Integration of a Low Cost Switching Mechanism into the NI ELVIS iLab Shared Architecture Platform

H.G. Msuya[1] and A.J. Mwambela[2]
[1,2]University of Dar es Salaam, Dar es Salaam, Tanzania

***Abstract*— This paper presents the development of a low cost switching mechanism into the NI ELVIS platform for online laboratories based on the iLab Shared Architecture. This came up after experiencing the limitations on using NI ELVIS II+ platform in deploying discrete experiments using common measuring and testing instruments; as well as the use of different components on the same experimental setup. This requires switching mechanisms as a solution to implement those experiments. The designed mechanism in this work uses analogue switching devices with digital control inputs connected to the NI ELVIS II+ Digital writer instrument. The mechanism were successfully tested using implementation of diode rectification characteristics experiments showing the switching mechanism between different components; whereas switching between different experimental setups was shown using Low Pass Filter, High Pass Filter and Band Pass Filter setups.**

***Index Terms*— e-learning, NI ELVIS, online laboratories, switching**

I. INTRODUCTION

The NI ELVIS is the platform commonly used by iLab Shared Architecture (ISA) in developing online experiments. It is one of the affordable solutions to developing online experiments [2], especially in developing countries. However it has its limitations, such as use of different components on the same setup as well as having multiple setups available on it concurrently. Every time a new circuit or component is needed, someone needs to remove the existing one and wire a new setup. This maintenance is not ideal for a system that is designed to be shared among different courses and universities that will not necessarily have the same assignments and setups simultaneously [3].

The above limitations required a switching mechanism as a solution to implement those experiments. This led to various studies on how to implement switching mechanism on the NI ELVIS platform as it can be seen from the works done in [3] and [4].

In this work, authors were motivated to develop an alternative switching mechanism at a very low cost and more affordable especially to Universities in developing countries by integrating electronics switching devices to be used in NI ELVIS II+ ISA lab experiment development. The electronics switches are cheap and can work with less complexity in providing flexibility to students to perform the same experiments using different components; as often done in conventional laboratories.

A. Analogue Switching Devices

The devices form the interface between analogue signals and digital controllers. CMOS analogue switches are easy to use; they offer better switching characteristics, low supply voltage and small packages. Fig. 1 shows a simplified implantation of an electronics analogue switch. Connecting an n-channel MOSFET in parallel with a p-channel MOSFET allows signals to pass in either direction with equal ease. Thus, the switch has no preferred input or output because it has no preferred direction for current flow. The two MOSFETs are switched on and off by internal inverting and non-inverting amplifiers. These amplifiers level-shift the digital input signal as required, according to whether the signal is CMOS- or TTL-logic-compatible and whether the analogue supply voltage is single or dual.

The parallel arrangement of n-channel and p-channel also makes low resistance switches. From Fig. 1, taking the p- and n-channel on-resistances (R_{ON}) in parallel (product over sum) for each level of V_{IN} yields a composite on-resistance characteristic for the parallel structure.

There are a lot of such analogue switches with digital control input; it is required that the switch to be used should have minimum effects on the signal passed. Therefore some recommended test procedures for analogue switches should be taken in order to enable selection of right switches to use in electronics design as well as considering their availability as needed. Important tests were done to determine the "ON resistance" characteristics, analogue signal range and leakage currents of the analogue switching devices.

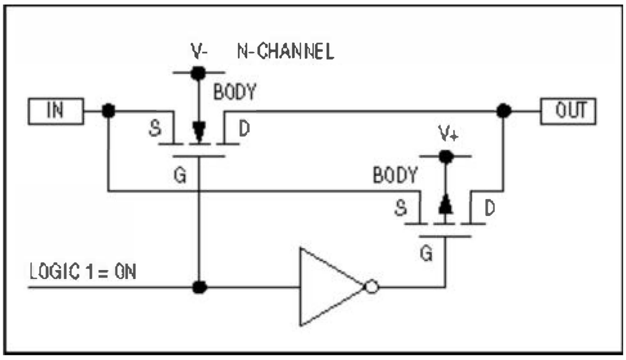

Figure 1. The internal construction of a typical analogue switch

B. *The NI ELVIS II+ Digital Writer Instrument*

The NI ELVIS platform has the Digital Writer as one of its 12 instruments (see Fig. 2). The instrument can be programmed to write TTL compatible digital data to eight consecutive lines at a time using a 5 V voltage level logic through an 8-bit port. The specified data may be in the form of manually created patterns or predefined patterns such as ramp toggle and walking 1s. The eight consecutive lines could be either the DO<0…7>, DO<8…15>, or DO<16…23> signal rows. The output of the NI ELVISmx Digital Writer Soft Front Panels (SFP) stays latched (at the last created value) until another pattern is output, the lines it is using are configured for digital data reading, or the power is cycled on the NI ELVIS workstation. Therefore it can be seen that a combination of 256 (i.e. 2^8) different outputs are possible to be generated from the port. Obviously not all of them will be used at the same time rather will be dictated by the nature of the experiment [7].

