

## **AC 2008-70: DESIGN OF APPLICATION-SPECIFIC INTEGRATED CIRCUITS FOR IMPLEMENTATION IN A NETWORK OF REMOTE LABS**

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Danilo Garbi Zutin obtained his BSc degree in Electrical Engineering from the State University of São Paulo (UNESP) in Brazil. As a student, he has developed undergraduate research during three years at the university and has joined an internship program at the Carinthia University of Applied Sciences, Austria, where he has worked within the Remote Electronic Laboratory project. The work was focused in developing a system for testing and designing ASICs as a part of the tele-learning system of the institution. The work has resulted in a system that allows designing and testing ASICs by means of an online platform. His areas of interest are Remote Labs, Virtual Labs and e-Learning.

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Hatem Al Bakhiet obtained his B.SC degree in Computer Engineering and Digital Technology from Al Balqa Applied University, Jordan in 2001. Since then, he has been working with Princess Sumaya University for Technology, Jordan, in the computer center as a network engineer. He is an expert LabVIEW programmer and a remote lab designer. Al Bakhiet was a visiting technical advisor to Carinthia University of Applied Science, Austria, in the field of remote engineering. In

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# Design of Application-Specific Integrated Circuits for Implementation in a Network of Remote Labs

## Abstract

A solution to implement a remote laboratory for testing and designing analog Application-Specific Integrated Circuits of the type (ispPAC10) is presented. The application allows electrical engineering students to access and perform measurements and conduct analog electronics experiments over the internet. PAC-Designer software, running on a Citrix server, is used in the circuit design in which the signals are generated and the responses are acquired by a data acquisition board controlled by LabView. Three interconnected remote labs located in three different continents will be implementing the proposed system.

## Introduction

Technology-enhanced learning is becoming a new important trend in higher education worldwide. In particular, engineering education is becoming an exciting emerging field of research because it involves a multitude of disciplines which aim to resolve the pedagogical problems that arise with the advancement of technology. In addition, laboratory experiments and instruments are becoming sophisticated and expensive for universities to purchase and maintain. Remote labs offer a solution and represent a practical alternative through which students may conduct experiments online, anywhere and at anytime. Compared with traditional laboratory practice, remote labs offer flexible learning in time and place, access to a wide number of distributed experiments and cost-cutting strategies<sup>1-4</sup>.

Nevertheless, it is still difficult to share instrumentation and experiments among laboratories<sup>3</sup>. Each one has its own security policy and adopts a proper technology in accessing and controlling real devices. A common integrated framework, offering indexing facilities, unique logins, file sharing and the seamless access and run of experiments, is the main challenge in order to create a network of online laboratories. Grid technologies can be used to set up an effective network of remote laboratories for education purposes by sharing instrumentation and resources. However, the evolution of remote laboratories from the current client/server architecture to grid-based architecture requires well-defined tools for location, security, and integration of resources, and further research is currently being conducted to examine this issue<sup>5-7</sup>.

From the engineering education point of view, the main goal of developing remote laboratories remains the necessity to provide instructors with a tool for creating resources for designing electronics experiments for students to perform online. Such experiments may involve controlling the gain of an amplifier or designing different types of filters and activating relays, electronic switches, among other devices, without concern to the problems related to programming instruments, hardware communication and their integration to the Internet. This would eventually enable students to focus on the aspects related to the subject they want to explore.

In this paper, an analog electronics interactive laboratory (iLab) is developed, at Princess Sumaya University for Technology, Jordan, as an attempt to enable students to perform remotely and in real time several distinct experiments. The laboratory will form part of a network of web-based remote labs as efforts; by the Remote Electronic Lab (REL), Carinthia University of

Applied Sciences, Austria, are continued in this direction <sup>8-9</sup>. The laboratory is based on an Application-Specific Integrated Circuits, of the type (ispPAC10), which can be programmed by PAC-Designer software. The signals are generated and the responses are acquired by a data acquisition board controlled by LabView. The ultimate aim is to link REL with iLab, and a remote lab at Universidade Estadual Paulista, Brazil.

Simple experiments were performed within the range of the ispPAC10 analog functions, such as a 20 dB gain amplifier and analog low-pass, high-pass and band-pass filters. The cutoff frequencies can be adjusted by the user based on the ispPAC10 adjustable parameters. Basically, other analog functions can be implemented, depending on the wish of the user.

