17th Symposium IMEKO TC 4, 3rd Symposium IMEKO TC 19 and 15th IWADC Workshop
Instrumentation for the ICT Era
Sept. 8-10, 2010, Kosice, Slovakia

Mobile-Learning on Electronic Instrumentation based on FPGA

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Abstract- Based on the availability of broadband connections, the development of mobile technology provides to final users more and more services. One of these is remote teaching that gives the possibility to students to choose time and place to study. The learner can remotely interact with an actual experiment and real devices placed in any other part of the globe by simply using a common Personal Digital Assistant (PDA). In this paper an application of remote teaching that combines mobile technology and Field Programmable Gate Arrays (FPGA) is given. The experiment is performed on an existing e-learning laboratory allowing remote control of FPGA applications. Example of an automatic railway remotely controlled is shown.

Keywords- Mobile learning, remote laboratory, digital electronics, FPGA.

I. Introduction

Thanks to the availability of broadband connections, in the last decade a great amount of engineering research has been focused its interest in the telework area, allowing the remote development, testing, updating and maintenance of digital systems. This new scenario has allowed to revolutionize several fields such as industrial processes, electronic measurements, digital electronics, etc.. As an example in industrial field, a project manager has no longer the physical bond to attend the work site, since he/she can physically control a process/application located in different parts of the globe using a Personal Digital Assistant (PDA) as mobile terminal connected to Internet. Also in the teaching and remote learning fields of electronic measurement and digital electronics applications, a lot of simulated and real experiments on analog and digital circuits, physically located in several distributed remote laboratories in the world, are available on Internet and can be remotely performed and controlled [1,2].

An interesting application of remote laboratory experiments is the hardware implementation of projects based on Field Programmable Gate Arrays (FPGA), large-scale integrated circuits designed to be configured by the customer or designer after manufacturing. In fact, FPGAs contain programmable logic components called “logic blocks” that can be configured to perform complex combinational functions. Moreover, FPGAs can be programmed several times and are more adaptable to specific requests of the customer with respect a custom Integrated Circuits (IC).

In the literature, examples of remote teaching and execution of FPGA applications have been presented in [3], but they are not manageable with a portable PDA.

In this paper the authors propose a new application on FPGA in VHDL (VHSIC Hardware Description Language) and its installation in an e-learning system that includes a geographically distributed laboratory [4,5].

The aforementioned framework allows remote control of FPGA-based applications and no additional software installation is required on client’s PDA/PC for operating on FPGA hardware. In this way the user obtain the full control simply using Web based educational environment. In order to fully understood what happen when a generic user try to connect at the laboratory server of the remote laboratory, the content access procedure has been divided in the following steps:

- The first part consists of providing to learners the theoretical concept, about FPGA technology and VHDL language, using didactic material available on the Web and accessible under the control of a Learning Management System (LMS).
- The second part consists of project simulation of digital circuits for ALTERA FPGA devices, using Quartus II software environment, accessible for learners by using Microsoft Remote Desktop Protocol (RDP).
- The third step allows an effective interaction with hardware, before checking the behavior of the real FPGA device (ALTERA MAX 7000S) and then operating on it by means of a dedicate software.

As previously mentioned, the data transmission and the remote control of the FPGA board are possible by means of specific software interfaces developed in LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) and accessible from the LA.DI.RE. (the acronym of the Italian “LAboratorio DIdattico REmoto”) remote didactic laboratory distributed over a geographic area [4].

In the following section the architecture description of the remote laboratory LA.DI.RE. realized at University of Sannio is given. Then, the ALTERA FPGA board structure, the realized experiment providing on-line interaction with an FPGA-based application are briefly described in section III.