It can be seen from the fig. 2 that 24 lines are available placed in three groups of 8 lines each. When using the digital writer instrument one of the groups is made active at a time by choosing it from the drop down list. Any one of the group may be activated and set to a certain binary number, but when the “lines to write” option is changed into another group; the binary number with be maintained i.e. the other group will show the same binary number as it was in the first group. This means no possibility of using two or all three groups of “lines to write” at the same time in different arrangements and have the flexibility of changing the patterns the way user wants.

Since 8 lines of bits can be used at a time, putting them into different possible combinations they give 256 (i.e. 2^8) combinations. Each combination can give rise to a different result when connected to a combinational circuit which defines the specific output according to the input fed into it. This means few number of lines from the Digital Writer instrument can be extended to control many switches, i.e. for 8 digital lines from digital writer instrument can give up to 255 digital output (leaving all zeros combination as a default state of the Digital writer lines). It might be less depending on the design of the combinational circuit chosen.

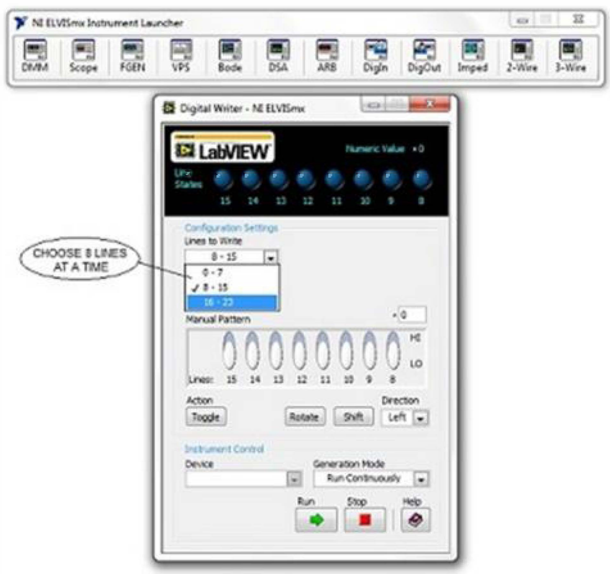

Figure 2. NI ELVIS II+ Digital Writer Instrument

II. THE LOW COST SWITCHING MECHANISM

A. *Design of the Low Cost Switching Mechanism*

The main design idea in this work was to control the switching devices using the NI ELVIS II+ Digital Writer instrument. The outputs of the digital writer were connected to the control inputs of the analogue MOSFET switches. There are three groups of “lines to write” from the digital writer instrument each with 8 “lines to write” output. One group can be used at a time; which means 8 bits were available to be used concurrently. These could be used to control 8 switches, whereby each bit controlled a single switch inside the analogue switching device. When a certain switch had to be in ON state, the corresponding bit from the digital writer instrument had to be at logic high state, i.e. 5V; and it had to be at logic low state i.e. 0V, when the switch had to be in OFF state.

In the hardware part, the analogue switching device was mounted on the NI ELVIS II+ board, and wirings were made to connect the output of the digital writer instrument to the control input of the analogue switching device. Fig. 3 shows the wiring model used to place the control mechanism with each bit controlling a single switch inside the analogue switching device.

In the fig.3, experiments which shared Function Generator and Oscilloscope were mounted on the board and control mechanism for the switching between those experiments was done. When the user run experiment 1 or wanted to use component 1 in the experiment, he/she had to make S_1 at ON state by setting the first bit (bit 0) of the digital writer lines to high state i.e. logic 1 (5V); whereas other bits had to be at low state, i.e. logic 0 (0V). The same thing applied to all other experiments or components, using the switches with corresponding bits from NI ELVIS II+ digital writer instrument

However, the approach of using one bit to control a single switch exclusively was considered to be underutilization of the available lines of the NI ELVIS II+ digital writer instrument. This is due to the fact that, when taking 8 lines in different combinations give rise to 256 combinations, i.e. 2^8, which means 255 switches, leaving the default value of the NI ELVIS II+ digital writer instrument, could be controlled by the 8 lines in different combinations. This could be achieved by using the combinational logic circuit added next to the NI ELVIS II+ digital writer instrument. The combinational logic circuit could take N-lines giving out 2^N lines. Fig. 4 shows the placement of the combinational logic circuit and its role in increasing number of lines going to the switches for controlling them.

