

Low consumption and high performance Intel, AMD and ARM based Mini PCs

Peter Dukan*, Attila Kovari**, Jozsef Katona***

* ADMAXON Ltd, Dunaújváros, Hungary

** , *** College of Dunaújváros/Institute of Informatics, Dunaújváros, Hungary

*dukan@admaxon.com, **kovari@mail.duf.hu, ***katonaj@mail.duf.hu

Abstract – Earlier we have already tested an ARM-based SBC (Single Board Computer) solution, which cannot keep up with the performance of a Mini PC, but we achieved nearly the same functionality in its installed Linux system, while consumption outpaced its rival. Since then, the ARM has undergone a huge development; though, Intel and AMD have taken steps to reduce their consumption and AMD has launched their APU solution. We will try to present that development in this paper and find the answer where the ARM-producers are in comparison with Intel and AMD, regarding performance, consumption and price.

I. INTRODUCTION

In the early 2010s, the interest on Mini PC market shifted towards the ARM architecture. The first cheap hackable, Linux-friendly ARM-based Mini PC, the MeLE A1000 was introduced in 2012. [1] We tested the use of this ARM-based Mini PC as thin client and the speed of Linux system based on this architecture and the test results were published. [2] During our research, we found that although the computing performance of MeLE A1000 is similar to an Intel Pentium III processor, there is a significant difference in consumption, which today is an important aspect regarding the continuous increase in the number of electronic devices and the energy consumption growth in households.

Since then ARM-based devices continued to spread, which the major x86/64 architecture based CPU manufacturers – such as Intel and AMD – could not ignore, as the market is huge. The reduction of consumption while increasing the performance had to be done in parallel for the manufacturers. Besides the battle that takes place between the ARM and x86/64 manufacturers, the number of ARM-based processor manufacturers has continued to increase.

Former continuous frequency increase has been replaced by resource multiplication to help parallel processing; therefore, manufacturers often reduce the frequency in order to improve consumption (Fig. 1). Instead of the previous 3 - 4 GHz CPU clock frequency, the speed of processors was decreased between 1.5 and 3 GHz, while the consumption was successfully reduced by half or thirds.

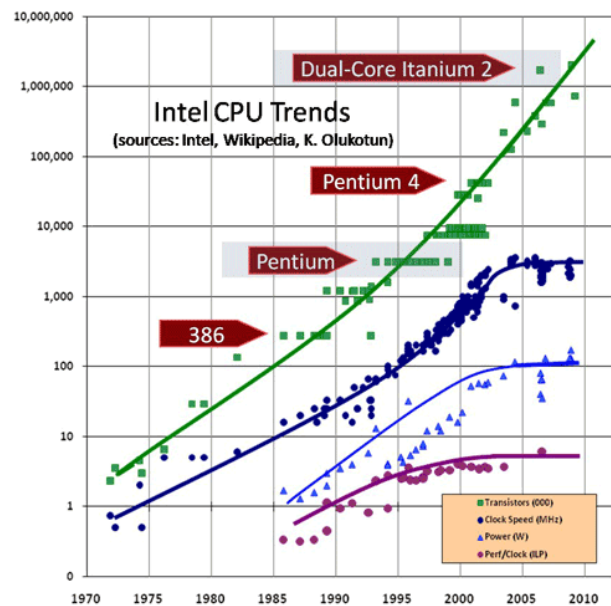


Figure 1. Intel CPU trends [3]

The Mini PCs appearance has become possible by the increasing degree of integration. Each architecture targets SoC (System on Chip) solutions. By the x86/64 architectures the north and south bridge functions are increasingly concentrated in a single IC (Integrated Circuit). The result of this was the spreading of ITX motherboards, giving the number of Mini PCs increased.

Regarding the future of Mini PCs a greater spread is expected thanks to the attitudinal change of IT in the last few years, which was affected by the Cloud technology. The development directions of information technology address service-oriented applications. Partly due to this development, the local resources are continuously replaced by the central resources of service providers. [4] Although the SaaS (Software as a Service) solutions are the most popular ones, the IaaS (Infrastructure as a Service) is more acceptable, or in case of companies, PaaS (Platform as a Service) solutions are also available. Due to these, the gap is narrow among Mini PCs and thin clients, as we often only run a browser on our machine.