II. The remote didactic laboratory

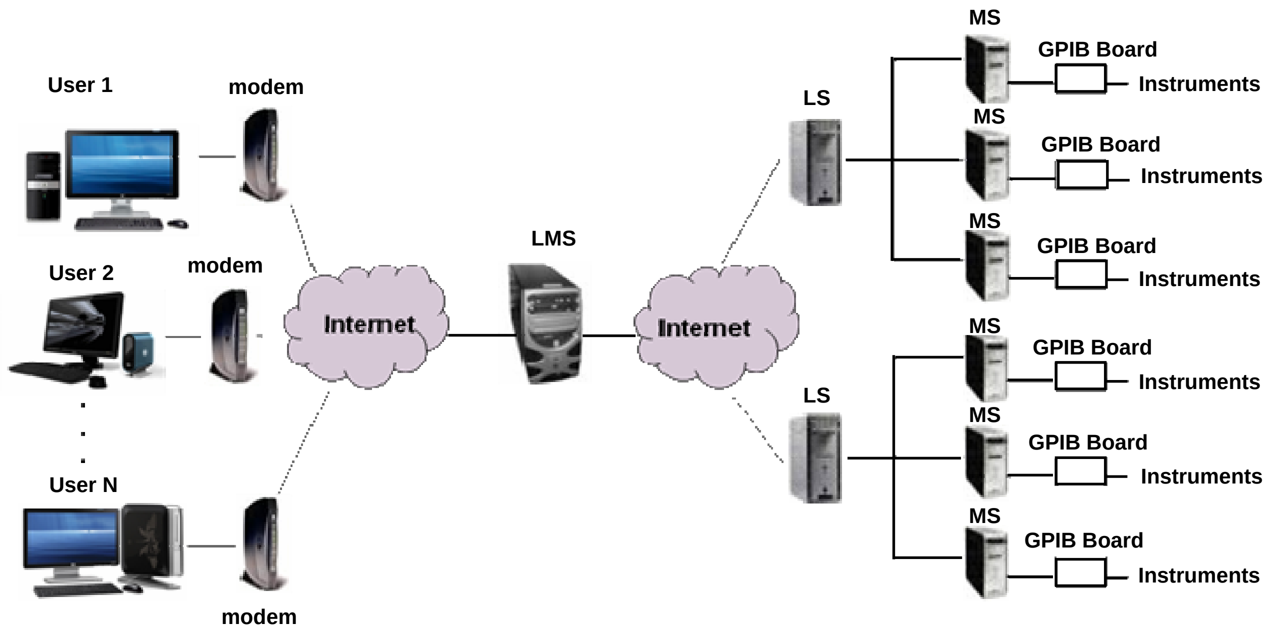

Fig. 1. The remote didactic laboratory structure.

The remote didactic laboratory LA.DI.RE. is composed mainly of three architectural layers. Afterwards, the main tasks for each layer are explained:

1) The presentation layer: it handles the display of the executable file on the client side by a common web-browser and operating system. The only required software is Java 2 Runtime Environment.

2) The intermediate layer: it manages the system from the server side and it is distributed as in Fig. 1:

   a. a Learning Management System (LMS) running on the central server called laboratory portal that interfaces with the outside world through the Web Server that resides on the same machine.
   b. one or more Laboratory Servers (LSs) which interface each laboratory with the distributed system. Currently there are three operating LSs at the University of Sannio in Benevento and at the University ”Mediterranea” in Reggio Calabria, Italy. It allows access and control of measurement instrumentation through a service called Bridge Service. The LS is the only machine in a laboratory that is accessible from Internet, other machines communicate by using local network. The LS can be used for access security services.
   c. one or more Measurement Servers (MSs) placed in the laboratory allow the interaction with one or more instruments. Each MS is physically connected to instruments via the IEEE-488 (GPIB) interface board. This interface allows to connect multiple measuring instruments to the same MS by means of Virtual Instruments (VIs) realized in LabVIEW. A multifunction data acquisition board allows to interact with circuits from scratch and to realize custom virtual instruments.

3) The storage layer: it manages the data relating to user profiles and data related to exercises or programs available in different laboratories. It is based on a set of geographically distributed databases, organized through the Relational Database Management System (RDBMS).

