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Survey: Internet of Thing Using FPGA

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Abstract *Everything in its way to be computerized and most of the objects are coming to be smart in present days. Modern Internet of Thing (IoT) allows these objects to be on the network by using IoT platforms. IoT is a smart information society that consists of smart devices; these devices can communicate with each other without human's intervention. IoT systems require flexible platforms. Through the use of Field Programmable Gate Array (FPGA), IoT devices can interface with the outside world easily with low power consumption, low latency, and best determinism. FPGAs provide System on Chip (SoC) technique due to FPGAs scalability which enables the designer to implement and integrate large number of hardware clocks at single chip. FPGA can be deemed as a special purpose reprogrammable processor since it can process signals at its input pins, manipulate them, and give off signals on the output pins. In this paper, using FPGA for IoT is the limelight.*

Index Terms— **FPGA, IoT, Altera, Xilinx.**

I. Introduction

There is no universal definition for the term IoT; different definitions are used by different parties, foundations, and groups to describe a specific view of what IoT means.

In [1] IoT is defined as *a system that permits the devices for communicating with each other directly without human intervention.*

In 2012, The International Telecommunication Union (ITU) published an overview of the Internet of Things and IoT is defined *as a global infrastructure for society of information that enables interconnected things to communicate with each other and performs advance services based on existing and evolving interoperable information and communication technologies.* [2]

In [3], many definitions of different groups have been promoted. In a call for papers for a future topic issue of IEEE communication journal, IoT is defined as *a framework wherein all things have a representation and existence in the internet. IoT goals for offering new applications and services bridge both physical and virtual worlds.*

Also as recorded in [3], a definition of IoT is offered by Oxford Dictionaries that defines IoT as: Internet of Things (noun): *The interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data* [4].

For the purpose of this paper, IoT can be defined as a smart society consisting of smart devices that can communicate with each other through the cloud without human's intervention.

Information can be share among certain devices through the internet. Such devices are smart devices include smart phones, tablets, PCs, and so on (see Fig. (1)). Many other smart devices have been introduced recently which can communicate with each other using the internet and other communication techniques. These techniques include RFID, near-field communications, various types of barcodes, and so on. The capabilities of communications are built in and allows for new services. [1]

Internet of Things is the technique of machine talking to each other which is called device- to-device communication or machine-to-machine communication (M2M). [1, 3]

Fig. (1): IoT World.

In this paper, introduction to IoT and its basic concepts have been reviewed also a discussion about using FPGAs for IoT systems is presented in this research.

The rest of this paper is organized as follows: section II presents the related works, the revolution of IoT discussed in section III, in section V, the most popular IoT systems are mentioned, FPGA for IoT presented in section IV, the advantages of using FPGAs in IoT platforms has been discussed in section VI, and finally, conclusions are discussed in section VII.

II. Related Works

In [5], Ajay Rupani and Diskshant Pandey have publish a review and study of FPGA implementation of Internet of Things at International Journal of Science Technology & Engineering (IJSTE), they discus a vision of IoT as a future. They discus that IoT becomes a utility with increased sophisticated in sensing, actuation, communications, control, and in creating knowledge from vast amounts of data. Also they discuss how the FPGA can be used to achieve IoT in different applications.

In 2015, Sang Don Kim and Seung Eun Lee were implemented an IoT environment configured using Altera FPGA. In this research, the researchers present a temperature and humidity monitoring system in which the temperature collected using external sensor which communicates with FPGA via the USART2 and the results are displayed using VGA monitor. [6]

In [7], a web server architecture has been proposed and implemented using FPGA and the authors are illustrated the concepts of network reconfigurable FPGA-based web service.

Different proposed methodologies of IoT based FPGA are discussed in [8], the authors suggested tease low cost FPGA for implementing IoT subset including TCP/IP protocol, control system, and data acquisition. Also they suggested demonstrating the IoT systems by implementing a multi sensor control system connected to Internet Server & a Server Application running on a dedicated IP with control & data logging facility.