### Configuration of the ispPAC

The ispPAC10 is an in-system programmable analog device from Lattice Semiconductor, which allows the implementation of several analog circuits such as low-pass and band-pass filters, amplifiers, oscillators, etc. Its basic building block contains four integrated programmable analog modules known as PACblocks and a programmable analog routing pool, as shown in Fig. (1). Each PACblock emulates a collection of op amps, resistors and capacitors. The ispPAC10's flexibility permits one to vary a filter's gain, corner frequency, and other characteristics without the need for external components. Additionally, because the ispPAC10's analog circuitry is based on continuous-time, as opposed to switched-capacitor technology, filters implemented with the ispPAC10 are not subject to the sampling and aliasing problems often encountered when using switched capacitor filters. Due to the frequencies used in the proposed experiments, it is understood that the sampling/aliasing problems associated with switched capacitors are far from being noticed, although this issue describes one feature of the ispPAC device that might be important depending on the application being developed. The ability to program the internal capacitor values of the ispPAC10 allows the designer to realize thousands of distinct analog circuits and filter characteristics from a given circuit architecture.

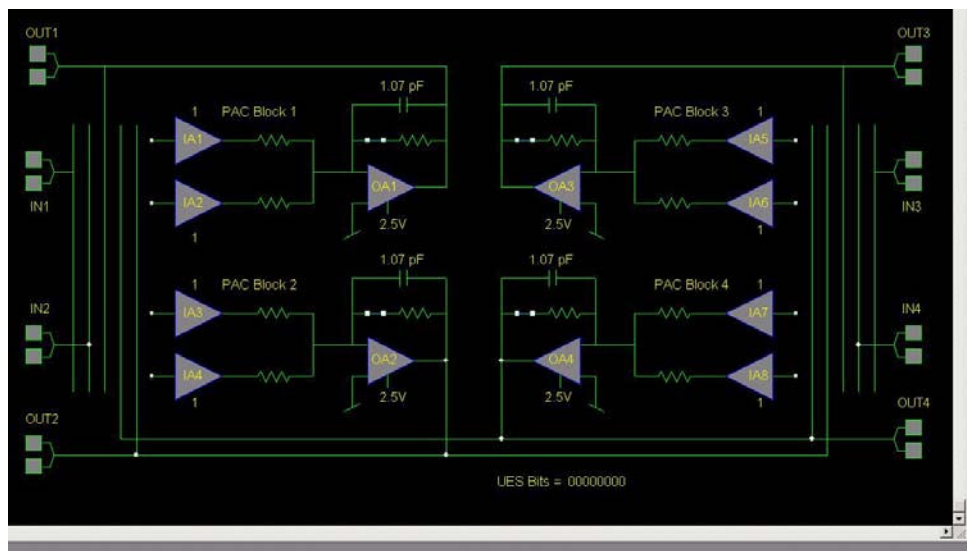


Fig. (1) Basic Building Block of the ispPAC10.

By assuming a fixed architecture, the ordinarily complex task of designing a desired analog circuit or filter can be reduced to a simple table-based process requiring minimal calculations.

The ispPAC10's in-system programmability enables programming, verification, and reconfiguration when the device is assembled onto a printed circuit board using an IEEE standard 1149.1 compliant serial port (JTAG). Circuit programming and uploading are achieved by means of a windows-based application called PAC-Designer. The analog circuit can be design and simulated at a PC with free schematic-based software and a built-in simulator or it can be exported to PSPICE and instantly downloaded to configure an E2-programmable Lattice ispPAC.

A block diagram of the remote lab ispPAC10 analog circuit is shown in Fig. (2), in which the programmed chip is connected to a National Instruments LabView-controlled data acquisition board. The signal input to the circuit can be generated internally, with the data acquisition (DAQ) card or externally using a signal generator. The circuit was designed and assembled to offer the same functionalities to the remote lab user. Furthermore, this remote analog electronics laboratory may also be used for testing and designing analog application specific integrated circuits other than the ispPac10 such as ispPac20, ispPac80 and similar chips.

