APPENDIX VI: NEXT GENERATION LAB – A SOLUTION FOR REMOTE CHARACTERIZATION OF ANALOG INTERGRATED CIRCUITS

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Abstract- In this report, we describe the development and use of a remotely operated laboratory based on Microsofts .NET technology. The Next Generation Lab combines the latest in web technology with industrial standard instruments to make a cost effective solution for education in the field of analog CMOS integrated circuits.

INTRODUCTION

With the mass proliferation of the Internet, interesting possibilities have emerged for extending its use into new areas, including distance-education – a rapidly growing part of the university curricula. By utilizing the WEB, the potential exists for offering courses to remote students, who can participate without other technical requirements than a personal computer and a telephone line.

Laboratory and computer-aided-design modules are vital parts of engineering education, but so far, these elements have been considered impractical for distance-education. On the other hand, user-friendly, computer-controlled instrumentation is revolutionizing the way measurements are being made, and is now permitting net-based techniques to be utilized for setting up remote laboratory access. Such a remote laboratory can, for example, be used in conjunction with courses in electrical engineering, allowing remote students to gain hands-on experience in a wide range of areas. As an added benefit, this technology may offer students the opportunity to work with sophisticated equipment, of the kind they are more likely to find in an industrial setting, and which may be too expensive for most schools to purchase and maintain. Much of the same arguments can be used with regards to software for computer-aided-design.

The basic concept and feasibility of remote system control via the Internet were investigated in two Siv.ing. (M.Sc.) student theses at the Norwegian University of Science and Technology (NTNU) [1], [2]. Further development was pursued in 1998 in collaboration with Professor Shur at Rensselaer Polytechnic Institute (RPI) in Troy, NY. This work has been described in several publications [3]-[11].

So far, the work on the remote laboratories has been dedicated to semiconductor device characterization. It includes several experiments that are performed on a microelectronic test chip, and is used as a lab module in a course on modelling of semiconductor devices at the senior or first year graduate level. In Norway, this is a course that is presently being taught remotely from UniK,located in Oslo, to students at NTNU in Trondheim. The remote lab is planned to become a permanent part of this course.

The main objective of the work presented in this paper is to bring the remote laboratories to the circuit level by developing a Web based lab devoted to characterization of analog integrated circuits. The laboratory is based at the Department of Physical Electronics, NTNU. 4th year students in the courses Analog CMOS 1 and 2 will use this lab.

PHYSICAL ARCHITECTURE

Next Generation Laboratory (NGL) is built with three main objectives; scalability, easy to add experiments and real time feedback to the user. Through the use of technologies like web services, which are a framework for remote method calls using Hypertext Transfer Protocol (HTTP) and Simple Object Access Protocol (SOAP), the possibility for a distributed architecture emerges. The NGL has a web service that provides a web interface to GPIB (General Purpose Interface Bus) and DAQ (Data Acquisition) boards on the lab workstation, separating the computer connected to the instruments from the application logic. This makes it possible to use dedicated web servers for the web application and lower cost workstation connected to the instruments. Figure 1 shows an example of a possible architecture. The individual workstations can be connected to one or more device under test (DUT).

The physical architecture of the NGL prototype contains the NGL web server and one lab server. Connected to the lab server are a vector network analyser, a power supply, and a Data Acquisition (DAQ) board. These are in turn connected to the DUT, which is a IC containing 9 operational amplifiers (OPAMP) designed as project work in the Analog CMOS 1 course.

We chose to measure the frequency response of the opamps connected in a closed loop as a prototype experiment. The experiment allows the user to specify closed loop gain, bias current and offset from common mode level at positive input of the opamp. The wiring diagram for the AnCMOS chip is shown in Figure 2.