The realized VIs are stored in the MSs, where the LabVIEW environment is installed. No adjustments are necessary to include the VIs in the virtual learning environment and the remote user can access all resources, hardware and software, without need of downloading specific additional plug-ins.

III. FPGA board and realized experiment

A. FPGA board

The Altera UP1X board package consists of the following tools needed for development projects.
- Altera FPGA board UP1X;
- Altera Quartus II development software;
- Cable ByteBlaster for programming the FPGA board via computer using the parallel port of the PC.

FPGA Altera UP1X is a board based on two devices: the MAX7000S (EPM7128SLC84-7) and FLEX10K (EPF10K70RC240-4), as shown in Fig. 2.

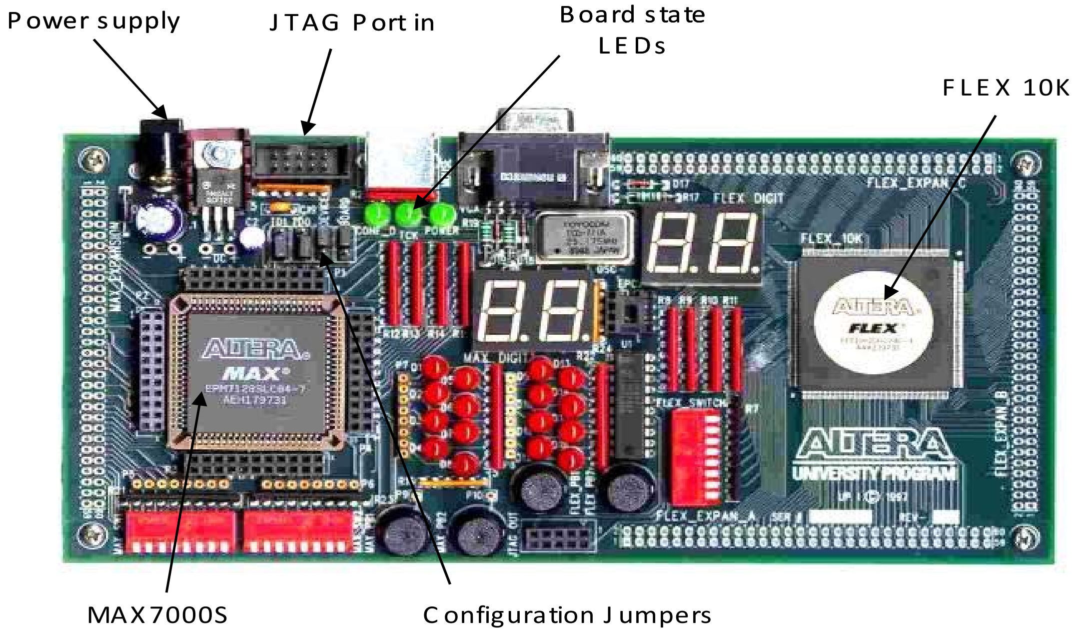

Fig. 2. AlteraUP1X main board.

The Altera MAX7000S is a multiple array matrix with a number of gates ranging from 600 to 2000. The device configuration is achieved by programming an EEPROM internal memory, thus the configuration is stored even without power supply. Altera FLEX10K (Flexible Logic Element Matrix - FLEX) is a family of FPGAs with a number of gate equivalent ranging from 10,000 to 250,000 and is programmed by configuring a SRAM memory. In this experiment only a few components of the UP1X board are used. A power input module, that receives either a DC regulated (DC_IN) or an unregulated (RAW Input) and feeds the internal circuitry, is located on the upper left top of the board. On the right of the power module, the JTAG Port in is used to connected the ByteBlasterMV cable. The three green LEDs, (CONF_D, TCK and POWER) inform the designer on the board state; the POWER light is always on when the board is properly powered, the TCK LED turns on during the programming process, while CONF_D LED turns on when the FLEX and/or MAX are configured. Several FPGA configurations are given by setting different position of the four jumpers, located between MAX7000S and JTAG connector.
Most of the components on the UP1X board are useful for local programming and test and, hence, were not considered in our experiments. Further details on these components can be found in [3,6].