Gasim Alandjani and et.al. propose an ECG machine design on FPGA using capacitance scaling technique while the device is operating on various WLAN specific frequencies. The design an energy efficient ECG based FPGA to get fundamental knowledge about proper functioning as heart. Xilinx Kintex-7 FPGA device is used in this research to design the ECG system. [9]

III. IoT Revolution

In 1999, the term "Internet of Things" (IoT) was used for the first time by British technology pioneer Kevin Ashton to illustrate a system wherein physical world devices could be connected to the Internet via sensors. [2]

Relatively, the term "Internet of Things" is new which is the concept of combination the computers and networks to monitor and control devices. This concept has been around for decades. For example, systems for monitoring meters remotely on the electrical grid via telephone lines were implemented at the late 1970s. In the 1990s, advanced wireless technology allowed machine-to-machine (M2M) enterprise and industrial solutions for monitoring equipment and operate to become widespread. Later the IP was used to connect devices to the internet like soda machine at Carnege Mellano University in US and a Coffee pot of the Trojan Room at the University of Cambridge in the UK which remained Internet connected until 2001. [2]

In the International Economic Forum (Davos), the head of Google Eric Schmidt in his speech he said: "There will be a lot of Internet addresses, which are a numerical addresses customized for each machine, and to a lot of smart devices, sensors and interactive tools to the degree that you will not feel the existence of the Internet on it, it will become like the air we breathe without feeling it. Then added: Imagine entering an interactive room, and be able to communicate with all smart devices in this room!" mentioning to the evolution of smart devices and devices to attire technology which are connected to the Internet. [5]

The Internet of Things is still in its beginning and the possibilities are endless. By comparing the use of internet today to how the internet was envisioned just 25 years ago, the growth of the Internet of Things sensed as being potential inherent. [1]

By 2010 billions of devices are expected to be connected wirelessly [10].

V.IoT Applications and Examples

Many products could be buy and they are Internet connectable. The following applications and examples are popular as IoT products. Fig. (2) illustrates IoT applications of schematic form.

1. **Wearables:** these are device-to-device development. Many wearable products have been implemented.

For example: wearable health care devices.One of the newest wearable items is Google Glass device which is enabled people to use numerous Internet applications on the go. [1]

2. **Connect Vehicles:** for example the car navigation system or mapping applications of the smart phones that enabled the folks to find their way for unfamiliar places. [1]
3. **Home Automation:** usually, these systems use small data packets of information satisfy the communication between devices with relatively low data rate requirements [2]. Smart thermostats, smart appliances, intelligent lighting, and many otherses smarted house devices are home automation scenarios [1].
4. **Location-based services:** many useful services of location based can also provide by Internet of Things. Automate notifications, tracking children, eldercare, and location-based marketing are examples of location- based services. [1]

IV. FPGA for IoT

Prototypes based FPGA, specifically geared to meet the design and verification constrains resulted by the complexity of IoT devices [11]. FPGA is a device that was made of thousands or even millions of transistors which are connected to perform logic functions. FPGAs perform functions of simple addition and subtraction to complex digital filtering and error detection and correction. Aircraft, automobiles, radar, missiles, and computers are examples of FPGA based systems. Xilinx, Altera, and Quicklogic are just some companies that manufacturing FPGA kits [12].