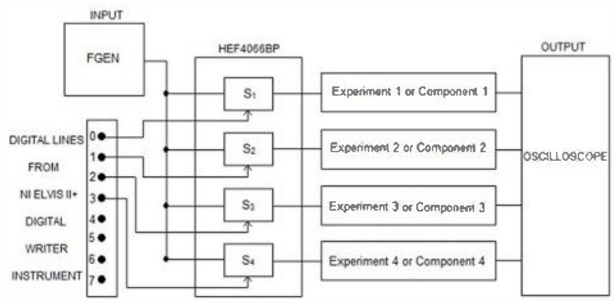

Figure 3. Control Mechanism of the Analogue Switches using One Bit per Switch

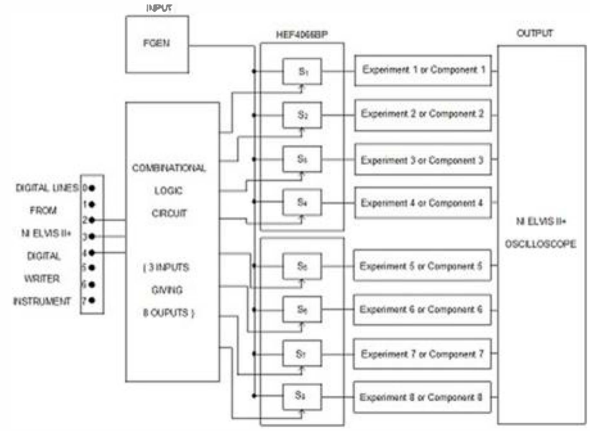

Figure 4. Control Mechanism of the Analogue Switches through Combinational Logic Circuit

Thus, the addition of the combinational logic circuit made less number of lines from the NI ELVIS II+ digital writer instrument to control many switches in a relationship of N-inputs to outputs of not more than 2^N-1.

B. Experiment for Demonstrating the Switching Mechanism

There are three main types of experiments done in the iLab Shared Architecture, batched, interactive and sensor experiments [1]. In this work, interactive experiments were used for this demonstration to make the switching taking place in real time. Three scenarios which required switching system were considered in the selection of the experiments for demonstration of the concept. The first two scenarios used one bit for controlling a single switch whereas the third scenario used combinational logic circuit to enable control of many switches using less number of lines from NI ELVIS II+ digital writer instrument.

In the first scenario, half wave rectification and full wave rectification experiment were used to demonstrate switching between components in the same setup. The proposed switching mechanism implementation for rectification circuits was as shown in Fig. 5 and Fig. 6.

The second scenario used low pass filter, high pass filter and band pass filter to demonstrate switching between experimental setups. For all of them to be available online while mounted on the same NI ELVIS II+, one setup should have an access to the function generator and oscilloscope at a time. This was made possible through implementation of the switching mechanism to the setups as shown in fig. 7. The real lab equipment photos of the setups for demonstration of the switching concept are shown in fig. 8.

Lastly, the experimental setup with component switching was mounted on the NI ELVIS II+ together with filter setups so as to have switching between different experimental setups and components switching at the same time. This made use of the combinational logic circuit.

C. Implementation and Tests

In this work, the analogue switch HEF4066BP was chosen considering its availability and the important parameters that were tested as shown in the table of results (Table I). Its pin descriptions are shown in fig. 9.

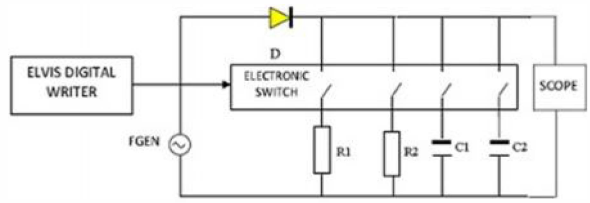

Figure 5. Implementation of Half Wave Rectifier Circuit with RC Filtering Network

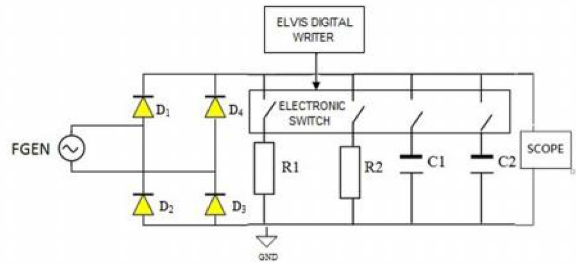

Figure 6. Implementation of Half Full Rectifier Circuit with RC Filtering Network