B. The FPGA-based experiment

The proposed experiment is an example of a FPGA-based traffic control system of a railway station. Depending on the inputs entered by the user, the control system generate signals that rule 4 railway switches (points) to a position corresponding to a shift of the train from one track to another. Moreover, traffic signals system governs rail traffic, so that the simultaneous presence of two or more trains is managed by the common rules of precedence in order to avoid possible collisions. A sketch of the station under test, consisting of 5 tracks, is shown in Fig. 3.

The track marked as 1 is reserved for trains coming from North and going Southward, track 2 is for trains coming from South and moving Northward, while the track 3 is a “deposit” track that allows both the input and output trains. The tracks marked as 4 and 5 link the tracks 1-2 and 2-3, respectively. All points are marked with the following identification letters: S1, S2, S3 and S4 (see Figure 3).
As this system is a simple dynamic system that evolves with time depending on the user’s input signals, it can be modeled as a finite state machine. The inputs are the incoming trains that lead the system to a specific state, which is recognized by the user by means output signals.
The main precedence rule is that each train that no need to change its track has precedence over a train that is about to change its track.
As an example, in the case represented in Fig. 4a the train B (which does not change its track) have priority over train A, which has to go Northward but it is still on track 1. In fact, before to change the S2 and S3 points, the train A must await the departure of train B.

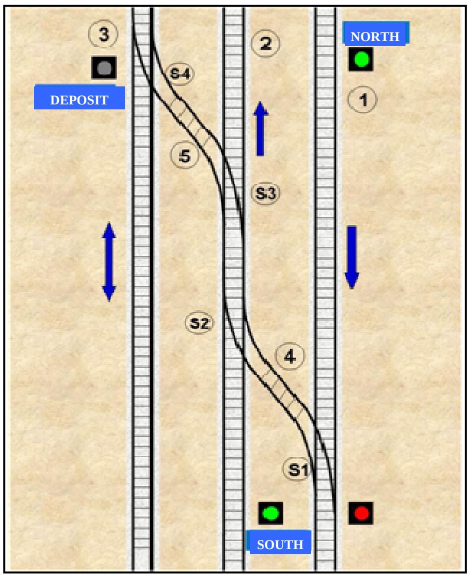

Fig. 3. Train station outline.

The main precedence rule is no more valid when the train B arrives as the train A is already on track 4, moving to track 2, as shown in Fig 4b. In this case, the point generates a red signal waiting to train B.

