

# Applying PBL to a Course on Measurements & Instrumentation - Case Study of Speed Sensing

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**Abstract :** This paper presents application of Project Based Learning – PBL using design, simulation, and construction of hardware/software modules for Speed Measurement. Speed Measurement setup had been developed for demonstration in theory, laboratories and project demos for academia in measurements & instrumentation courses. A traditional measurement setup-Stroboscope that is commonly used for demonstration in laboratories is presented to serve as a base for comparison. The proposed speed measurement for laboratory is envisioned based on counting the number of state changes of a sensing switch. Different approaches and possibilities are discussed that could be implemented in student's education. This approach is aimed at increasing knowledge, skill levels of students and help in using theoretical knowledge for application to practical & real-world problems. It also presents opportunities in instilling design thinking, skill development, integration and team work. Models based on only Software and ones that include hardware are presented for simulation & actual measurement. National Instruments – NI's software - LabVIEW, Multisim & hardware - myRIO & ELVIS ii+ are used for demonstrating different models presented here.

**Keywords:** Measurement, Instrumentation, LabVIEW, myRIO, ELVIS, Multisim, Project Based Learning.

## 1. Introduction

Measurement & Instrumentation plays a vital role in industries. Various commonly measured and controlled parameters are Level, Flow, Pressure & Speed. To educate students, the laboratory courses related to measurements and instrumentation employ setups to measure and control such parameters.

Traditionally measurements & transducers laboratories are based on calibration and measurements of corresponding parameters using readily available setups where everything is preset and rigid without scope for modeling, simulation or design changes. Theoretical concepts are better learnt when practically developed, realized using software modeling, design simulations and hardware measurements. When flexibility is available, instructors get the opportunity to make changes in design requirements, specifications to cover all the required objectives and outcomes of a course. In this process students get to understand varied design considerations, modify their existing designs and develop better solutions for real world problems. To implement this, PBL based approach using NI tools is employed.

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Modeling, Simulation and Measurement of speed is carried out using LabVIEW. Laboratory Virtual Instrument Engineering Workbench – LabVIEW is a

graphical programming language from NI, where each program file is called as a VI - Virtual Instrument, has a front end (front panel) and back end (block diagram) approach. To simulate an electrical circuit, Circuit design software like Multisim is used. A system is only complete when there is an actual hardware implementation. Prototype designs and hardware setups are aided through NI Hardware platforms. NI offers various Hardware prototyping devices like myRIO, ELVIS ii+. They are Reconfigurable devices designed for aiding students in developing a prototype. It could be used for data acquisition through its I/O and interfaced to PC's for further processing and visualization through LabVIEW and Multisim software.

This line of NI Software and hardware tools provides a good development platform for students to model, simulate, design, implement and test their prototype designs.

One of the commonly measured and controlled parameters in industries is speed. So speed measurement is considered here and Project Based Learning is applied for Speed Measurement using NI tools. The same or similar approach could be employed for various parameters as experiments in the laboratory course on Measurements or Instrumentation.

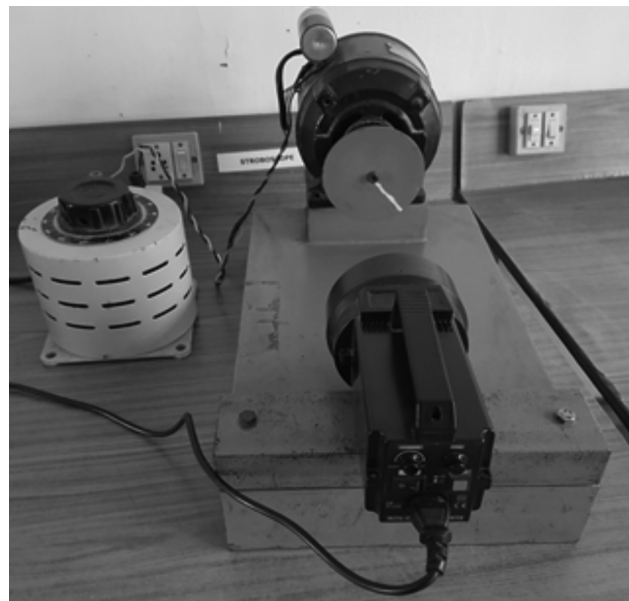
Some of the notable articles referred and used for development of PBL based Speed sensing are given below. [1] (Clive L. Dym, et al., 2005) discussed about design thinking for engineering education, Teaching and Project Based Learning, system dynamics, reasoning, estimation and team environment. [2] (Julio Garcia, Patricia Backer, 2007) discussed about LabVIEW and Multisim for use in Electronics Laboratories. Similarly [3] (S. J. du Preez, et al., 2007) have discussed about using LabVIEW for learners. [4] (Barry Paton, 2009) demonstrated the use of ELVIS II, Multisim, LabVIEW for various applications. [5] (Ed Doering, 2014) have demonstrated the use of myRIO. [6] (NI's, 2003) Measurements manual demonstrates various concepts of measurements, measuring and analysing using instruments for various parameters. [7] (M.Srikanth, et al., 2019) discussed the usage of LabVIEW, Multisim to demonstrate software modelling, design, simulation, and applied the same with interfacing myRIO hardware for level measurement. [8] (Antonio de la Piedra, An Braeken, Abdellah Touhafi, 2012) presented a survey on Sensor Systems, FPGAs and