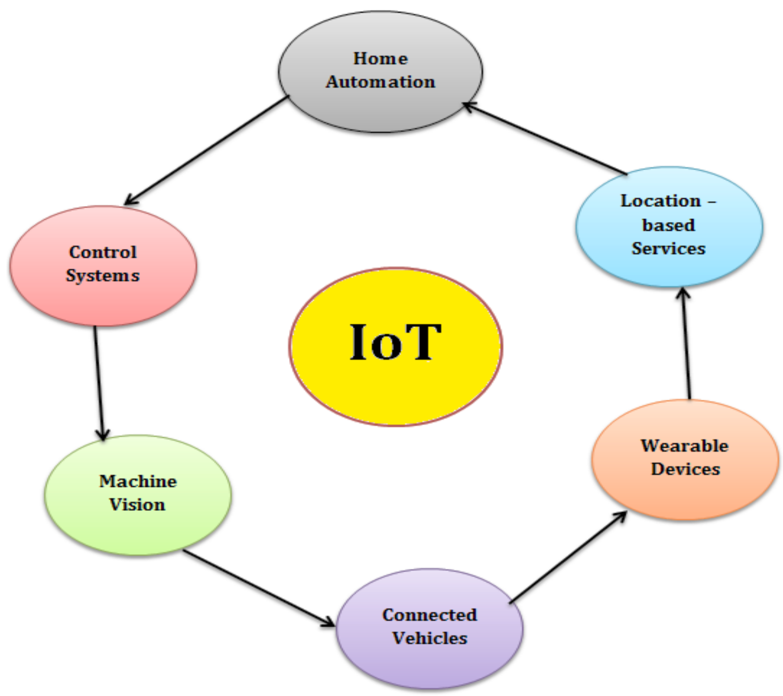

Fig. (2): IoT Applications.

Using FPGA for IoT fills the gap between hardware and software and offer many advantages such as: Flexibility, Reliability, Low cost, Fast time-to-market, and Long term maintenance. IOT is implemented on various FPGA devices to project various devices for several applications. [8]

Many designs of FPGA based IoT systems are discussed by Microsemi Power Metters [13].

Motor control system is shown in Fig. (3) below, Medical health care monitored is shown in Fig. (4), fig. (5) Shows the cloud based communications module, and fig. (6) shows control plane interface based FPGA.

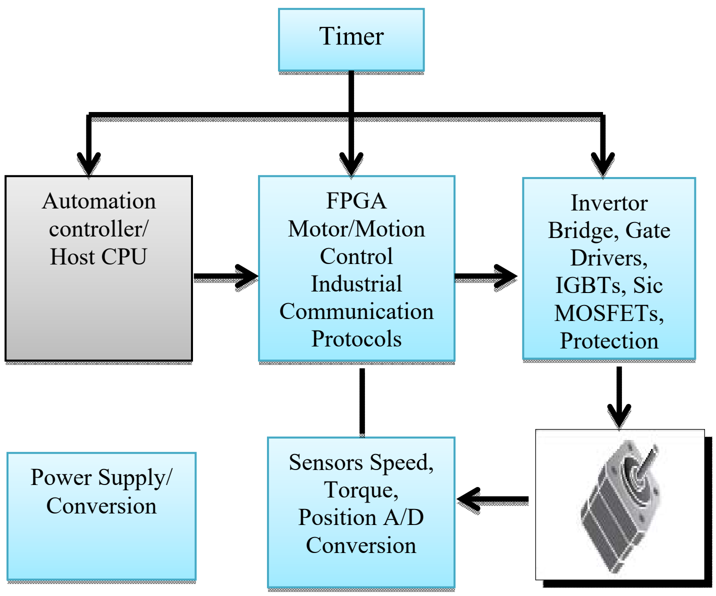

Fig. (3): Motor control system. [13]