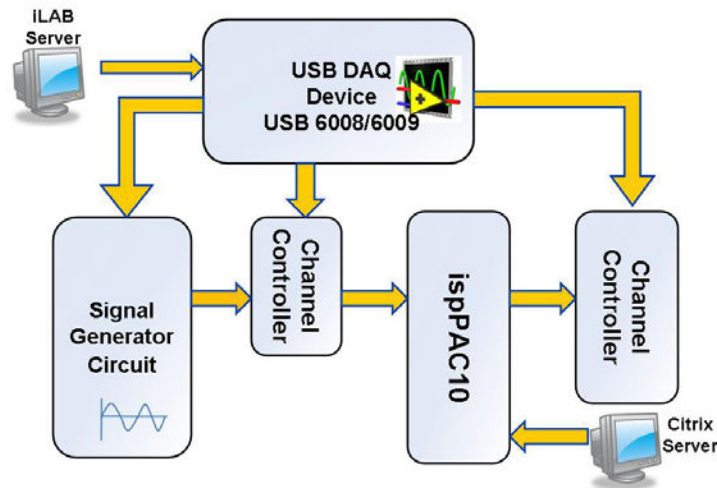


Fig. (2) The Remote Lab ispPAC10 Analog Circuit.

The ispPAC10, which operates within a voltage range from 1 to 4 V, should be first configured in such a way as to connect the differential inputs to a single-ended signal because the device is fully differential. Thus, one of the differential inputs was connected to a DC bias. In addition, the input signal must either be AC coupled or have a DC bias equal to the DC level of the other input. To compensate for this requirement, all the inverter analog inputs were connected to the differential input  $V_{REFOUT}$  once all performed experiments were carried out in single ended mode.

## System Design

The remote electronic laboratory system has the architecture shown in Fig. (3). Real experiments are carried out on the server side, where the user can control these experiments via the Internet by setting the parameters of the input signal such as waveform, frequency, amplitude and offset. The circuit outputs may then be read and compared with the input waveform signal.

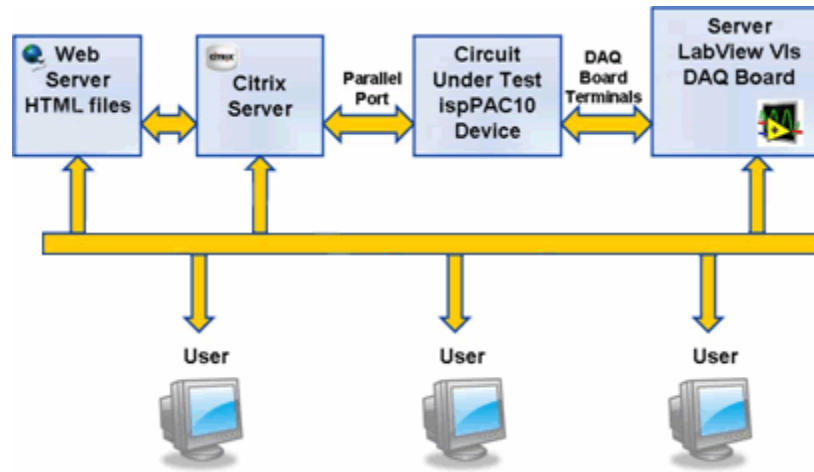


Fig. (3) The Remote Electronic Laboratory System.

The user interfaces of the system are the LabView front panels of the virtual instruments. In order to make these virtual instruments available for remote users, the VIs front panels were embedded into HTML with LabView and were published with its built-in web server. Therefore, the front panels are remotely reachable via a standard web browser and they were designed in a way that the user does not need any knowledge of LabView Programming in order to take advantages of the system facilities. Thus, the client simply needs a web browser and a proper version of LabView run-time engine that contains some libraries and web browses' plug-ins. This software is available free of costs at the National Instruments website and it is automatically downloaded on the first attempt to access the system. Furthermore, the driver software has an application programming interface (API), which is a library of VIs, functions, classes, attributes, and properties for creating applications. This is a library of polymorphic VIs that replaces large parts of a complex DAQ application with a simple configuration dialog.

On the other hand, a PAC-Designer software was installed on a Citrix server. The Citrix MetaFrame is a Windows NT application for delivering Windows based applications to several desktops and supports up to 15 simultaneous connections. Once installed, the PAC-Designer becomes available to be remotely accessed. The user access system does not control the access to the Citrix server, which must be made separately.

The interface for the proposed analog electronics experiments was designed to look similar to a real oscilloscope and a function generator and to have nearly the same functionalities as real devices. To access the remote lab, the user is asked to insert a username and a password. If both are valid, the system enables access to the lab, as shown in Fig. (4). Furthermore, only one user can access the remote lab at a time. Subsequently, the time-slot of the user control access system was set at thirty minutes.