their applications. [9] Through to [18] applies PBL approach a particular field or a course in engineering like embedded systems, communication, analog electronics, robotics etc. [19] and [20] demonstrated the PBL application to programming courses. [21] discussed PBL in general, challenges and requirements. [22], [23] and various other documents have been referred for understanding and development of the following models.

The further sections describe the PBL based Speed measurement in detail.

## 2. Methods & Modeling Of Speed Measurement

This section first presents a traditional setup and then various models for PBL based approach for speed measurement. It also presents various methods for Design, modeling, simulation and measurement of speed using LabVIEW, Multisim and respective hardware.



**Traditional setup of speed Measurement: Stroboscope**  
**Fig.1: Traditional Setups**

### A. Traditional speed measurement trainer Setup.

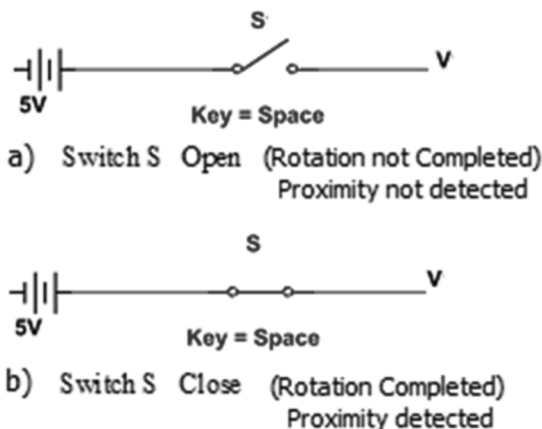
Traditional laboratories make use of readily available starter/ trainer setups to demonstrate measurement of parameters of interest. A traditional trainer setup generally used in labs for speed measurement is shown in figure Fig.1. These trainer kits help in demonstration of the basic measurement principle and are only used for calibration and measurement of the required parameter.

The setup shown here allows for understanding of the stroboscope concept in less than half an hour where students could observe the variation in number of markings (White Marking on the shaft disc) with changing flashing frequency or the harmonics. The harmonics are found out, used in calculations for determining actual speed.

### B. Modeling speed measurement.

Most of the industrial machines are run by electric motors and the rotation of rotor is used for measuring the speed. Speed of the rotor is generally measured by connecting a slotted disc to the rotor and using a proximity sensor to detect the presence of a slot. As the rotor rotates, the iron slot makes the movement near and far away from the proximity sensor. This movement is detected by the proximity sensor to generate a pulse. The number pulses depend on number of rotations and slots in the disc. i.e pulses are proportional to the number of slots in the disc and in turn to speed of the shaft.

A speed measurement setup is developed here for use in laboratories, with a motor and its shaft connected to a slotted disc. A proximity sensor is used to detect the slot in the disc. This proximity sensor acts as a switch and is a Normally Open/Close – NO/NC type. The switch changes state based on the detection of the slot. An “ON” state (Switch Close) is used to indicate detection of slot and “OFF” state (Switch Open) for absence. When there is only one slot in the shaft, detection of a slot is equivalent to one rotation of disc. The detection of a slot creates a pulse which has two edges, a Positive and a Negative edge. A positive edge occurs when there is a transition to detection and a negative edge occurs when there is a transition to no detection.