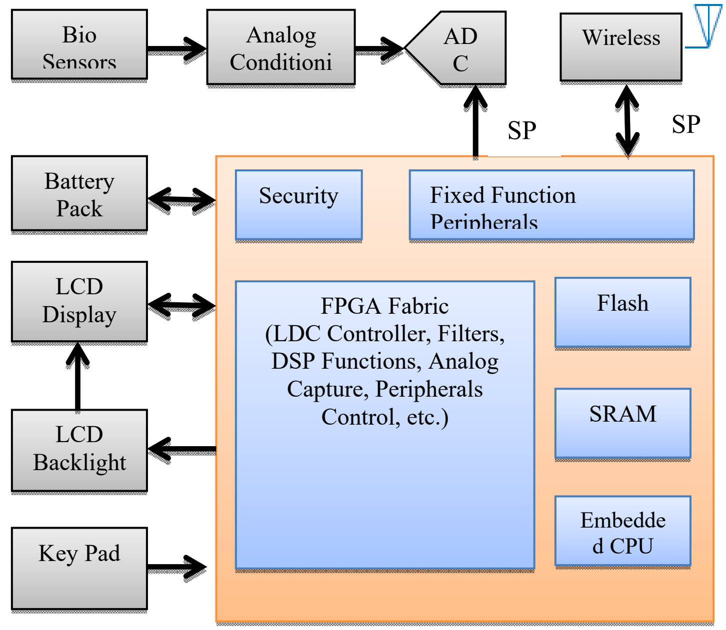

Fig. (4): Medical healthcare monitor system.

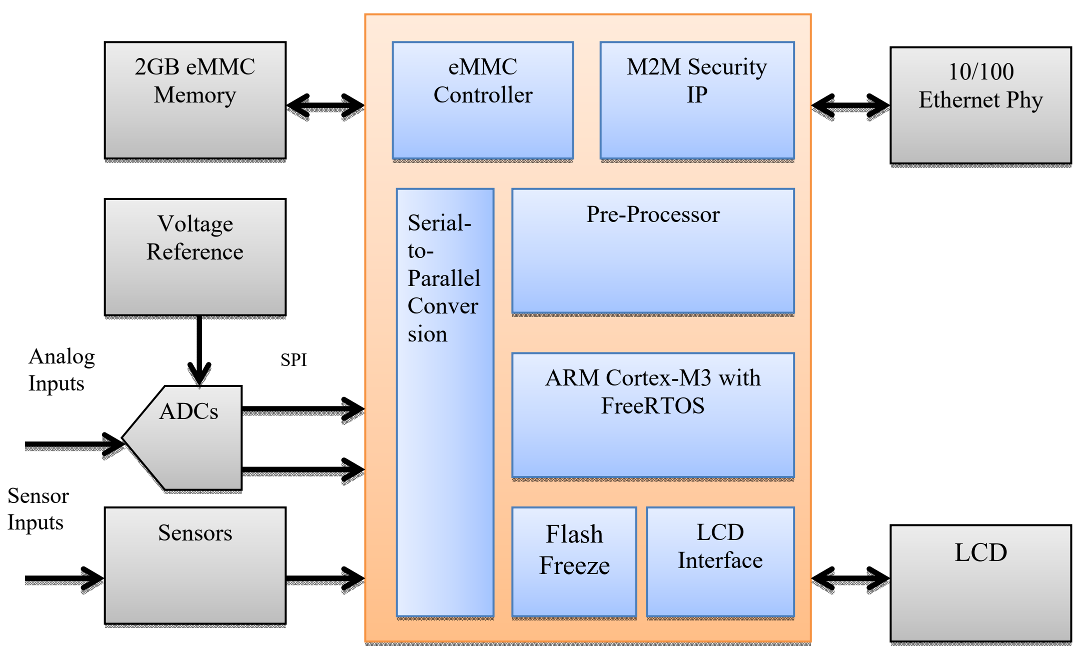

Fig. (5): Cloud based communications module.

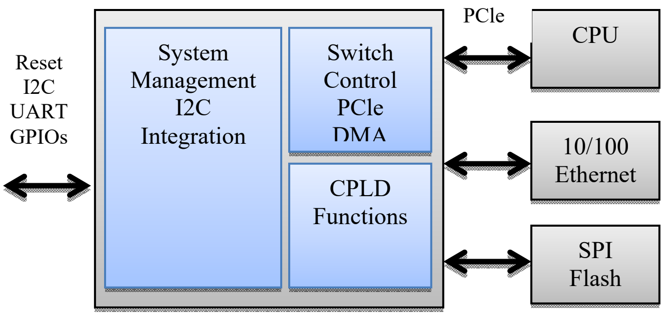

Fig. (6): control plane interface based FPGA. [13]

In present time, Intel FPGA (formerly Altera) provides many FPGAs based IoT systems. Smart city infrastructure and building automation, smart grid control, healthcare system infrastructure, car automotive systems, and machine vision systems can be seen at Altera web cite [14].

