Effects of DSP integration besides ARM structures on Video Decoding

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***Abstract*— Today, the ARM processor architecture is used in many electronic devices as the central processing unit. Studies in this field have rapidly progressed because of using ARM architecture in indispensable devices in our daily life such as mobile phones, media players and audio systems. At the same time, users' expectations in this processor are increasing every day. Recently, ARM processors cannot meet these expectations of users alone. At this point, embedded system designers are using engaged DSP processors. They started to produce chips whose popularity is getting higher day after day with the name as System on Chip (SoC) containing ARM and DSP cores together. In this study, an OMAP series chip has been researched. Benefits of using DSP alongside ARM processor are stated during encoding video data in several formats.**

Keywords— **ARM; DSP; codecs; OMAP; Pandaboard**

I. INTRODUCTION

The basis of electronic devices in our daily lives are composed by microprocessors or microcontrollers described as the central processing unit. Developed devices' performance values can vary according to the speed of central processing unit (CPU) used inside. In this sense, the technological developments on the central processing units are the main factor in determining the level of technological development of electronic devices.

Each passing day with the incremental advances in nanotech promotes directly to the central processing unit. In particular, the developments around the world are made for the purpose of minimize the consumption of energy resources and protect them. In this sense, recently designed ARM processors are used in every field with the high performance and low power consumption. Over 90 percent of the mobile phones classified as smart phones use the ARM architecture for the processor unit [1]. In this way, they can achieve high performance with long-lasting charge.

But today, only single core ARM processors are not enough on mobile phones due to offering more interactive user interface and especially multimedia applications designed for more interaction with users than before. As a result of this sufficient usage, dual-core ARM processors are designed.

Dual-core Arm processors are ideal for using in low screen resolution systems such as mobile phones, though, it is inadequate to use in systems aimed at encoding quality of the raw videos into other formats such as camera surveillance systems or decoding high definition resolution videos known as Full-HD to play on high screen resolution systems such as media players. To overcome that problem, developers have engaged in researches about easing overloads on the central processing unit.

Chips known as SoC has been designed for the purpose of mentioned problem [2]. Digital Signal Processing (DSP) unit has been merged next to ARM CPU within the SoC chips to provide extra processing power and ease overloads on ARM.

Digital signal processors abbreviated as DSPs can be identified as a single board computer (SBC) which are optimized for sensing, processing and producing real-world signals such as audio and video [3]. Micro Processing Units are less powerful when comparing with DSPs. The main reason is about the designing architecture. DSPs are specified for the multiply process. At that point, CPU unit is playing tiny role on control stage. Main process is executing on DSP cores [4].

In addition, memory blocks in SoC chips designed as separate for ARM processors and DSP. With this kind of design, both processors (DSP + ARM) can directly access memory blocks. Also there is a shared memory point with ARM and DSP [5]. In addition this development, SGX hardware as the graphics card is also integrated inside some advanced SoC structures next to ARM + DSP to accelerate more [6].

In this study, some tests are performed separately about decoding several video formats on ARM and ARM + DSP architectures by using Pandaboard having OMAP 4430 SoC chip. The performances of using only ARM and ARM + DSP together are observed and listed. Results show benefits of using DSP unit as a co-processor of ARM.

In the next section, a brief overview of hardware platform that we used in study is presented. Both OMAP 4430[6] and Pandaboard[7] is descripted in details. Methods used in tests are clarified in section 3. In the same section, video data specifications are stated as well. Section 4 reveals the experimental results. Results are presented with the graphics and comparing tables. Section 5 discusses the results and concludes the paper.

II. MATERIALS

In this study, topics about performances of mentioned SoC chips in such cases where ARM is not enough alone to decode encoded video formats are discussed and comparative results are carried out. For this purpose, experiments implemented on OMAP 4430 SoC chip developed by Texas Instrument. In this section, information about embedded system development board known as Pandaboard and OMAP 4430 chip used in Pandaboard as SoC unit is provided.

A. *OMAP 4430*

OMAP 4430 is an electronic chip developed by Texas Instrument and categorized in system-on-chip (SoC) class. Open Multimedia Application Platforms abbreviated as OMAP is defined within high performance applications processors by Texas Instrument [8]. ARM Cortex A9 dual-core processor is used inside the SoC as central processor unit with the speed of 1.2 GHz each. TMS320 series of DSP specified for images and known as ISP (Image Signal Processor) core is integrated in SoC next to ARM. Over those cores, SGX540 graphics core also is embedded as graphical accelerator inside the SoC. ARM, DSP and SGX cores placement can be seen in Figure 1 as block diagram.