**Fig.2 : Modeling of Speed measurement using SPST switch**



**Fig.3 : Pulse generated from proximity sensor with rotations.**

The presence and absence of a slot detected by a proximity switch is modeled as switch open and close state, is depicted in the figure Fig. 2. The typical value of voltage (v) is

$\approx 5V$ , Switch is closed, Proximity is detected.

$\leq 0V$  Switch is open, Proximity is not detected.

According to above hypothesis if the iron slot on the motors rotor is detected, the voltage detected is 5V otherwise a 0V is detected. This could be modeled as a 1 or a 0 in digital world. A sample sequence of pulses generated from the proximity sensor is shown in figure Fig.3. Counting the number of 1 and 0's with respect to given time is used to determine the speed. Counting the number of pulses could be done based on counting the number of change of states but since a pulse has two change of states, the counting need to be done based on counting number of positive or negative edges.

The typical counting relationship for a +ve edge count is

$= \text{Count} + 1$  if +ve edge of pulse detected

$= \text{Count}$  Otherwise.

This is modeled, designed and simulated in different ways using LabVIEW or a Multisim software.

### A. Methods using LabVIEW

The methods presented here use LabVIEW to demonstrate the two simplified models - Software Simulation of Speed and Hardware based Speed Measurement. These are demonstrated without using frequency measurement functional blocks for better understanding of students.

Case a) Software Simulation of Speed Measurement using LabVIEW:

This method demonstrates concept of Speed measurement using only LabVIEW software, eliminates need for hardware setup through simulation of speed measurement in LabVIEW (Software only simulation). This helps in remote learning and also provides flexibility to the instructor in changing the design specifications for example: multiple proximity sensors, or different voltage signaling, Sampling rate, maximum number of rotations, threshold etc.

A Boolean control switch is used to represent the Proximity switch that is used to detect the rotation of shaft in speed measurement setup. The switch state can be simply changed by toggling/clicking on the switch to represent rotations/detection of slots.

This model used Boolean switch for simplicity. Instead, a numerical control may also be used to represent a Proximity switch, since the proximity switch actually presents in terms of changes in voltage, ideally 12V and 0V for its ON and OFF states. If a numerical control is used, the numerical value or the analog input voltage depicting proximity sensor value need to be converted to Boolean value (false/true) through a comparator and referencing with typical threshold voltage of 3V. “Bool to 0,1” block is used to convert to digital value.

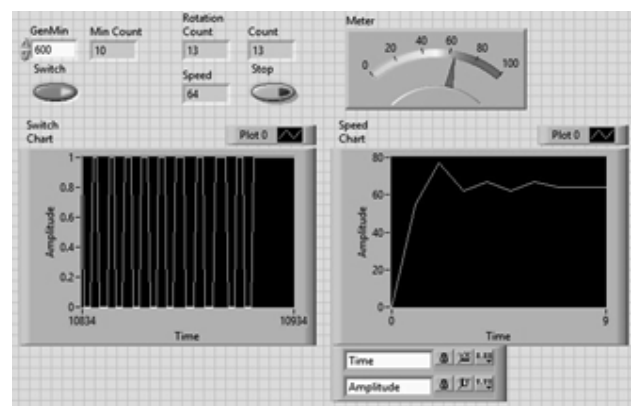
In a physical real setup based on the ability to charge and discharge or change state at the input circuit of hardware acquisition device and the response ability of the proximity switch, voltage levels may not be 12V and 0V respectively. This may be any value between 0 and 12V making it important to set the threshold voltage for considering an “ON” state or “OFF” State. This also limits the range of speed measurement. Fast acting devices may be required for improved measurement range. Alternatively, threshold voltage may be fine-tuned based on the respective setups for different speeds.

The front panel of the VI is shown in figure Fig.4a. The block diagram is shown in figure Fig.4b. An infinite while structure has been used to represent continuous measurement until stop. The detection and counting of the switch pulse could be modeled in LabVIEW to perform simulation based on +ve, -ve edge or both (any). For simplicity only Positive edge based setup is considered here. Such a concept of edge detection is normally introduced to students through “Event” attributes in Verilog HDL/VHDL.