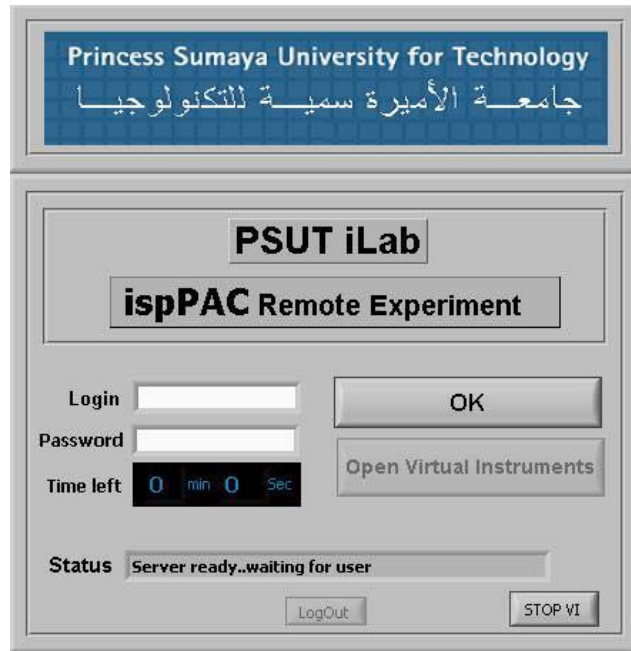


Fig. (4) A Front Panel View of the Remote iLab Access.

The development of the virtual instruments can be divided into three parts, the virtual oscilloscope, the virtual function generator and the user access control, each one with well defined tasks. The virtual oscilloscope should work similarly to a real oscilloscope. The user should be able to measure some properties of the signal and also to visualize the waveform signals. In order to do that, the VIs acquires data from two analog channels simultaneously. The data acquisition properties such as sampling rate and number of samples are calculated based on the parameter called TimeBase sent by the user according to the following equation:

$$\text{TimeBase} \times \text{Sampling Rate} = \text{No. of samples} \quad (1)$$

This parameter specifies the time interval to be displayed on the oscilloscope screen. The calculation is an iterative process. In each iteration, the sampling rate is decreased by one unit and the number of samples is calculated. This process is repeated until the number of samples reaches a maximum value. This calculation is necessary to prevent a misrepresentation of high frequency signals and to ensure that the number of samples will be high enough to visualize the requested time interval when sampling lower frequencies signals.

The function generator VI uses the DAQmx API VIs to output an analog waveform signal. The user is able to choose the waveform shape, amplitude, frequency and signal offset. The number of samples per buffer and the sampling rate were initially specified in order to control the waveform generation. Although, these parameters should not be of the users concern because the LabView program calculates these parameters based on the desired frequency provided by the user to ensure that the number of samples is as high as possible, thus maintaining a good quality of the signal. This is achieved according to the following equation:

$$\text{Frequency} \times \text{No. of samples per period} = \text{Sampling rate} \quad (2)$$

The basic operation of the remote lab was based on controlling the DAQ by programming the virtual instruments which represent the experiment equipment such as the function generator and oscilloscope. A web server hosts the HTML files that contain the ASIC laboratory home page with information about the implemented exercises, as well as the links to login onto the system. This server is actually separated from the LabView server which is in turn connected to the circuit under test via the DAQ card and therefore controls all the data acquisition and generation for the experiments, as well as all the measurements performed.

At the Carinthia University of Applied Sciences, Austria, the DAQ card used was the National Instruments USB 6251, which has an input sampling rate of 1.25 MS/s and an output sampling rate of 2.86 MS/s, while the iLab remote lab at the Princess Sumaya University for Technology, Jordan, implemented a USB 6009 device. This system used an external circuit to generate signals because this hardware has a much more limited sampling rate (48 KS/s).

A minimum of 20 samples per period of the generated signal were considered, which leads to a maximum frequency of 143 KHz possible for analog waveform generation. For the input, the sampling rate is divided by 2 as two analog channels are measured simultaneously since the DAQ card has only one ADC. In addition, the DAQ card has 16 analog inputs, which allow 8 analog channels to be read simultaneously (differential mode). We assumed that the user should be able to read and analyze the signals applied to the ispPAC10 inputs and outputs. As there are 4 inputs and 4 outputs, there are 8 different nodes that the user should be able to measure. Therefore there is no need for an analog MUX. A data acquisition of two simultaneous channels was configured in order to read one input and one output of the ispPAC10 at the same time.

The analog electronics ispPAC10 experiment set-up at the iLab remote lab at the Princess Sumaya University for Technology, in addition to the USB 6009 DAQ is shown in Fig. (5) while the user control access interface of the experiment input/output is shown Fig. (6).

