Impact of Internet on Business Activities in Serbia and Worldwide

Uticaj Interneta na poslovanje u Srbiji i svetu

DOI: 10.15308/SINTEZA-2014-882-886

APPLICATIONS OF THE SINGLE BOARD COMPUTERS IN THE SOFTWARE DEFINED RADIO SYSTEMS

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Abstract:
In this paper, we present applications of single board computers in the systems of software defined radio (SDR). In recent years, single board computers gained tremendous boost. Using operating system, this systems on chip are very versatile and able to execute various extensive tasks. Their applications vary from supervision and monitoring, to implementation of low level system functions. We presented applications of single board computer to software defined radio receivers and transmitters.

Key words:
Single board computer,
Software defined radio,
Networking.

INTRODUCTION

In the last ten years, there is a tendency of exponential growth of numbers of gates per chip. It is not unusual to see chips accomodating more then billion gates. Hence, almost every modern complex chip becomes a computer. Nowadays, decisive factors for overall system performances can be summirized in following: software, board size, and time-to-market. Small computer units offering versatile functionalities have appeared lately. Special class of this computers are known as single board computers (SBC). A single-board computer can be defined as a general purpose computer built on a single board with microprocessor(s), memories, input/output(I/O) ports and other features of a functional computer. In this paper we describe applications of SBC in systems of software defined radio (SDR).

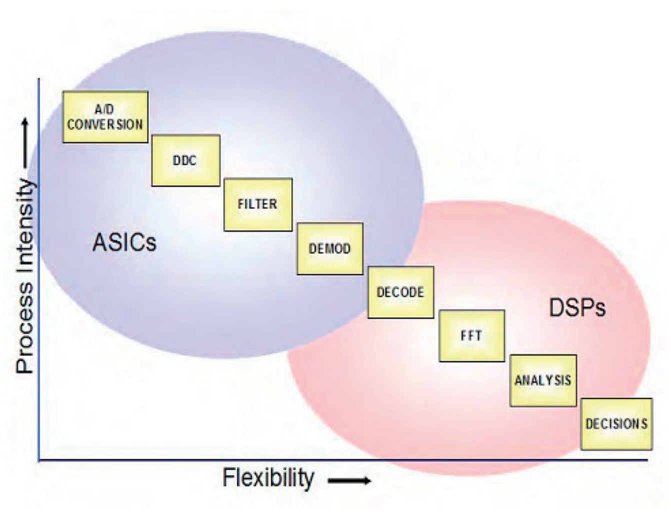

Fig 1. Most important signal processing tasks associated with SDR systems, according to [1]

The concept of a software radio refers to a class of radios that can be reprogrammed and thus reconfigured via software, using as much open source hardware and software as possible,

and especially commercial off-the-shelf (COTS) components. It means that SDR represent type of radios that are substantially defined in software and can significantly alter their physical layer behavior through changes to their software.

According to [1], some of the most important signal processing tasks associated with SDR systems are shown on a two axis graph, with compute processing intensity on the vertical axis and flexibility on the horizontal axis (see Fig. 1). Flexibility means the uniqueness or variability of the processing and how likely the function may have to be changed or customized for any specific application, [2]. At the lower right are tasks like analysis and decision making which are highly variable and often subjective. Programmable general purpose processors (GPP) or DSPs are usually chosen for these tasks since these tasks can be easily changed by software, [1].

Single board computers were created as demonstration or development systems, not only for educational systems, but also as controlling units in embedded systems. The idea behind this concept was to integrate all functions of conventional computer onto a single printed circuit board. Single board computers does not rely on expansion slots for peripheral functions, which makes main difference in comparision to desktop or laptop personal computers. Historically, this type of computers were being designed using various architectures of microprocessors. As well as this, range of their apllications was growing with time. Today we have a situation where most of modern devices have at least one SCB. Enormous increase in processing speed and versatility of SBC, together with a size, power consumption and cost reduction, give us opportunity to use SBC as a COTS SDR platforms.

ARCHITECTURE OF SINGLE BOARD COMPUTERS

Single board computers emerged owing to the increase of integrated circuits density. Smaller overall size and costs of the system can be obtained by putting all the functionalities on one board. One way to do this is by reducing the number of circuit boards required, and by eliminating connectors and bus driver circuits.