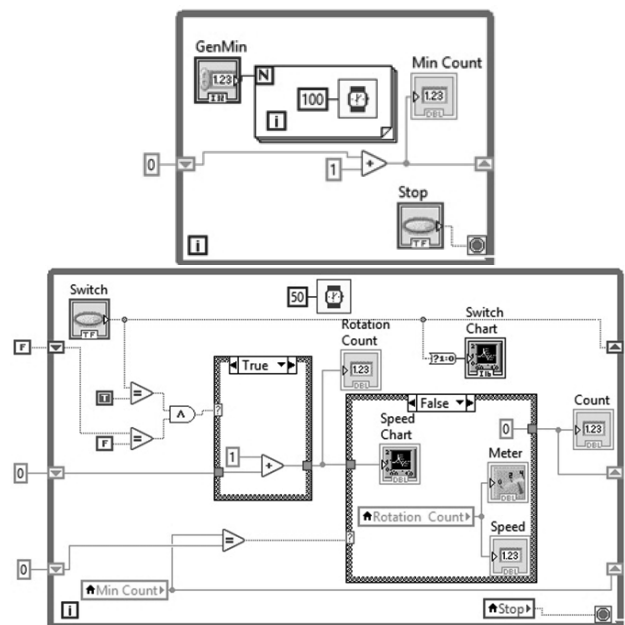
Sampling rate concept may be demonstrated using

a “wait ms” function. A 1000ms time may be used to sample every second. This would allow for changing and detecting the state of the Boolean Switch. For a more accurate representation of a motor rotating faster than 30 RPM, a faster sampling is required. So sampling rate may be increased to one sample for 50ms. Considering a basic motor speed around 500 RPM, around 1 sample for 50ms gives the sampling rate to be around 1200 samples per minute satisfying the Nyquist rate to give reasonable accuracy.

Additionally it uses a concept similar to software delay timers in microprocessors and use polling to check for required time rate. A Software delay Timer is used to keep track of time: 1 Minute or Per Minute Timing. This is achieved by using a “for” loop of 600 iterations with iteration time of 100ms to give 60



**(a) Front Panel**



**(b) Block Diagram**

seconds or 1 Minute. Since this should happen continuously it is placed in a while loop with “Stop” control. Also incorporated is to refresh, display speed as number of rotations per minute using local variables.

A concept to note here from the figure Fig.4b is that there are two loops running in parallel - the software time delay setup that uses a “For” inside a “While” structure and a regular “While” structure including two case structures, used for counting number of state changes.

This demonstrate the concept of concurrent or parallel programming where two “While” loop structures are running/executing in parallel. State change counter loop executing at rate of around 50ms per sample and the other Software Time delay loop executing at “1 iteration per minute”. The concept of concurrent programming is normally introduced in course on Digital Design, Real Time Operating Systems or embedded systems but students face difficulty in understanding it.

```
// Concurrent process 1
While(1)
{
for(i=0; i<600; i++)
{
delay(100);
}
Min_Count = Min_Count + 1;
}

// Concurrent process 2
While(1)
{
if(Switch==1 && Previous_Switch==0)
{Rotation_Count = Rotation_Count + 1;
}
if(Min_Count<>Previous_Min_Count )
{
Speed = Rotation_Count;
Rotation_Count=0;
}
delay(50);
}
```

© An Equivalent structural/C program

Fig.4 : Speed simulation in LabVIEW

This Software time Delay based example helps to demonstrate the same in a simple understandable way by using “Highlight Execution” feature of LabVIEW.

An equivalent structural program based on C language is given in figure Fig.4(c).

Case b) Measurement based on LabVIEW and myRio/ ELVIS ii+: This model is based on an actual speed measurement hardware setup. A hardware/software device like myRIO/ELVIS ii+ is used along with LabVIEW based set up of case 'a' shown in figure Fig 4.,

Here Boolean switch is replaced with hardware device - myRIO's analog input acquisition block. This case demonstrates integration of myRIO hardware and LabVIEW software and serves as a classic example for Hardware in the Loop Simulation. This Analog input acquisition block acquires proximity sensor signal and is equivalent/similar to a numerical control in LabVIEW simulation. The methodology of how numerical control is already discussed in case 'a', hence not discussed.