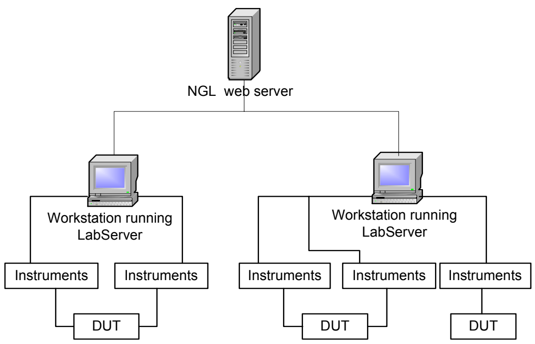

Figure 1 The physical architecture of NGL

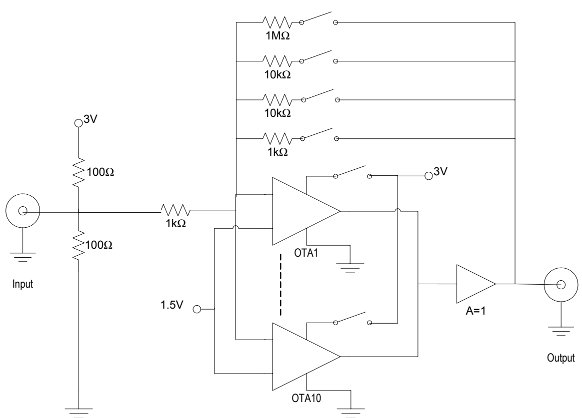

Figure 2 Wiring diagram for the AnCMOS chip

SOFTWARE ARCHITECTURE

The NGL is based on Microsoft's emerging .NET technology and Scalable Vector Graphics (SVG) from Adobe. The .NET framework has a large class library that was extensively used for the NGL. The NGL application, except for the LabServer and client-side, was written in C#, a modern object oriented programming language. The LabServer was written with a combination of Managed and Unmanaged C++. For the client-side we chose JavaScript. Figure 3 gives an overview over the NGL prototype.

Each of the instruments connected to the DUT is represented in software by a corresponding object. This object provides the basic functionalities of the instrument, it makes use of a proxy object on the web server which is a local representation of the LabServer web service. The fact that the methods for writing GPIB strings and using DAQ commands are located on another computer is thus made transparent for the instrument object

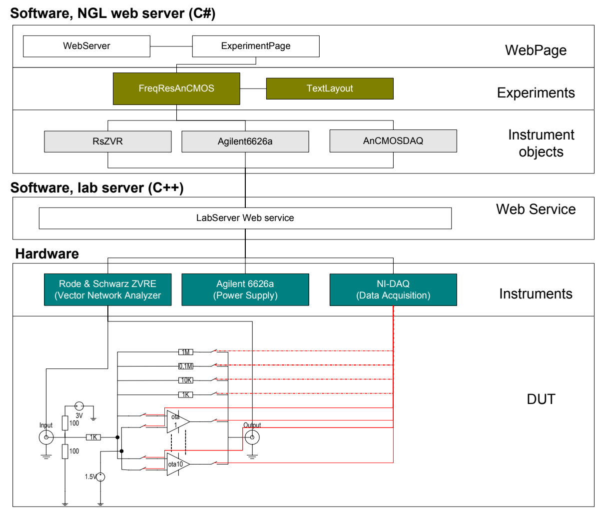

Figure 3 Prototype Overview

The NGL does not only provide scalability in hardware, but also in software. All experiments are implemented as an object in the NGL application. *Experiment* is the base class for all experiment, and all classes that inherit *Experiment* are automatically available through a JavaScript menu on the NGL web application. In C# an object can be casted to the type of it's parent and still retain the specialization of the child. This makes it possible to run-time decide which experiment to run, and in addition provide a common framework for all experiments i.e. the same queue control and XML (Extended Mark-up Language) formatted string to show the result. This of course limits the possibilities for experiment especially in the way results are presented, but the graph engine can handle both linear and logarithmic plots, auto scaling of values from yotta to yocto, sizing of plots and "unlimited" number of plot. The actual number of plots is of course restricted by the space on the web page.

The prototype experiment is of a batch type set-up, the user specifies the parameters and runs the experiment. Running the experiment takes around 300ms and to ensure thread safety the NGL application implements a simple form of queue control. When a user submits the parameters, the web application checks to see if there are other experiments running, if there is no experiments running it takes control and runs the experiment.

When it is finished it frees it's control and allows other experiments to run.

SVG is used to plot the results of the experiment, as mentioned the experiment provides an XML formatted string, this string is parsed by a SVGcontrol object which generates JavaScript that draws the graph.

The web application continuously provides the user with status update by means of writing and flushing the output stream without breaking the connection. This is especially important if the experiment has to wait for access to run.

Adding experiments to NGL architecture follows three simple steps:
1. Write one class that inherits *Experiments*
2.Compile and build into the NGL application
3. Test your experiment
The experiments can in theory be written in VB.NET, C#, PerlNET, C++, J++ or any other language that supports the .NET framework

The NGL is show in Figure 4

CONCLUSION

The NGL web application provides users with a reliable and efficient tool for analog CMOS integrated circuit experiments. It gives lecturers and students the opportunity to perform real experiments on actual circuits, using industrial standard measurement equipment.

