broad computer market, powering every device from a calculator to a phone all the way to a desktop or a server. It was found that the CISC machine outperformed the RISC machine by between 70% and 90%. Even though this performance gap is significant, it is not so huge as to suggest that one architecture is dropped in favor of another. Instead, more research must be done into the cost of developing and customizing each architecture, as well as into the cost of making the CISC architecture more energy-efficient. Still, this study accomplished what it sought to

do; namely, to quantify the performance gap between CISC and RISC processors in commercial devices.

1. Introduction

Currently, all computing devices are built on one of two architectures: reduced instruction set computing (RISC) and complex instruction set computing (CISC) machines. RISC chips dominate simpler and more mobile devices such as calculators, phones, and tablets because of their more efficient use of power. CISC machines, on the other hand, are generally laptops, desktops, and servers. Up until recently, the two processing architectures remained in separate market segments powering unique devices.

Recently, however, with the rise of connected platforms such as the smartphone, the distinction between what was once clearly a RISC device and what was once obviously a CISC device is beginning to become less clear. Intel, the main manufacturer of CISC processors, is now also building CISC chips for mobile phones and tablets. The leading RISC providers such as Nvidia and Qualcomm are now pushing to have their devices at the heart of laptops and eventually desktops. Even Calxeda, a subsidiary of Hewlett-Packard, is pushing companies to adopt its RISC-based servers.

Bearing in mind the developing cross-pollination of devices occurring in today's market, one must consider which processing architecture is better for consumers; it begs the question, is there one architecture to rule them all? This study aims to test both RISC and

CISC to determine which architecture can provide the speed, energy efficiency, and flexibility that all devices demand.

2. Background

a) Previous Studies

The most informative study that has been done into the differences between RISC and CISC up to this point was performed by Calxeda (Figure 1). It clearly indicates that while CISC may be a faster architecture, RISC is vastly more power efficient. In fact, while the traditional Intel machine was 28.5% faster, the new EnergyCore machine designed by Calxeda was 19.4x as power-efficient. With this study in mind, one can draw the conclusion that the market needs to question the absolute dominance of CISC at the higher levels of computing, such as in servers and desktops.

b) Basic Differences Between CISC and RISC

CISC and RISC differ mostly in the way they handle instruction sets and the way in which those sets are written. CISC uses sets that can be pulled through the processor multiple times, each time accomplishing a different function. One of these lines of code can perform many basic functions, whereas a RISC machine would utilize many smaller instruction sets. Furthermore, CISC machines are built to cope with all of the problems a user might throw at it; RISC computers, on the other hand, are often specialized to perform about 80% of tasks more efficiently and quickly. As a result of these design differences, RISC is often utilized for specific cases such as calculators, set-top boxes, and modems. Often praised for being more flexible, RISC machines usually require more development time but can also run at the same speed as CISC chips due to this optimization.

c) Industry Biases

It is generally accepted that CISC is significantly faster than RISC, although the gap is seldom addressed if ever with hard numbers. In addition, RISC is considered to have better power-efficiency, which is in fact documented with numbers, such as in the Calxeda study. This study will consider biases when selecting candidate machines to compare.

3. Data and Methods

Bearing in mind the biases mentioned in section 2c, it was determined that for this study, it would be most appropriate to compare a high-end RISC machine to a low-end CISC computer. As a result, the ODroid-X board, based upon the Exynos 4420 processor, was selected to represent a commercial RISC chip (see Figure 2 for full specifications). It has the same processor as the widely popular Samsung Galaxy S III and was thus thought to represent the full capabilities of a 2012 RISC processor. For a CISC machine, an HP

Compaq 6910p was selected, running on an Intel Centrino vPro processor (full specifications in Figure 3).

In order to ensure that each machine was being tested with as much as possible being controlled for, both had Ubuntu Linux version 12.04 installed. The ODroid device had a specially made ARM version of the 12.04 software, coded version 12.11. For all intents and purposes the two versions are the same when comparing across the architectures. This particular software was selected because of it is open source and designed to run on any device, thus ensuring neither piece of hardware would have more support outside of the basic drivers. All updates were installed on each version of the 12.04 software to ensure the two machines were as identical as possible.

To test the capabilities of each machine, this study employed the Phoronix Test Suite (PTS), a cross-platform testing suite available for Windows, Mac, and Linux. The software also runs on both x86 (CISC) and ARM (RISC) machines equally. This study employed the pts/cpu suite of tests, which uses 29 tests in total to test CPU performance. Of these 29 tests, only 13 ran successfully on the RISC machine. Although more ran without issues on the CISC machine, those tests were ignored because there was no equivalent RISC score.