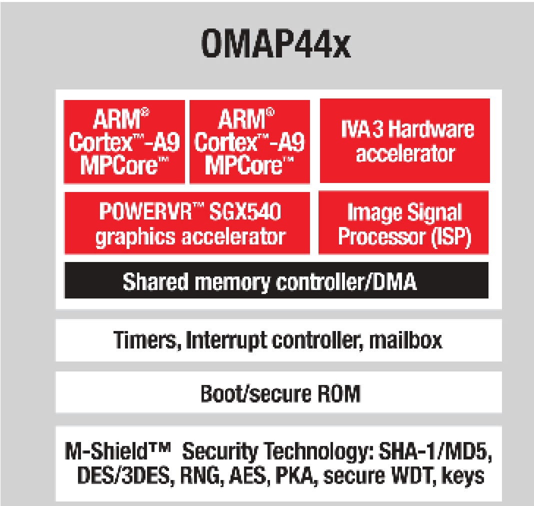

Fig. 1 Block Diagram of OMAP 4430 SoC [6]

B. *Pandaboard Rev B*

Pandaboard Rev B is application development kit using OMAP 4430 SoC manufactured by TI as central unit of processes [7]. Such these boards provide users developing mobile and embedded solutions such as face detection, monitoring systems, media players etc. [9], [10], [11].

The most conspicuous feature of Pandaboard is that can operate with SD memory card which has own operating system downloaded in. That helps users to develop their software applications on board without changing platform. Otherwise, developers have to re-compile their applications for ARM architecture on other computers. That is called as toolchain process in literature [12].

Furthermore, as seen in figure 2, two USB ports, Ethernet port, HDMI out, wireless connectivity antenna, audio input - output are provided on the board as embedded on. Thanks to these ports, board can connect external devices directly in environment.

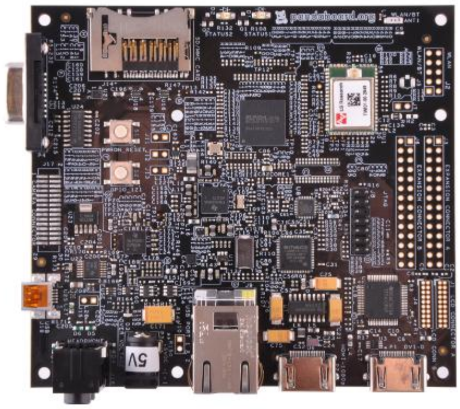

Fig. 2 PandaBoard Rev B [7]

III. METHODS

In this study, raw video with the duration of 1 minute length and encoded to three different format, are used to analyze of decoding performance comparisons on both ARM and ARM + DSP structures separately. MPEG, Matroska and DivX codecs are selected in encoding process. As a result, test data are created with mkv, mpeg and avi file extensions on another Linux based computer. Video data's characteristics vary due to differences in codecs used in coding. Videos' specifications appear in Table 1.

TABLE I
Test Videos' Specifications

Format	Bitrate	Coding	fps	Res.	Sound
Mpeg	6613 kb/s	mpeg1video	25	720p	No
Mkv	1647 kb/s	h264	25	720p	No
Avi	5367 kb/s	Mpeg4	25	720p	No

Test videos are performed in two separate stages on Pandaboard. To do this, two separate SD memory card have been used. Ubuntu 11.10 Linux operating systems have been installed to both SD memory cards. One of these SD memory cards has been underpin with SYS_Link program on Operating System to establish DSP Bios as a reinforcement unit to ARM Bios. Sys Link provides to interact between DSP core and ARM core. On the other hand, DSP module is not defined on another operating system installed SD memory card to run system with just ARM core.

Gstreamer based totem player is used to decode and analyze the videos. Analysis on ARM is recorded and graphs are created with the SAR program with the help of recorded information while decoding process.

As a first step, DSP + ARM architecture is used simultaneously to decode encoded videos. In the course of this process, load values on ARM are recorded by SAR. In the second step, videos are decoded on non-supported DSP operating system in order to monitor performance of only ARM decoding capability. As in first step, load values of ARM are also recorded to compare each other. Ultimately, the values obtained by SAR prove the importance of the DSP structure within SoC.