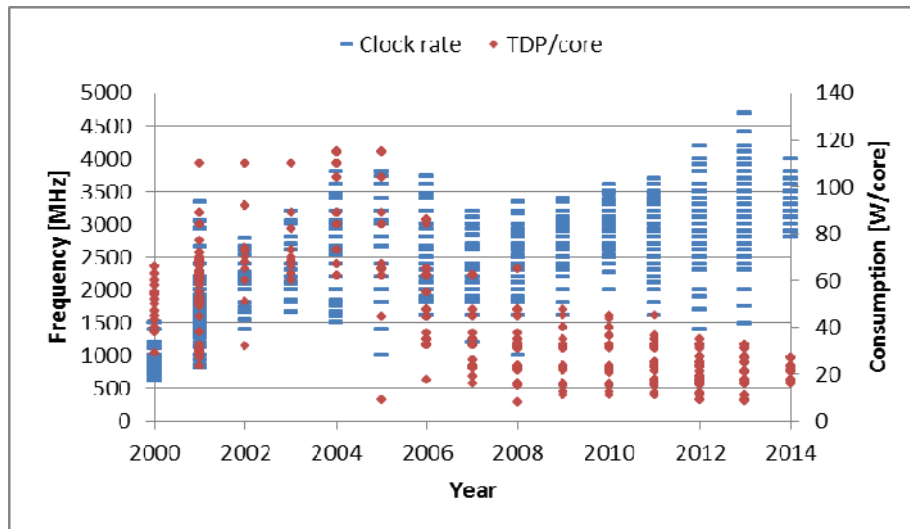


Figure 2. Increased parallel processing with lower consumption

II. ARCHITECTURAL DIFFERENCES

Although the Mini-ITX motherboards appeared by VIA Technologies in 2001 [5], they were used for a long time in connection with industrial and embedded systems. Significantly, in 2008, by the release of Intel Atom processors, the Mini-ITX have become widespread (at this time the Mini-ITX 2.0 standard was defined by VIA as well). Linked to this standard, a new motherboard type was released, such as the Nano-ITX, Pico-ITX and Mobile-ITX. Because the Mini-ITX standard does not have a power supply description, the standard 20 or 24-pin ATX supplies can be used, but in many cases separate PCB or motherboard's DC power supply is used to generate the required voltages from a simple DC supply.

As already mentioned, the increase of the degree of integration is contributed significantly to the appearance and spread of Mini-ITX standard. Of course, with the integration levels, more and more heat is generated in a smaller place, so its dissipation has become a challenge for hardware manufacturers. With the appearance and spread of SoC solutions, this problem was more and more significant. The frequency reduction resulted lower consumption and lower calculation performance. The solutions are new energy efficient architectures and increased parallel processing (Fig. 2.). Nowadays, we can say that the future is the SoC solutions, and certainly they help the spread of such philosophies, like the IoT (Internet of Things). [6] [7]

Different manufacturers used different solutions for the mentioned problems. In the beginning, the Hyper Threading (or officially known as simultaneous multithreading /SMT/) seemed to be the appropriate response and that is what Intel and AMD have followed, but by now both large company abandoned its use. The introduction of a new cache level is another solution, so now at least three, but sometimes four cache levels are also applied. [8] The third solution is related to the second and meant to integrate the GPU (Graphical Processing Unit), which was first used at the APU (Accelerated Processing Unit) by AMD, and today by Intel (Iris Pro and Bay Trail versions).

III. INVESTIGATED MINI PCs

Numerous low power consumption but relatively high performances x86/64 architecture based processors have been introduced by Intel and AMD recently. On the other hand, the ARM based processors are continuously increasing performance at low power, and by now the performance of this architecture has a comparable level with low power x86/64 based processors. The latest low power (primarily less than 10W) x86/64 based processors have 4 cores and run about 1.5 - 2.5 GHz clock speed. The new (also low consumption) ARM based processors have 4 or 8 cores and also run about 1.5 - 2 GHz clock speed. For this reason, our selected Mini PC's CPU architectures has 4 cores processors and nearly 2 GHz clock speed. In the examination, an x86/64 based Intel, an AMD and an ARM based Mini PCs were tested. In this given range of Mini PC's hardware, low power, but relatively high performance processors are selected to test: Intel Celeron N2930, AMD A4-5000 APU and Amlogic S802.