Finally, all background tasks were closed during testing. The machines ran without anything other than PTS using the CPU. Both were constantly plugged into a power supply to ensure that the device would not rely on battery power. At the conclusion of every pts/cpu suite of tests, the machine would be powered off for 10 minutes before being restarted, with the pts/cpu test repeated again. The numbers reflected in next to each test are an average of many tests run. Each test has a standard deviation of under .37%.

4. Results

a) Floating Point Operations

The testing suite offered three different tests to determine the floating point operational (FPO) skills of the two devices: Stream, POV-RAY, and C-Ray. Each acts as a unique way to test FPO. Stream runs four separate times, each time producing a different number due to the fact that each test is slightly different. POV-RAY and C-Ray run once each.

Figure 4 shows the value of each individual Stream test average as well as the percent with which CISC bests the RISC processor. Figure 5 does the same for C-Ray, and Figure 6 does so for POV-RAY.

Taking the average value of the Stream scores, the study shows that the FPO performance of the CISC is 68.85% better than that of the RISC. It would, however, be more appropriate to take the average of the Streams 1 and 2 and compare that to the average of Streams 3 and 4. Doing so shows that the first set of Streams are 47.6% faster on CISC, whereas the second set of Streams are 90.1% faster. C-Ray and POV-RAY indicate that

CISC offered 58.6% and 73.3% better performance, respectively. Due to the even spacing of the values of differential performance, it appears safe for this study to take the average of those four percentages, allowing for a net performance advantage of 67.69%.

b) Graphical Simulations

PTS has three different graphical simulation (GS) tests in its pts/cpu suite: TSCP, Crafty, and SmallPT. Each test is only run once per cycle. Figure 7 shows the average value of the TSCP score, as well as the percent by which CISC bested RISC. Figures 8 and 9 do the same for SmallPT and Crafty, respectively.

This particular branch was more difficult to assess given the wide range of scores. The CISC device was actually significantly outperformed by 161526.5% by the RISC device in the Crafty test, but this is most likely due to a computer error. This study does, however, assume that the RISC device has at the very least better than the CISC device at this particular test, but it will not quantify the performance gap. Therefore it is left to examine the values of the SmallPT and TSCP tests, both of which turned out with very different results. Their gap between the percent differences was over 110%, making it difficult to assess the true difference in graphical power between CISC and RISC. A simple average would not suffice for a comparison here, so a weighted average would be more appropriate. Assuming that the lower number of 87.9% is more reasonable given that RISC actually outperformed CISC in one of these tests, at actual advantage is approximately 125%. While this number is more a product of statistical maneuvering than hard science, it does represent a reasonable minimum of the general performance gap between CISC and RISC based on the data.

c) Basic Computer Tasks

In order to test the ability of a machine to perform some basic, daily computer tasks (BCT), PTS uses the OPENSSL, Lame MP3, and FLAC Audio tests. Each test is run once per cycle. Figure 10 shows the results of OPENSSL and the gap between CISC and RISC performance, while Figures 11 does the same for Lame MP3 and Figure 12 does so for FLAC Audio.

Liked with the GS tests, BCT has somewhat confusing results. While FLAC and Lame MP3 both indicate that the basic performance of the CISC machine is about 70% better, the OPENSSL test indicates otherwise. Given that RISC machines are built to do the majority of tasks quickly with few exceptions, this study will assume that SSL-related tasks are some of those not designed to function as well on this particular RISC machine. Therefore, this study can conclude that tasks that cooperate with the RISC processor will run about 70.25% slower, whereas those not designed for the processor will run significantly slower–as shown with the OPENSSL test, possibly 856.67% slower.

d) Raw Computational Power

There was only one test of raw computational power (RCP) in the PTS suite used for this study. RCP was separated from FPO because FRO is a more specific version of the RCP branch of tests. However, the two are to be considered to be testing a similar area of CPU performance. Figure 13 shows the values of the Himeno Benchmark test for both devices as well as the percentage difference between the two, once more in favor of CISC.

Relative to scores in the other areas of CPU performance, the 377.9% advantage that the CISC machine has when compared to the RISC computer demonstrates an abnormally large performance gap when compared to the rest of the data. While most of the other gaps remained around 70%, this gap is over five times that. Bearing this difference in mind, this study concludes that the RCP numbers should be taken lightly, although they do continue the trend of superior CISC performance.

5. Conclusions

The information collected in this study, no matter the interpretation, demonstrates that CISC is clearly a better performer than RISC. The gap in performance, however, requires some more thought. As mentioned in the previous section, the CISC outperforms RISC by 67.69% in FPO, ~125% in GS, 70.25% in BCT, and 377.9% in RCP. Given the potential inaccuracy or misleading qualities of the RCP study, the FPO, GS, and BCT studies are to be taken most seriously when determining the performance gap. By doing a raw average of those three studies, the performance advantage would be 87.64% in favor of CISC. However, by aggregating all test scores regardless of specialty and eliminating the outliers of Crafty, Himeno, and OPENSSL, the performance gap then becomes 70.6% in favor of CISC.