A 12V DC Motor's speed is controlled by one channel of RPS with a range of 0-30V 3A. Other channel of

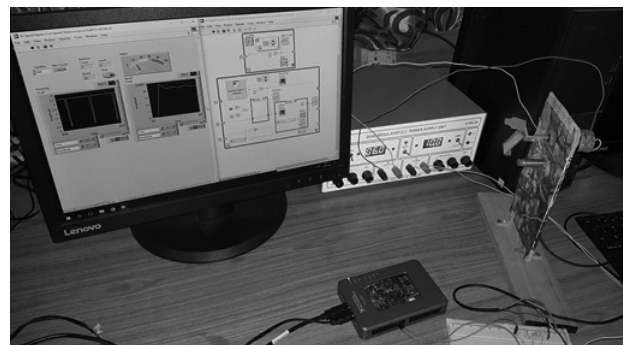


Fig.5 : Speed Measurement setup using myRIO

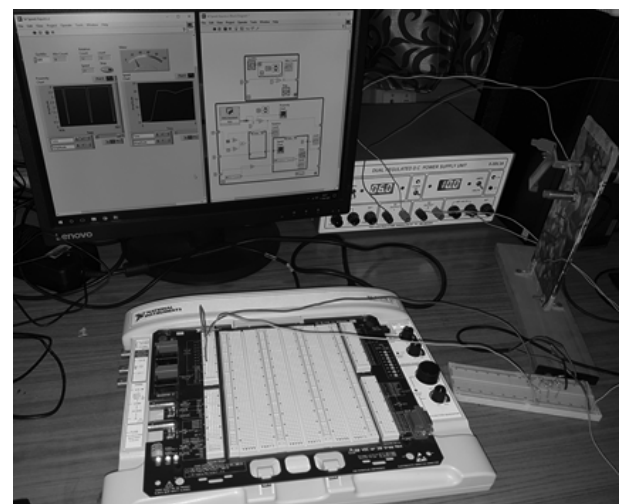


Fig.6 : Speed Measurement setup using ELVIS ii+

RPS is used to power up the 12V Proximity Sensor with 4mm sensing capability. The actual signal from Proximity sensor is scaled down to the range of 0 to 4V by using a voltage divider network to connect to analog input 0 of myRIOs MXP connector. The physical measurement setup using myRIO is shown in figure Fig.5.

In case 'a' the switch had to be pressed manually to make a change in state. Here a Boolean control switch is replaced with myRIO's analog input acquisition block, so no manual clicking or switch change is needed and when motor is powered up rotating, it causes for the change in state as it is acquired by the analog acquisition block of myRIO from the proximity sensor. The change in analog input voltage could be observed with proximity chart in real time at one sample per 50ms and is processed further in LabVIEW to display the speed in Rotations per Minute.

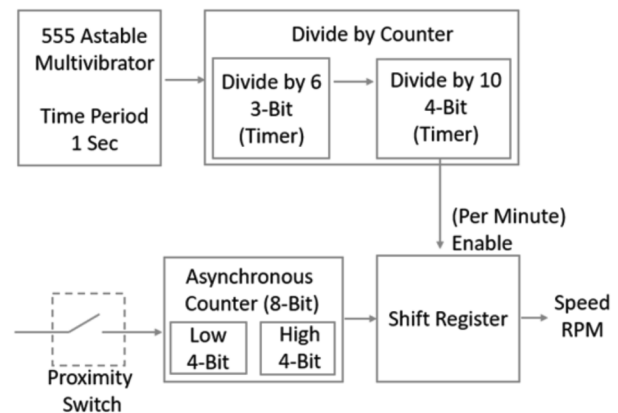
Observe that the acquired proximity sensors analog input voltage value is around 4V in one state and above 0 in another. These values depend on the type of proximity sensor, its characteristics, applied voltage and the voltage divider network etc. As discussed earlier in case 'a', this may also vary based on the characteristics of hardware acquisition device and speed of rotation also. Threshold may be fine-tuned to consider ON/OFF states respectively.