A. Intel Celeron N2930

Intel launched quad core Celeron N2930 "Bay Trail" series (Atom based) processor in Q1 2014. The processor's max TDP is 7.5 W, the scenario design power is 4.5 W only. The clock speed is 1.83 GHz, burst frequency is 2.16 GHz. The processor supports DDR3L-1333 system memory, maximum 8 GB by 2 channels and USB revision 3.0 also. The GPU is based on the Ivy Bridge GPU ("third generation" HD graphics), which offers either 6 or 16 Execution Units, but the HD Graphics of Bay Trail CPUs comes with only 4 Execution Units (EU). The core clock of Bay Trail is significantly lower, depending on the specific model. The base GPU frequency of N2930 is 313 MHz, the burst is 854 MHz. [9]

The new ZOTAC ZBOX C-series nano Mini PCs combine new fan-less chassis with high-performance processors. The ZBOX CI320 nano has a N2930 CPU inside, but there is not a memory and storage (Fig. 3.). I/O ports: 1 x SATA 6.0 Gbit/s, 1 x eSATA, 4 x USB 3.0, 2 x USB 2.0, Gigabit Ethernet, Analog out, Microphone input, optical S/PDIF, WiFi 802.11ac, Bluetooth 4.0, HDMI, DisplayPort, Card reader, integrated IR receiver. [10]



Figure 3. ZOTAC ZBOX CI320 Mini PC [5]

To build a Mini PC from components, there are also some Mini-ITX motherboards available based on N2930 CPU, for example Jetway NF9M, Advantech AIMB-215 or ASRock IMB-150.

B. AMD A4-5000

The AMD APU Kabini core A4-5000 is a low power mobile quad-core SoC for low-end laptops, which was presented in the middle of 2013. The processor's TDP is 15 W, which is higher than Intel's N2930, but there is not an AMD processor about 2 GHz clock speed under 10W TDP. The AMD's new low power, quad core processors A6-6310, A8-6410 also have 15 W TDP, but as a Mini PC to purchase and test, it was not available; therefore, A4-5000 was examined. A4-5000 APU has four CPU cores with a clock speed of 1.5 GHz (no Turbo), the chip also integrates a Radeon HD 8330 GPU with 128 shaders, which is based on the Graphics Core Next (GCN) architecture and clocked at 500 MHz. [11]

ZOTAC announced at the end of 2013 the ZBOX nano series AQ01 Mini PC with quad-core AMD A4-5000 APU (non-fanless) but without onboard memory and storage (Fig. 4.). I/O ports: 1 x SATA 6.0 Gbit/s, 2 x USB 3.0, 5 x USB 2.0, Gigabit Ethernet, Analog out, Microphone input, optical S/PDIF, WiFi 802.11ac, Bluetooth 4.0, HDMI, DisplayPort, Card reader, integrated IR receiver. [12]



Figure 4. ZOTAC ZBOX nano AQ01 Mini PC [7]

To build a Mini PC from components, nowadays the following motherboards have A4-5000 processors: ASRock QC5000-ITX/WiFi or BIOSTAR A68N-5000.

C. Amlogic S802

Many Android media players based on Amlogic S802 Meson8 platform with quad core Cortex A9r4 processor, which is the set-top box version of the M802 SoC, first were launched in Q1 2014. The clock speed of the processor is 2 GHz. The GPU is octa-core ARM Mali-450 MP6 running with 600 MHz speed. [13] The CPU supports maximum 4 GBDDR3/3L, LPDDR2/3, USB 2.0 and OTG but no USB 3.0. The Tronsmart Vega S89 Elite fan-less media player has this SoC with 2 GB DDR3/3L

system memory and 8 GB NAND flash (Fig. 5.). The media player includes Google's Android 4.4 Kitkat operating system. I/O ports: 2 x USB 2.0 host ports, micro USB OTG port, micro SD card slot, 10/100 Ethernet, WiFi 802.11a/b/g/n, Bluetooth 4.0, HDMI 1.4b, AV, optical S/PDIF and a built in IR sensor for remote control support. [14]



Figure 5. Tronsmart Vega S89 Elite media player [10]

IV. COMPARISON AND TESTING

A. Comparison of Mini PC's price and main parameters

The main parameters and prices of the examined Mini PCs can be found in Table I.