IV. Test Results

Decoding of encoded videos with Mkv, DivX and MPEG codecs has been respectively tested on Pandaboard having only ARM and ARM + DSP supported operating systems installed on two different memory cards. Load values of ARM have been recorded. Records' length is considered as 100 second. 60 second is test video length used in records and other 40 seconds decided as starting and finishing idle times.

As shown in Figure 4, decoding of videos in MKV format makes heavy load effect on the processor. Figure 3 shows that the load disappeared out of the processor due to usage of DSP. Dual-core ARM processor located within the OMAP 4430 even not able to decode videos in real time analysis alone. Decoding process for the same video cannot be finalized at the same time in solo ARM structure when the compare with decoding on ARM + DSP structure of same video.

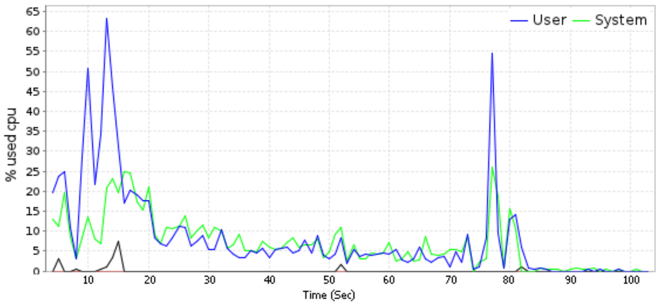

Fig. 3 Load values on ARM during the decoding of Mkv video file with the help of DSP core

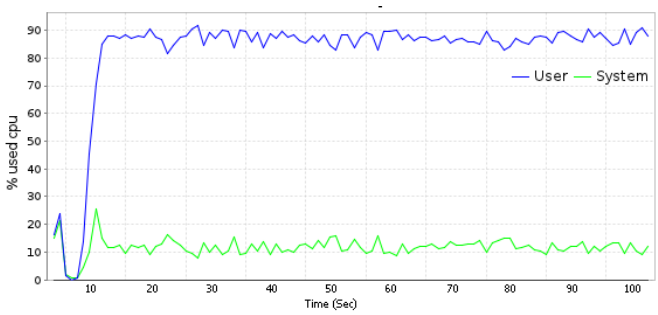

Fig. 4 Load values on ARM during the decoding of Mkv video file with non-DSP support

As a stand-alone decoding on 1.2 GHz dual-core ARM processor is maintained behind the schedule. As can be seen in Figure 4, during the 100 sec. recording, decoding process is not completed. This led to the shift in video playback. 24 seconds delay measured between the frames at 50^{th} second of decoding of the videos on stand-alone ARM and ARM + DSP structures (Figure5).

Fig. 5 Frames at 50^{th} second of decoding videos. Difference between ARM and DSP cooperated system (left) and stand-alone ARM system (right) is measured as 24 seconds. Lag can easily seem while decoding videos on stand-alone ARM systems.

Graphs about the decoding avi video format encoded with DivX codecs presented in Figure 6 and 7. Avi encoded videos can be decode more easily than Mkv format [13]. As shown in figure 6, there is heavy load on ARM without DSP support similarly as mkv decoding process in Figure 4. However 1.2 GHz ARM dual core speed suffices for avi decoding operations with 2 seconds delay at high CPU usage rate.

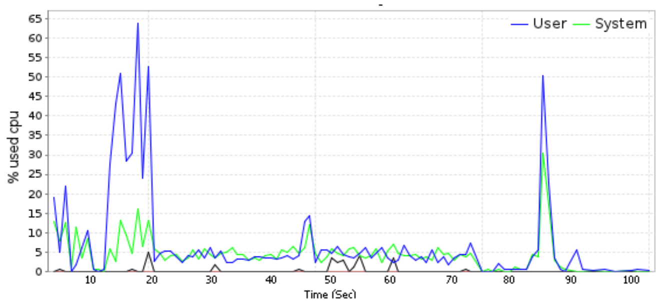

Fig. 6 Load values on ARM during the decoding of Avi video file with the help of DSP core

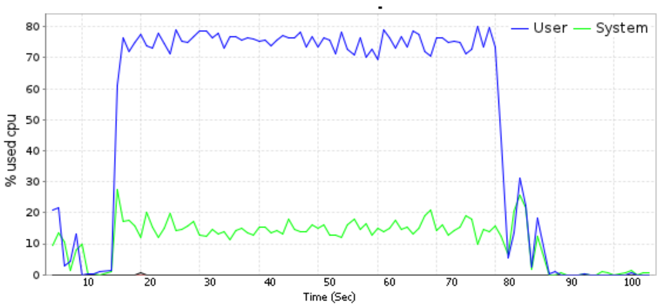

Fig. 7 Load values on ARM during the decoding of Mkv video file with non-DSP support

2 seconds delay can be seen in Figure 8. Same frame capturing method implemented with the previous one (Figure 5).