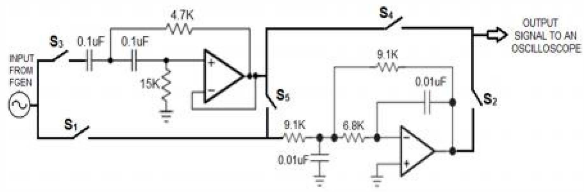

Figure 7. Circuit Diagram for Low Pass, High Pass and Band Pass Filters with Switches

Figure 8. Lab Equipment for Demonstration of the Switching Concept

The control mechanisms were made using LabVIEW programming in which virtual instrumentation of the function generator, oscilloscope, digital writer and variable power supplies were used. The interactive user interfaces were made using the front panel of the LabVIEW program. Control buttons for the switches were included to make the switching activates easy for the students. The bootstrapping procedures were followed for the deployment of the iLab Shared Architecture [5].

1) Diode Rectification Characteristics Experiments

The components to be switched were at the output where the network of resistors and capacitors were place. The switching was to be done by allowing signal to go through different resistors at different time and combined with different capacitors. Fig. 10 shows sample results when switching was done to allow different components.

TABLE I.
RESULTS FOR SWITCHING DEVICE TESTING

SN	Parameter	Conditions	Value at 25ºC	Units
1	"ON" Resistance	V_{DD}=5V V_{DD}=10V V_{DD}=15V	0.14 0.12 0.08	kΩ
2	Analogue Signal Range	V_{DD} 3V to 15V	0 to ~V_{DD}	V
3	Leakage Currents Switch "OFF"	V_c=0	±0.1 to ±50	nA

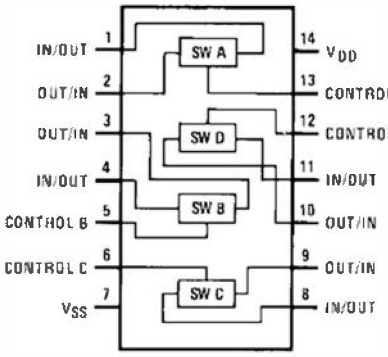

Figure 9. Pin-out Descriptions of HEF4066BP

2) Analogue Filter Experiments

These experiments were used to demonstrate the switching mechanism between different experimental setups mounted on the same NI ELVIS II+ protoboard. The input signal was allowed to enter the setup which the user wanted by pressing the enable button designed for each experimental setup. Fig. 11 shows the sample results of the switching between different experimental setups in which all the experiments were placed in the same interactive user interface separated in tabs.

In the fig. 11, the tab for Low Pass Filter experiment was opened shown in two parts. The upper part shows when the Low Pass Filter experiment was disabled by the switch; whereas the lower part shows when it was enabled. Fig. 12 shows the results for frequency response of the Low Pass Filter when the other tab was correctly opened after turning OFF the previous.

All the tabs followed the same principle of enabling and disabling the experiments. In this way switching between different experimental setups were made possible with the principle which applied also when different experimental setup used different VIs i.e. not all in the tabulations of one VI.

In the third scenario, PIC16F876A was used to implement the combinational logic circuit for extension of the digital lines from the NI ELVIS II+ digital writer instrument from N-lines to 2^N digital lines. Out of 2^N digital lines obtained, 2^N-1 digital lines were used since the default state of the NI ELVIS II+ digital writer instrument was not used for control purposes. The PIC16F876A was used instead of the individual logic gates in order to save the board space.

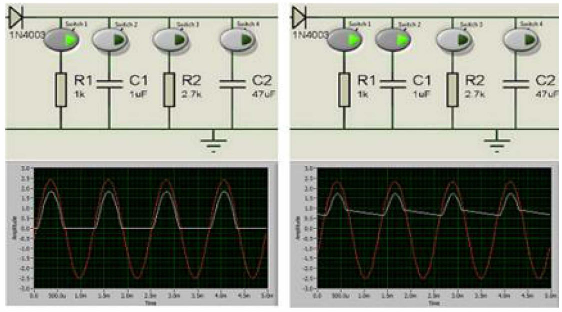

Figure 10. Half Wave Rectification Experiment Results with Components Switching

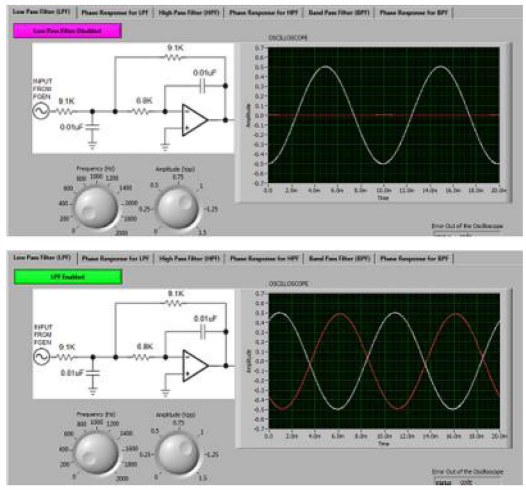
Figure 11. Low Pass Filter when Disables and Enabled by the Switching System