National Instruments provides many other hardware devices like ELVIS II+, ELVIS III, myDAQ etc. Similar setup could be used with that respective hardware to demonstrate the same.

A setup developed using ELVIS ii+ is shown in figure Fig 6. This model is similar to that of myRIO discussed earlier. It demonstrates Hardware based measurement & design of systems using different hardware.

Since an ELVIS ii+ board is a different hardware device, corresponding acquisition and conversion blocks have been used for signal acquisition. Here the DAQ assistant block, configured to measure analog input 0 with one sample on demand sampling is used. The obtained signal is of the waveform data form. To convert this waveform signal, a data type conversion block is used for this purpose. Apart from the two blocks and the ELVIS ii+, the principle of measurement, block diagram of VI remains the same. ELVIS ii+ provides a wide array of instrument

features which makes it suitable for various measurements. myRIO offer the advantage of being used as a standalone device.



**Fig.7 : Basic Functional Block Diagram for Speed Measurement.**

#### D. Method using Multisim

The method presented here uses Multisim instead of LabVIEW to demonstrate the simulation model of cases b.

Case c) Software Simulation of Speed Measurement using Multisim: Here a set up similar to case 'a' is used. Electrical Circuit simulation of Multisim is used to demonstrate the same that was developed using programming/mathematical simulation model of LabVIEW. So correspondingly the terminology and components used are changed based on the requirement of Multisim for circuit simulation.

The basic block diagram of the speed measurement circuit is shown in figure Fig.7. The detailed design of the respective blocks is shown in the respective Multisim design circuits through figures Fig.8a to Fig.8d. Some Multisim design pages are not shown here as they are an equivalent replica including minor modifications of figure Fig.8.c.

Here Proximity switch is represented using a SPST switch S1 as shown in Figure Fig.8a and the counting logic is designed using flip-flops to form a counter and simulated in Multisim. The Multisim Design (Page 1) shown in figure Fig. 8a is designed to acts a frontend with off page connectors to all the components in other design pages.

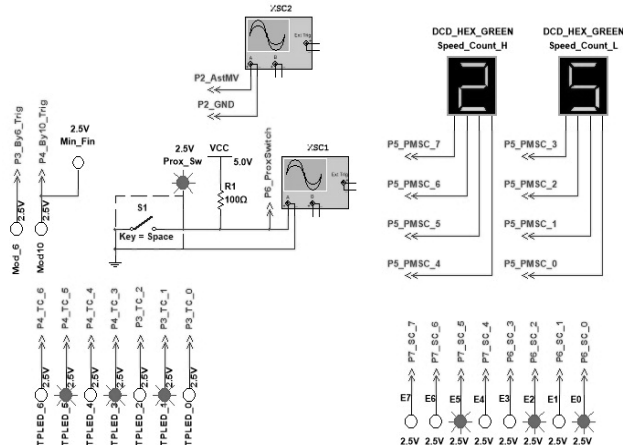
The speed count is shown in the Hex display. The same is shown using LEDs in bottom right, connected

by “Off page connectors” from sift register of Page 5 (figure Fig. 8d).

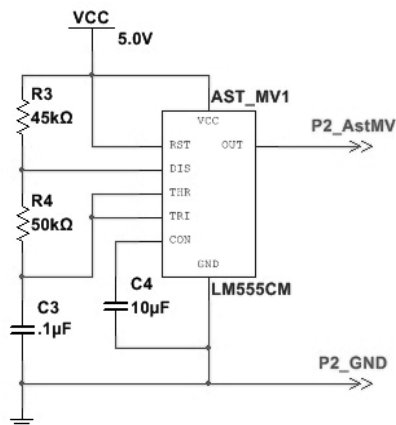
The status of timer is shown using LED connected by “Off page connectors” of Page 3 and 4 (figure Fig. 8c). on the bottom left. A Simple Up counter is used both for timing purpose and for counting the number of proximity switch changes.

Here “Per Minute” activation is implemented by a timer.