Granted that the performance gap most likely lies between 87.64% and 70.6%, it is clear that commercial devices do not have the same performance gap as noncommercial ones. The Calxeda server had a 28.5% performance gap, between 50% and 70% less than the difference between the two machines tested by this study. This difference demonstrates the importance of customizing a RISC chip to the software and to the needs of the device. Without optimization RISC processors cannot compete very closely with CISC machines.

Before the computer industry moves forward, it must consider the differences between CISC and RISC in terms of performance, cost, and potential. CISC is the clear winner in terms of performance, but its lead is diminished when companies begin optimizing the RISC processor for the tasks it is going to perform in that specific device. This customizing raises an issue of cost: if the cost of development is too steep, then the potential value that RISC offers is erased because of the fiscal barrier. Finally, it is critical to consider the potential of a chip. RISC is clearly very flexible, but as of late CISC chips have taken on RISC characteristics to fit in to mobile phones. As a result, CISC has proven itself to be very flexible.

Moreover, it is abundantly clear that CISC will offer inferior energy performance when compared to RISC. If it is determined by another study that the efficiency difference between the two is too great, then this study should be revisited to determine whether or not the energy costs of CISC will erase its performance benefits. Ultimately, this study finds that the future of computing lies in financial concerns due to the fact that development costs and energy costs are what might decide the processing architecture of the future.

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Figures

Figure 1

	EnergyCore ECX-1000	Intel Xeon E3-1240
Core Frequency	1.1 GHz	3.3 GHz
CPU Cores	4	4
Total Requests	1,000,000	1,000,000
Requests per Second	5500	6950
Latency (Average)	9 ms	7 ms
Power (Average)	5.26 W	102 W
Peformance/Watt Advantage	15X	

Figure 2

Processor	Samsung Exynos4412 Cortex-A9 Quad Core 1.4Ghz with 1MB L2 cache
Memory	1024MB(1GB) LP-DDR2 800Mega data rate
3D Accelerator	Mali-400 Quad Core
Video	supports 1080p via HDMI cable(H.264+AAC based MP4 container format)
Video Out	micro HDMI connector / RGB-24bit LCD interface port
Audio	Standard 3.5mm headphone jack and microphone jack
	HDMI Digital
LAN	10/100Mbps Ethernet with RJ-45 Jack (Auto-MDIX support)
USB2.0 Host	High speed standard A type connector x 6 ports
USB2.0 Device	ADB/Mass storage(Micro USB)

UART	System console monitoring for development (1.8volt interface)
IO PORTs	50pin IO expansion port for LCD/I2C/UART/SPI/ADC/GPIO interfaces
Display (Option)	HDMI monitor / LCD panel with RGB or LVDS interface
Storage (Option)	Full size SDHC Card Slot
	eMMC module socket
Camera (Option)	MIPI-CAM connector (MIPI-CSI 2 lanes)
Power (Option)	5V 2A Power

Figure 3

CPU	Intel Core 2 Duo T7300 / 2.0 GHz
Number of Cores	Dual-Core
Cache	L2 cache - 4.0 MB
Chipset	Mobile Intel PM965 Express
Platform Technology	Intel Centrino Pro
RAM	2.0 GB (2 x 1 GB)
Technology	DDR2 SDRAM
Speed	667.0 MHz
Hard Drive	160.0 GB HDD / 5400.0 rpm
Interface	Serial ATA-150

Figure 4

	RISC	CISC	% Difference
Stream 1 (MB/s)	1980.679	2943.454	48.6
Stream 2 (MB/s)	1966.458	2883.092	46.6
Stream 3 (MB/s)	1801.89	3453.114	91.6
Stream 4 (MB/s)	1799.483	3394.013	88.6

Figure 5

	RISC	CISC	% Difference
C-Ray (s)	442.261	183.215	58.5

Figure 6

	RISC	CISC	% Difference
POV-RAY (s)	4620.4	1234	73.3

Figure 7

	RISC	CISC	% Difference
TSCP (Nodes/s)	86926.4	261313.5	200.60%

Figure 8

	RISC	CISC	% Difference
SmallPT (s)	4173.3	506.8	87.9

Figure 9

	RISC	CISC	% Difference
Crafty (s)	0.083	134.15	-161526.5

Figure 10

	RISC	CISC	% Difference
OPENSSL (Signs/s)	5.89	56.351	856.7

Figure 11

	RISC	CISC	% Difference
Lame MP3 (s)	90.691	27.49	69.70%

Figure 12

	RISC	CISC	% Difference
FLAC Audio (s)	38.661	11.27	70.80%

Figure 13

	RISC	CISC	% Difference
Himeno Benchmark (MFLOPS)	185.389	886.057	377.9