Figure 8. Frames at 50th second of decoding videos. Difference between ARM and DSP cooperated system (left) and stand-alone ARM system (right) is measured as 2 seconds. Lag problem is not effective in decoding of avi format.

The data obtained from the decoding of videos in mpeg format, are shown in Figure7 and 8. Compared to avi and mkv formats, decoding process more easily carried out and it is almost terminated at the same time whether with DSP support or not. Latency values are under 1 second (Figure 11).

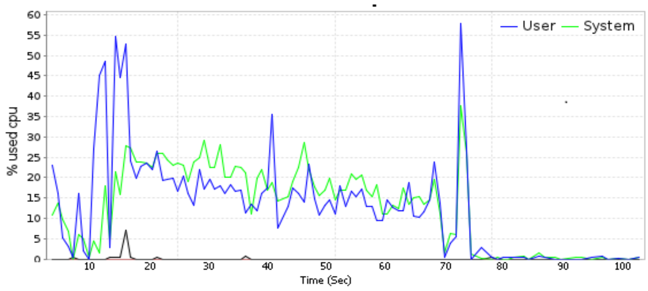

Fig. 7 Load values on ARM during the decoding of Mkv video file with the help of DSP core

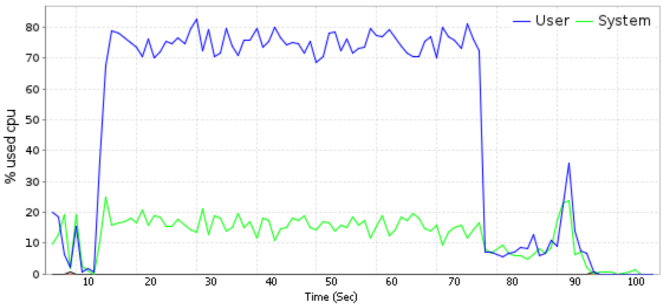

Fig. 8 Load values on ARM during the decoding of Mkv video file with non-DSP support

Fig. 11 Frames at 50th second of decoding videos. Difference between ARM and DSP cooperated system (left) and stand-alone ARM system (right) is measured as only 0.32 seconds.

V. CONCLUSION

In this study, the results presented in section 4 show that, the central processing units' loads are reduced thanks to DSP Units added within the systems next to the CPU. As a result, the processor remains idle, and these areas can be used for other tasks. Better performance results can be achieved with these chips known as SoC instead of stand-alone ARM structures.

Average load values generated by decoding 60 seconds test videos within 100 seconds records on ARM and efficiency rate of using DSP can be seen in table 2.

TABLE II
Average CPU Rates for DSP and None DSP Systems while Decoding

Format	ARM (%)	DSP + ARM (%)	Efficiency
Mkv (Matroska)	89	15	5.93
Avi (DivX)	76	11	6.90
Mpeg (MPEG)	74	14	5.28

As can be seen in Table 2, DSP cores are playing a mitigating role on ARM and helping system to speed up. First column of the table represents average of 100 seconds recorded loads on ARM systems without DSP integration according file extensions on left column. Second column shows the same issue but results gathered from DSP integrated system. Video files' extensions on the left column is hallmark in that column as well. The third column gives an idea about the quality factor on decoding applications. It represents efficiency ratio between ARM and ARM + DSP systems on decoding processes.

The results presented in this study prove that stand-alone ARM systems are inadequate for the operations such as video encoding or decoding. ARM + DSP structures should be used for better and long term solutions. Even in some cases as a result of inadequate structure of the ARM + DSP combination, SGX graphic cores are also added in addition to the these systems. Thus, researchers have engaged in research to design systems which can operate in high efficiency with low power consumption such as Pandaboard. However, some problems still be observed in this case. Speed of the cores is the most of the ruthless problem to be tackled. As a result of 32 bit microprocessor architecture of ARM, they can't catch up Intel 4-cores CPUs in speed [14]. Even the SoC structure with SGX and DSP unit, it is impossible to achieve. However, in the future, when the structures become 64-bit instead of 32-bit and DSPs have more expanded bandwidth for controls and data acquisition, aim will be achieved and results are expected to be more efficient [15].

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