Basic buliding blocks of SCB architecture are processor core, memory banks, buses and peripherals. Internal data bus is used to connect all the system's blocks. New multicore processor architectures over 1 GHz are now common feature of SCB platforms. General architecture of single board computer is shown on figure 2. Here, accent is put on a concept of SCB, not necessarily on an exact configuration of peripheral units.

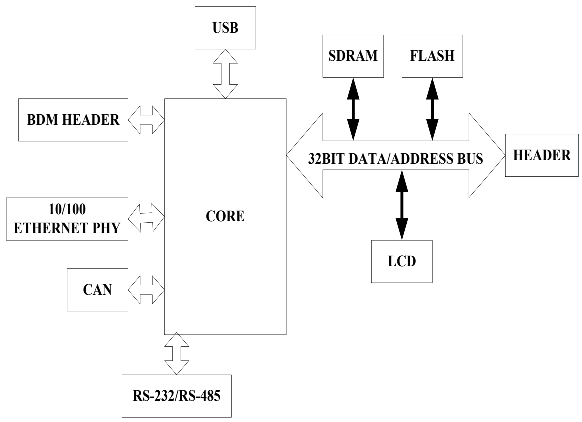

Fig. 2. Architecture of single board computers

Numerous SCBs use standardized form factors intended for use in a backplane enclosure. For instance, PCI, PCI Express, PXI, VMEbus, VXI, and PICMG. SBCs are based on various processor architectures, such as Intel architecture, multicore architectures, RISC etc. Thus, it is equivalent with the system built with a motherboard, except that the backplane determines the slot configuration. Single board computers also have connectors to allow a stack of circuit boards, each containing expansion hardware, to be assembled without a traditional backplane. SBC supports various standards for form factor and computer bus, such as PC/104, PC/104-Plus, PCI-104, EPIC, and EBX.

Given the fact that SCB is in its essence embedded system, various OS are running on its internal or external memories. As it is known, Windows OS is dominant on desktop PCs. However, presence of Linux OS in embedded systems is pronounced. Linux is open-source OS, characterized by high reliability and easy networking which is appealing for embedded applications in general. Various Linux derivates are common features of numerous SCBs. On one hand, we have Debian linux which is quite bared OS highly oriented toward embedded applications, and on the other hand, we have uBuntu OS, which is more user-friendly but also more bulky (memory resources). Pros and cons of both types of OS could be better overviewed in relation to specific application.

There are numerous advantages of single board computers over the bear-metal processors, usually implemented in low level embedded applications. Firstly, using OS gives large benefits in sense of easy networking, which is of utmost importance in the embedded applications. Also, various complex peripheral units could be easily approached, whereas by bear-metal processors, complicated drivers have to be written. Furthermore, it can not be neglected that SCB are working with much higher system clocks (often around few GHz), so that many demanding task are being performed in real time.

Also, segment of man-machine interface is rapidly growing, especially in recent years. This could be explained due to the availability of panels with better brightness, wider viewing angles, and lower costs. SCBs usually offer video/display support (LCD panel) directly integrated on the board.

Due to the reliability problems with connectors, many SCBs are now commonly defined across two distinct architectures: no slots and slot support. Embedded SBCs are units providing all the required I/O as s standlone boards. When we speak about possible applications of SCBs, they are so versatile, rangling from typically gaming applications (such as slot machines, video poker), machine control, to the radio systems etc. Single board computers are most commonly used in industrial situations where they are used in rackmount format for process control or embedded within other devices to provide control and interfacing. Due to high level of integration, reduced number of components and connectors, SBCs are in many cases smaller, lower in weight, more power efficient and more reliable in comparision to multi-board computers. When comparing conventional motherboards usually found in personal computers with SCBs, one might point out that former offers lower costs due to the high volume production. Also, letter is positioned in specialized market, therefore manufactured in much smaller numbers with the higher cost. On the other hand, embedded SBCs are much smaller (more compact size) with I/O resources (on-board digital and analog I/O, on-board bootable flash memory) more oriented toward industrial applications. Also, it should be added that very cheap SCB platforms are emerging constantly, [3].

In recent years, one can observe tremendeous growth of internet and intranet technologies. Rapid adoption of these techologies is primarily driven by consumer market. Serial interfaces are onboard features of every new developed SCB, no metter is it RS-232, USB or Ethernet. Need for connectivity and networking is emererging demand that defines onboard peripherals of SCB. Thus, recognizible feature of every SCB is support for various communication protocols. One of the well-known and utilized transport protocols is the Transmission Control Protocol (TCP/IP), which is used for connection-oriented transmissions. On the other hand, the connectionless User Datagram Protocol (UDP) is used for simpler messaging transmissions, but there is no control over the transmission process. TCP/IP is the more complex protocol, due to its design incorporating reliable transmission (acknowledgement) and data stream services. Other protocols that are frequenlt used are the Datagram Congestion Control Protocol (DCCP), Resource Reservation Protocol (RSVP) and the Stream Control Transmission Protocol (SCTP).