TABLE I.
MAIN PARAMETERS AND PRICES OF THE INVESTIGATED MINI PCs

Model	CPU Cores	CPU Clock [GHz]	RAM [GB]	GPU	GPU clock [MHz]	TDP [W]	Price [USD]
ZOTAC CI320 (Intel Celeron N2930)	4	1.83-2.16	2	Intel HD (Bay Trail)	313-854	7.5	200
ZOTAC AQ01 (AMD A4-5000)	4	1.5	2	AMD Radeon HD 8330	500	15	250
Tronsmart Vega S89 (Amlogic S802)	4	2	2	ARM Mali-450 MP6	600	<7	130

B. Cross-platform benchmark

The performance of the above mentioned Mini PCs mainly depend on the performance of the CPU, when it runs general or office applications. To compare the performance of the ARM and x86/64 based Mini PCs, a common benchmarking methodology is needed. The ARM CPU based Tronsmart Vega S89 Elite box has Android firmware only. The selected x86/64 based devices can run several operating systems but the test system was Windows 7 because the Android x86/64 is under development. So to compare the Mini PCs, a cross-platform benchmarking algorithm is needed, which is capable to benchmark system performance.

There is a relatively new cross-platform benchmark system, the Geekbench, which is developed by Primate Labs. Geekbench 3 is available for 32 and 64 bit Windows, Linux, Android and iOS operating systems. The Geekbench 3 scoring algorithm can be used to calculate single-core and multi-core performance by using

a number of different algorithms to measure system performance, and uses new workloads that simulate real-world scenarios. The reference of Geekbench 3 is a Mac mini with an Intel Core i5-2520M @ 2.50 GHz processor which has a score of 2,500 points. The main workload tests are based on the integer, floating point calculation performance and memory bandwidth measurement. [16]

C. Benchmarking results

During our tests, we measured the power consumption of each device. Of course, we registered only the peak values. The computing results were more balanced than the consumptions, regarding to the TDP values given by the manufacturers. Each CPU got a single-core and a multi-core score, which refers to the benchmarking subcategories (the integer, floating point and memory performance).

The first Mini PC was the Intel CPU-based device, which dissipated 9.7 W power during the Geekbench3 tests. The single-core score was 842 point, and the multi-core score was 2714. These values are lower than AMD APU's because this CPU has no hardware AES New Instructions support. The result was strengthened by the integer score with 892 single-core and 3371 multi-core performance, because the floating point score was lower (740 and 2924). The memory performance was not really differs in single and multi-core testing, so the results were 949 and 980.

The AMD APU based Mini PC was the second device to measure. The power consumption was about 18.3 W at peaks, and it reached 866 for single-core, and 2785 for multi-core performance. In this case, the integer calculations were more strengthened because it achieved 962 for single and 3668 for multi-core scores. Hence, there was only 712 and 2800 scores for the floating point calculations. The memory performance was near the same thanks to the same type of DDR modules (982 and 990).

The third test object was the ARM (Amlogic) CPU based Mini PC, with the lowest consumption about 5.4 W. Interestingly, the single-core performance was only 787, but the multi-core was lower than that of the other two CPUs with 2325. The integer operations calculated results were 990 and 3291, and the floating point operations got only 646 and 2192 points. Memory performance was much less because of the 32bit memory interface (667 and 602).

TABLE II.
BENCHMARKING RESULTS

		Single-core	Multi-core
ZOTAC CI320	Sum	842	2714
	Integer	892	3371
	Floating	740	2924
	Memory	949	980
ZOTAC AQ01	Sum	866	2785
	Integer	962	3668
	Floating	712	2800
	Memory	982	990
Tronsmart Vega S89	Sum	787	2325
	Integer	990	3291
	Floating	646	2192
	Memory	667	602

V. CONCLUSIONS

The purpose of our research was to analyze some CPUs with the lowest possible power consumption to determine the strength of the current Mini PC market conditions. The selected processors had similar parameters, but different processor architecture.

In the area of consumption, the ARM architecture based processors are preferred, although performance is slightly lower than the x86/64 rivals. This is mainly due to the fact that they are primarily intended to run general-purpose applications on them, so tasks that require floating point calculations are less recommended. The only limitation of the world-wide spread is the low-level software support.

In case of the x86/64 architecture processors, Intel clearly leads the ranking in consumption, but the computing power of AMD is nearly in the same position. The results of our measurements show that AMD is also primarily focused on running general applications, while Intel is slightly stronger in the floating point calculations.

Partly due to the spread of Linux and SaaS solutions, the type of architecture is becoming less and less relevant so that the software support can be improved in the future for ARM devices. In performance, the ARM manufacturers have caught up with Intel and AMD, so we expect a sufficiently strong competitor at the Mini PC market. The challenge is for Intel to retain the advantage, and AMD needs to decrease the consumption of their CPUs a lot.

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