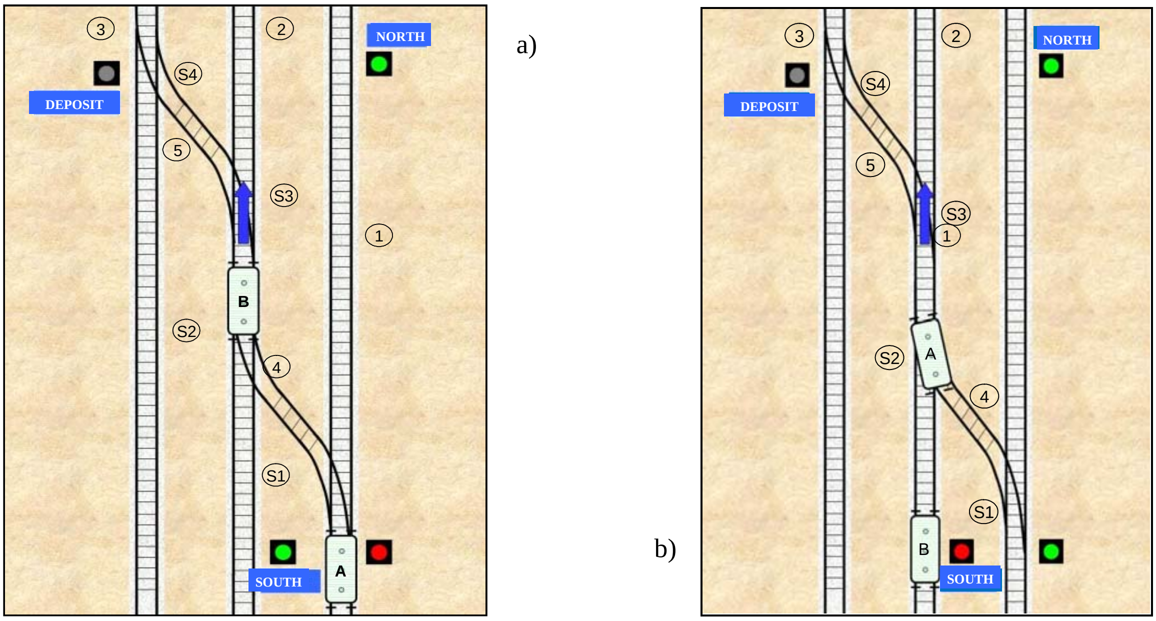

Fig.4. Railway station traffic examples.

C. The remote control of the FPGA-based experiment .

The set-up realized to remotely control the FPGA application described previously is shown in Fig.5. The user can execute the developed program on the FPGA board by connecting a common PDA to Internet. Then, after an authentication phase on the LMS, he/she is routed to the user interface of the program running on the FPGA board by means of a communication hardware interface.

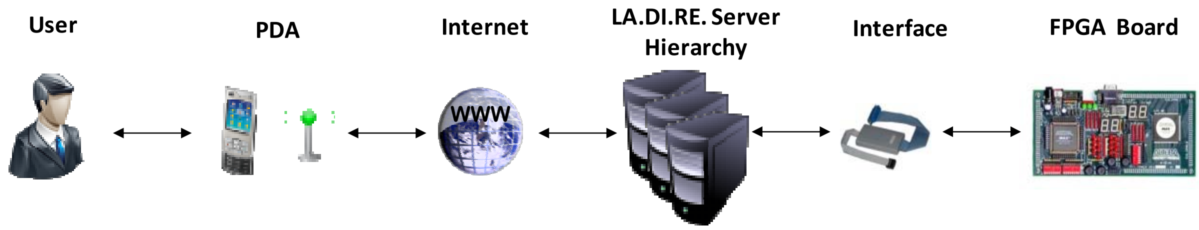

Fig.5. Remote configuration scheme.

In particular, remote control of the application running on the FPGA is given by the availability of:

1) a communication channel (Internet) that allows the data exchange between the remote client, that could be anywhere in the world and LA.DI.RE. LMS, that performs the user authentication and routes it to the specific LS;
2) a LAN including the LS and the MS that is physically connected to the FPGA;
3) several feedback signals from the MS indicating the FPGA operations to the client.