There are two configurations of SCBs: single core and multi-core architectures. Single core configurations have CPU frequencies up to 1.5GHz, whereas multi-core architectures work up to 7GHz. We can make comparision between two widespread SCBs, Beaglebone [5] and ODROID X2 [6]. Comparision of main differences and similarities is shown in table 1.

Table 1 Comparision of SCBs

SCBs	Comparision of SCBs		
	Type	Beaglbone	ODROID X2
1.	Architecture	ARM	ARM
2.	Number of cores	1	4
3.	CPU frequency	1GHz	1.7GHz
4.	Supported OS	Linux, Android	Linux, Android
5.	RAM	256MB	2GB
6.	Area	42cm^2	82cm^2
7.	Onboard Storage	0 MB	0 MB
8.	External Storage	MicroSD, USB	MicroSD, USB
9.	Ethernet	Yes	Yes
10.	Video Output	No	HDMI
11.	Price	50€	150€
12.	Price per MHz	0.05€	0.1€
13.	Price per MB	0.2€	0.075€

As it can be seen from the table, these two SCBs are typical representatives of their groups. On one hand, we have Beaglebone, a flexible board with compact size and low price. On the other hand, ODROID X2 is high end board with the most CPU power and the most RAM, suitable for demanding applications as it gives best performance/cost ratio. Therefore, application itself determines the choice of SCB. Furthermore, there are some other factors that should be taken into consideration, for instance: choice of OS, network connectivity, GPIO ports, types of connectors available and support of the SCB.

APPLICATIONS OF SINGLE BOARD COMPUTERS

In order to present applications of single board computers in modern radio systems, term of software radio must be thoroughly explained. Software-defined radio is a concept of a radio system which performs the required signal processing, replacing dedicated hardware by software. The main benefit is the flexibility of concept, having in mind that software can be easily replaced in the radio system. Therefore, same hardware can be used to design radios for many different transmission standards; consequently, one software-defined radio module can used for a variety of applications.

GNU Radio

GNU Radio is a open-source software development platform oriented toward signal processing based on blocks that implement particular functions of software radios, [7]. It can be used in conjuction with external RF hardware to design software-defined radios. In addition to this, GNU radio can be used without hardware in a simulation-like environment. Main purpose is to support not only wireless communications research but also real radio systems. Core concept of GNU radio is shown on figure 3.

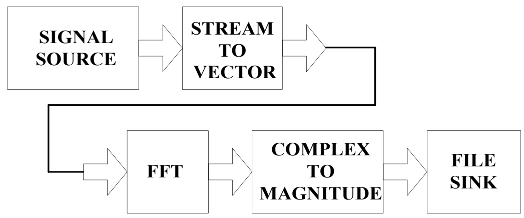

Fig. 3. Concept of GNU Radio

As it can be seen from figure 3, every block performs partcicular signal processing function. Hence, this concept allows you to design every part of the system independently, which gives tremendous flexibility. Furthermore, complete processing is performed digitally, which gives certain degree of controlability.

GNU Radio is versatile as it allows you to write applications to, for example, receive or send data, which is then transmitted or received using hardware. GNU Radio has all elements that are typically found in modern radio systems. For instance, modulators, demodulators, filters, channel codes, elements for synchronisation, equalizers, vocoders, decoders etc. These blocks mutually communicate by transfering data in various formats, such as bits, bytes, vectors etc. Furthermore, GNU radio provides a method of connecting these blocks and then manages how data is passed from one block to another. In addition to this, that to extend GNU Radio is almost trivial task.

As it was explained, GNU Radio is software concept. Hence, it can only handle data in digital format. Usually, complex baseband samples are the input data type for receivers and the output data type for transmitters. Analog hardware is then used to shift the signal to the desired central frequency. This concept is presented in next two subsections.

Critical signal processing part in GNU radio is developed by means of C++ programming language, using floating-point extension. Other parts are written by Python programming language. This way, real-time radio systems are implemented using user-friendly application-development environment. Advantage of GNU radio concept is the fact that allows development of algorithms for digital signal processing based on pre-recorded data. This way, actual RF hardware can be avoided. It should be added, that platfom used to implement GNU radio concept is SCB based platform.