The NGL web application provides a framework for distributed experiment set-ups spanning wide geographical areas.

Choosing ASP.NET as server-side technology provides distributed architecture with no additional cost.

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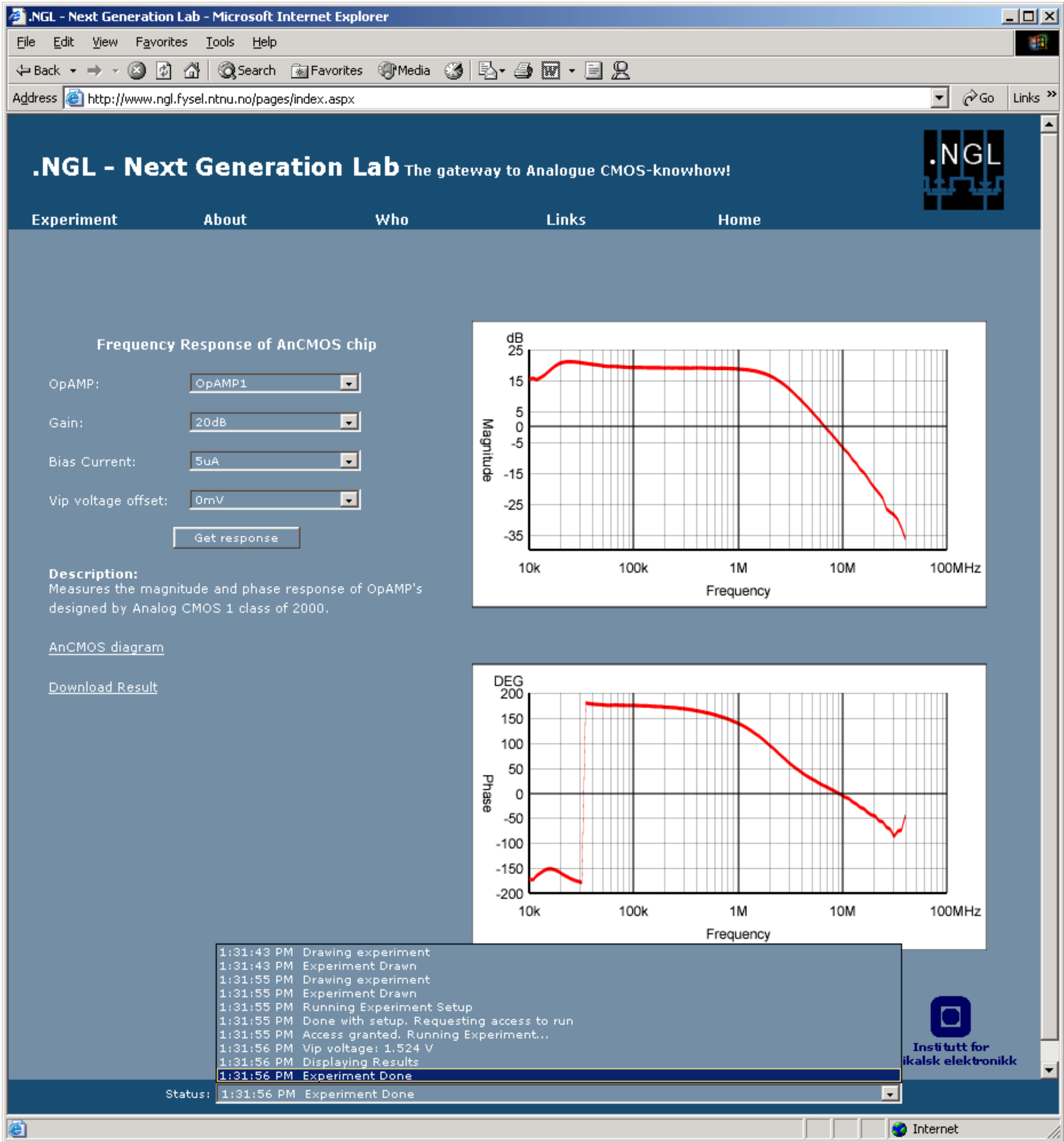

Figure 4 The NGL