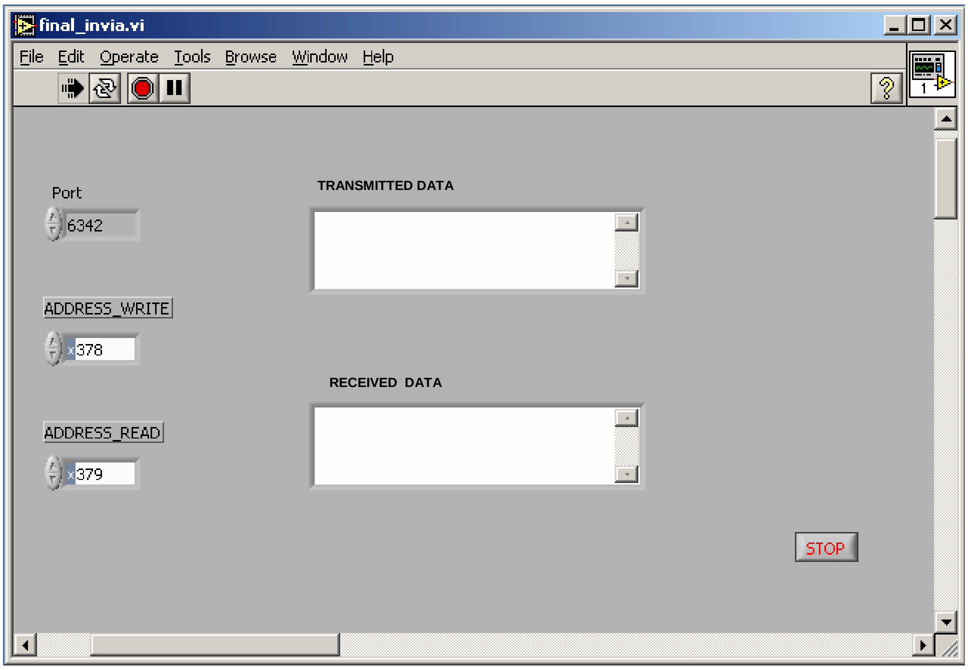

Fig.6. VI front panel

As previously seen, the remote control of the FPGA application has been realized by means of a specific software interface, a Virtual Instrument (VI) developed in LabVIEW, accessible from LA.DI.RE. web portal. The VI is capable of processing data from the Internet, in bit strings form, and of routing these data to the register of the parallel port connected to the FPGA board. As shown in Fig.6, a couple of text boxes were also considered in developing the VI, to account for local displaying of the input/output data flow between the FPGA and the network, as shown in Fig. 6.

SOUTH

a)

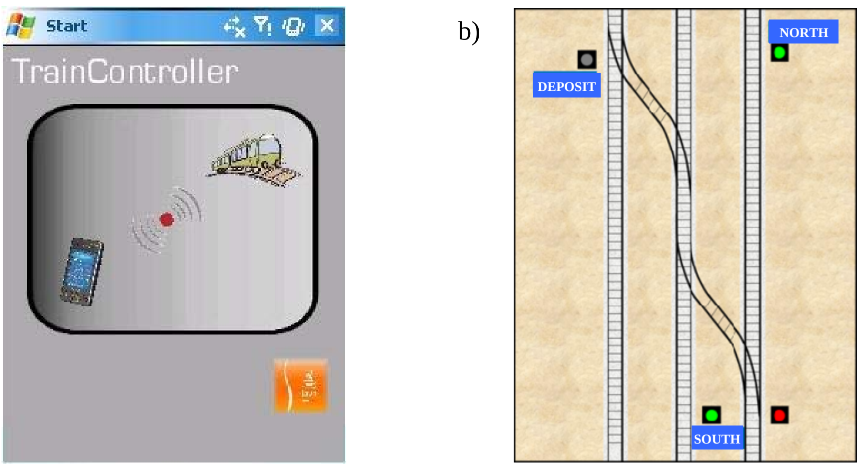

Fig.7. Remote PDA front panels.

The PDA thin client works as it follows.

1) When the application starts, a full screen image is displayed (Fig.7a), showing the application logo.
2) After that, an interactive graphical user interface representing the railway station, is shown (Fig.7b). The remote user has a continuous monitoring of the trains position and can also manage the train station incoming traffic. The remote user can select the incoming traffic and its destination while the FPGA application routes the traffic automatically.

IV. Conclusions

The evolution of broadband connections in recent years has allowed a fast and growing development of mobile applications in remote teaching. Combining FPGA technology, a remote didactic laboratory and a PDA, the paper presented a first and interesting application of mobile learning on electronic instrumentation that remotely controls the execution of a developed VHDL program on ALTERA programmable devices, with no additional software installation required on client's PDA/PC for operating on FPGA hardware. To see how it works, an automatic railway remotely controlled was shown, but many other applications can be considered, consistently with the potentiality of available FPGA devices and circuitry.

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