Wideband RF receiver

In this case, GNU radio concept is used in conjuction with RF hardware (analog part) to provide functionalities characteristic for high performance radio receivers. Therefore, this concept is based on symbiosis of analog and digital world. The block diagram of one radio receiver is presented on figure 4. As it can be seen form the figure, basic parts of the system are: Single board computer (SCB), Low-noise amplifier (LNA), Automatic gain control (AGC), Filter bank and Mixer. SCB control and supervise whole system. It sets frequency of local oscillator, select appropriate filter and adjust gain needed. Therefore, signal conditioning is performed. After that, signal processing in digital domain is performed, [8]. Also, functions such as sending I/Q data over LAN to other parts of network are usually performed in complex radio systems.

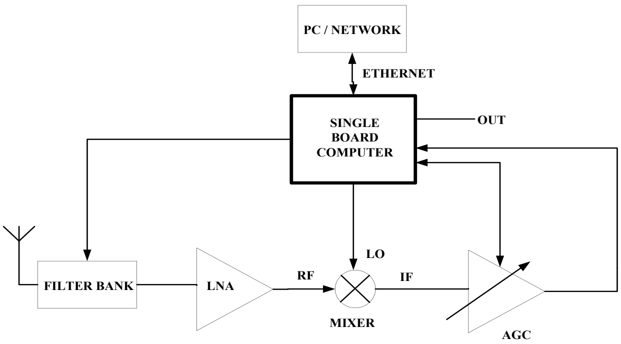

Fig. 4. Application of single board computers in radio receivers

Wideband RF transmitter

GNU radio concept can be also implemented in conjuction with RF hardware (analog part) to provide functionalities characteristic for radio transmitter. As it was mentioned in previous subsection, this concept is hybrid of analog and digital domain. The block diagram of one radio transmitter is presented on figure 5.

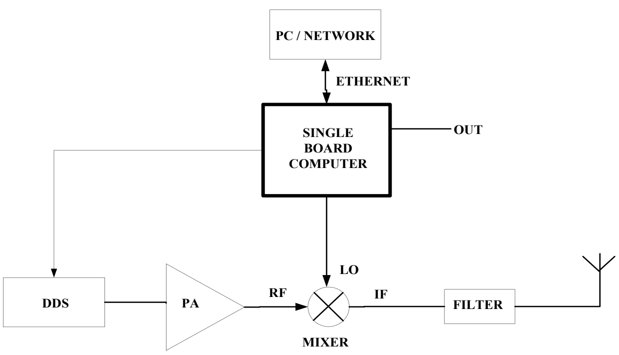

Fig. 5. Application of single board computers in radio transmitters

From figure 5, it can be seen basic parts of the system: Single board computer (SCB), Power amplifier (PA), Automatic gain control (AGC), Filter and Mixer. Generation of signal is based on direct synthesis in digital domain (DDS). The DDS provides digital domain generation of frequency-agile tone with outstanding level of residual phase noise, [9], [10], [11]. In its essence, direct digital synthesis might be considered as frequency synthesis that produces arbitrary signal waveforms based on fixed-frequency reference clock.

Signal synthesized in digital domain is now amplified, filtered and driven to the antenna. DDS uses profiles, which represent independent registers with signal control parameters (frequency, amplitude and phase). Each profile is independently accessible using three external profile pins to select the desired profile. Using SCB, all parameters of DDS are fully programmed. Papers related to this topic can be found in [12] and [13].

CONCLUSION

Single board computers are building blocks of every modern radio design. The most widely used off-the-shell SCBs are small embedded computers, as they allow simple transformation from hardware level into powerful computing platform at a modest price. It should be mentioned that there are advantages and disadvantages of this concept. On one hand, SCBs reduce development time for faster time-to-market. As well as this, many vendors offer various size, function and price range. On the other hand, it is not cost effective for large volumes. But, the presence of an easily programmable and reconfigurable COTS SDR platforms in the research arena, together with appropriate software design tools, could accelerate innovation and stimulate more rapid deployment and verification of new ideas, providing the processing power, scalability and reconfigurability required by today's communications problems.

Acknowledgment

This research has been supported by Ministry of Eduaction, Science and Technological Development of Serbia through the project TR 32051 in the field of software defined radio.

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