Altera offered many advantages to the manufactures, which are: [14]

1. Reduction of cost by avoiding ASICs' extensive.
2. Time to market advantage by avoiding the lengthy and risky development cycle.
3. Cost reduction and differentiation by integrating multiple ASSP functions into FPGAs.
4. Programmability during the design process and after equipment is in the field.
5. Reusability of one hardware platform for various systems with one basic design.
6. Adaptability to multiple industry standards and protocols.

Xilinx for FPGA also has an FPGA for IoT. [15] Many design examples can be seen on Xilinx web cite like: [15]

1. Single-axis motor control which is supported by Xilinx Sparton-7 FPGA kit.
2. Multi-axis motor control which is designed with Zynq-7000s All Programmable Soc.
3. Motor control which can be designed with Xilinx Kinetex-7 FPGA or with Zynq-7000s All Programmable Soc.

Xilinx provides hardware-accelerated torque control, speed control, and position control for single-motor and multi-motor applications for sensor and sensorless applications. [15]

VI. Advantages of FPGA for IoT

A field programmable gate array (FPGA) consists of a matrix of reconfigurable gates arrays form logic circuitry. When the logic arrays configured, these gates connected with a way that builds a hardware implementation of a software application. Gradually more tools are enabling the designers of embedded control system to create adapt FPGA-based applications more quickly and more easily. [16]

FPGAs are unlike processors; FPGAs are using hardware which is dedicated for logic processing and do not have an operating system. Different operations do not have to compete for the same processing resources since the processing paths are parallel. So that speeds can be very fast, and multiple control loops can run on a single FPGA device at different rates. [16]

The re-configurability of FPGAs provides the designers with unlimited flexibility. Christian Fritz, the product manager for motion control and mechatronics for National Instruments said: “Unlike hard-wired printed circuits board (PCB) designs that had fixed hardware resources, FPGA-based systems can literally rewire their internal circuitry to allow configuration after the control system is deployed to the field”. [16]

FPGA-based platforms may use for IoT prototypes for two purposes: [17]

First, a designer could deploy a platform based on FPGA according to the purpose of the platform, or could target an FPGA to implement a full-custom SoC application where the FPGA is used as a prototype of this application. Using the SoC Prototyping allows real-time functional verification and timing verification.

Second purpose is that FPGA-based prototype is perilous for producing an early validation of inexpensive platform design; automation of design is necessary for modeling, component selection, design space exploration, design entry and verification. Also, prototype of SoCs must consider that the achieved performance, power and size may not be as efficient as the final SoC.

Automation in wholly of the design processes is essential to make prototype fast and efficient, and to simplify the prototype translation into a design of the final SoC. [17]

VII. Conclusions

IoT is still in its infancy and the possibilities are endless. In the near future, FPGA will drive the IoT. IoT will interface with electricity, pressure, temperature, acceleration, position, Analog to Digital convertor (ADC), Digital to Analog convertor (DAC), and many other systems; FPGA, Arduino, Raspberry Pi, and Orange Pi are suitable to implement IoT platforms. Using the FPGAs in IoT systems provided Flexibility, Reliability, Low cost, fast time-to-market, and long term maintenance. The popular FPGA manufactures like Altera and Xilinx have started working on IoT by designing many IoT systems like control systems, machine vision systems, Artificial Intelligence systems, and many other FPGAs based IoT systems while many prototypes are in their progress to be completed. FPGAs have flexibility to implement IoT extendable systems. There is an expectation that the whole world become IoT world by 2020.

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