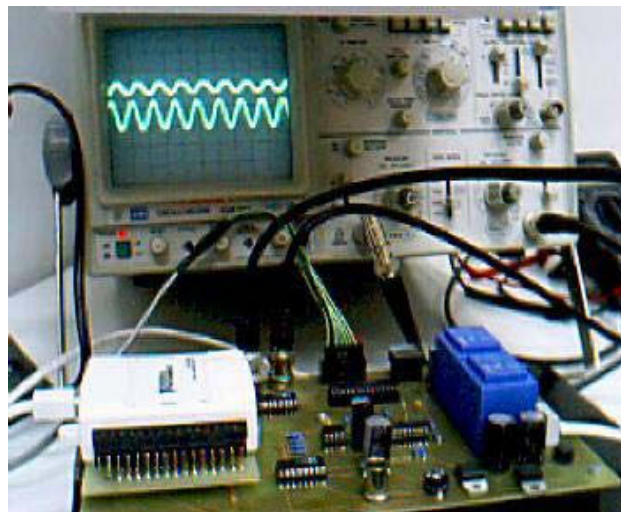


Fig. (5) The iLab ispPAC10 Analog Circuit Board, showing the NI DAQ card.



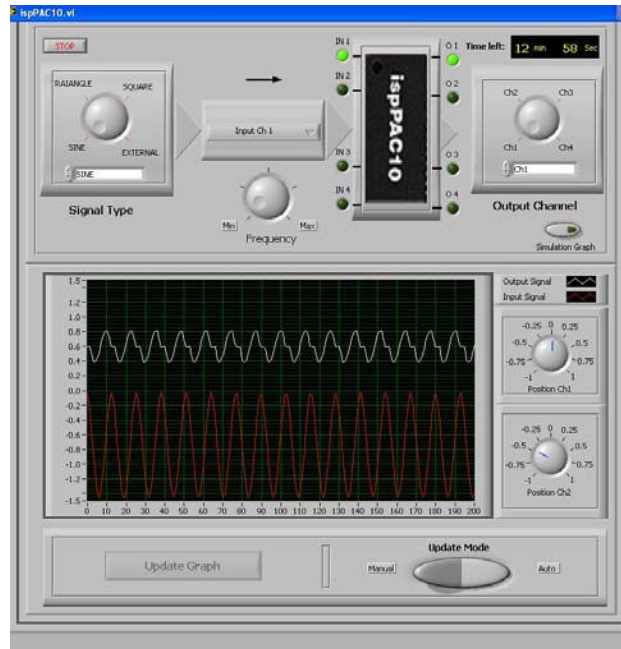


Fig. (6) The ispPAC Experiment Input/Output.

Due to the hardware limitations, the function generator could not generate signals within a large bandwidth, although the circuit behaviors could be well visualized for the performed exercises. Another important aspect found after the board development is the noise level that affects the measurements performed in the circuit. For signals with low amplitude and high frequencies the noise effects could be well noticed. For higher amplitudes this effect could hardly be noticed. This is an important consideration because the experiments with the ispPAC10 device can only be performed within a voltage range from 1 to 4 V, which leads to the constant use of low amplitude signals when conducting experiments. No measurements though were carried out to quantify the noise (white noise) level, but the presence of noise could be noticed on the waveform signals when performing experiments with low amplitude levels (0.1 to 0.2 V). In order to solve this problem, a cable with individually shielded analog twisted pairs was used.

## Conclusions

A remote analog electronics lab was successfully designed and implemented based on analog Application-Specific Integrated Circuits of the type ispPAC10. The PAC-Designer software is utilized to program the chip. It allows users to create circuit schematics, upload the design and subsequently perform measurements on the real hardware implementation. Two separate systems were developed with two different DAQ cards. The software programming was basically the same, but one of them required the signal inputs to the ispPAC10 IC to be generated with the aid of an external circuit. The response of the configured analog circuit was acquired by the data acquisition board in the same manner for both systems. One is running at Princess Sumaya University for Technology, Jordan and the other one at Carinthia University of Applied Sciences, Austria. The user interfaces at the client side were made of virtual instruments front panels published on the Web by a LabView publishing tool. It embeds front panels into HTML files to be accessed via standard web browsers.

Several experiments with the ispPAC device were performed in a satisfactory manner and the prospect of its utilization in advanced application seems promising. In addition, this remote lab solution offers a wide range of possibilities for applications in industries and for eLearning purposes. Three interconnected remote labs located in Austria, Jordan and Brazil will be implementing the proposed system in the near future.

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