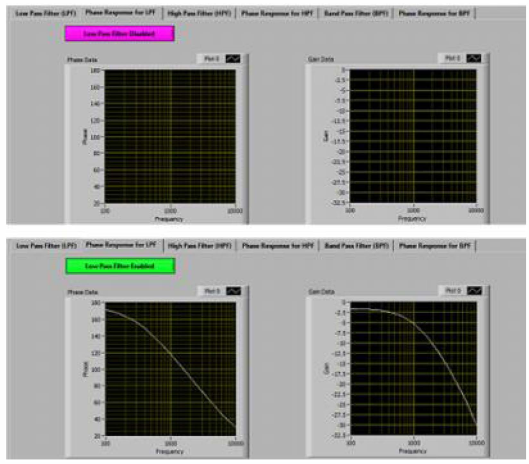
Figure 12. Frequency Response for Low Pass Filter when Disabled and Enabled by the Switching System

III. CONCLUSION

This paper presents integration of a low cost switching mechanism into the NI ELVIS iLabs platform; testing it in three scenarios, i.e. switching between components on the same experimental setup, switching between different setups sharing resources on the NI ELVIS platform and switching between many experimental setups with the aid of combinational logic circuit. All the scenarios for demonstrating the concept were successfully proved to be working properly.

This work has successfully proved the possibility of implementing switching mechanism to simple experiments at a very affordable cost and much reduced complexity. It is now not necessary for simple experiments usual done by Universities in developing countries to use complex and high cost switching mechanism in their implementation using NI ELVIS platform in ISA.

IV. FUTURE AND RESEARCH DEVELOPMENT

This work is very strong base for other researchers to build more complex experiments to be done in iLabs using the switching mechanism. From this, very complex systems with a lot of switching can be developed and made available online through ISA. Therefore, through this work, iLabs developers are encouraged to develop more interesting experiments for the future of iLabs and for optimum use of the NI ELVIS II+ platform.

Some features should also be added to the NI ELVIS II+ to provide room for more different and more challenging experiments to be set such as the provision of two terminals from function generator i.e. a positive and negative terminal. This will enable experiment such as that of full wave rectification to be set full on the NI ELVIS II+ without employing the external function generator that could not be controlled in software.

ACKNOWLEDGMENT

The authors would like to express their deep gratitude to the MIT Center for Educational Computing Initiatives for their technical support on the iLab Shared Architecture and the National Instruments for technical support on the instruments and LabVIEW programming skills.

REFERENCES

[1] Harward J. V. et. al., (2008): The iLab Shared Architecture: A Web Services Infrastructure to build Communities of Internet Accessible Laboratories. Proc. IEEE Vol. 96 (6) June.

[2] Gikandi, S. (2006): ELVIS iLab: A Flexible Platform for Online Laboratory Experiments in Electrical Engineering. M.Sc. Dissertation MIT

[3] Harrison, B. J. (2008): Expanding the Capabilities of the ELVIS iLabs Using Component Switching. M.Sc. Dissertation MIT

[4] Ayodele K. P, Kehinde L. O, Jonah O, Ilori O, Ajayi E. O. B, Osasuna O. O (2008): Development of an Operational Amplifier Virtual Laboratory Based on iLab Architecture and NI ELVIS. American Society of Engineering Education, AC2008-1098

[5] Kirky DeLong, Sardis Harward and Antonia Harward (2010): iLab Service Broker Bootstrapping and Time Of Day Test Lab Guide and iLabs InteractiveLabServer with LabVIEW Setup and Configuration. Version 11. Install Documents.

[6] NI ELVIS II Manual, 2008

AUTHORS

H.G. Msuya is with the department of Electronics and Telecommunication Engineering of University of Dar-es-Salaam from 2009, Dar es Salaam, Tanzania. (E-mail: hubertmsuya@udsm.ac.tz)

A.J. Mwambela is with the department of Electronics and Telecommunication Engineering of University of Dar-es-Salaam from 1989, Dar es Salaam, Tanzania. (E-mail: nkomo98@yahoo.com)

This work was supported in part by Carnegie Corporation of New York through iLabs project in Selected African Universities with Grant No. BD03109.R04.