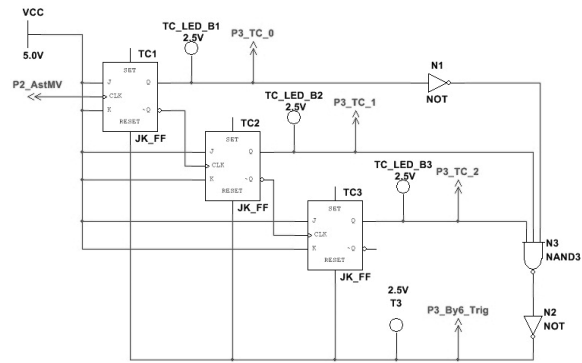
Timer circuit uses a 555 Timer based Astable Multivibrator for clocking. A counter using flip-flops is clocked by this 555 timer and act as a timer for required time rate. A 555 based Astable Multivibrator shown in figure Fig.8b. It generates a Square Wave with a time period of “1 Second”. A two stage “divide by” counter is used so as to generate a pulse every minute. This is achieved by using a first stage as



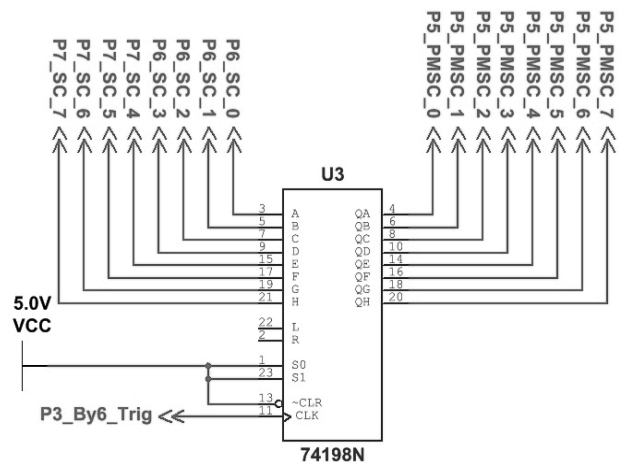
(a) Multisim Design (Page 1):  
Main Page acting as User Interface with off  
page connectors other pages.



(b) Multisim Design (Page 2): Astable Multivibrator



© Multisim Design (Page 3):  
Divide by 6 Timer Circuit;  
Used for Per Minute Signaling.



(d) Multisim Design (Page 5): Shift Register.

Fig.8 : Simulation of  
Electrical Circuit for Speed Measurement

shown in figure Fig.8c with a divide by 6 using a 3-bit asynchronous counter and second stage with a divide by 10 using a 4-bit asynchronous counter, not shown here.

The proximity counter is also implemented using flip-flops. An 8-bit counter split into two 4-Bit counters Low 4-Bit (Page 6) High 4-Bit (Page 7), are used, not shown. This 8-Bit counter is used to count the number of changes in the SPST switch which represent the Proximity sensor that is used to detect the rotations of motor. This is reset every minute using “Off page connector” from page 4.

Here the counter is designed assuming maximum count of around 250 RPM. Finally, a shift register's as shown in figure Fig.8d is used to store the speed count for a specific minute as it takes the count value from the proximity counter and gets enabled for every minute through the timer counter pulsed by the 555 based astable multivibrator. The RC values of the

astable multivibrator need to be carefully selected for achieving the required “per minute” timer pulse in multisim's circuit simulation.

### 3. Comparison, Analysis & Applicability of Different Learning Methods of Speed Measurement

In Academia, for education of students every course has certain objectives and outcomes. The typical requirements for theory/laboratory course on Measurements/ Instrumentation are presented here.

1. Demonstrate knowledge on various measuring instruments, principles of sensors & transducers.
2. Compare, Analyze the operation, performance of sensors, measurements and instruments.
3. Design measurement and signal conditioning circuits and sensing mechanisms.
4. Select and apply programming skills, appropriate sensor, measuring technique and instrument.
5. Solve problems and provide engineering solutions for societal use.
6. Practice professional and ethical principles.
7. Effectively work as an individual and as a member in a group.
8. Prepare and present technical documents, communicate effectively among professionals & people.

Traditional setups as shown in figure Fig.1 seldom involve modeling, programming, or circuit design that help in applying the knowledge, nor provides skills in design, using different tools etc. LabVIEW and Multisim software's provides features to perform this modeling, programming, design, simulation and verification as discussed in cases 'a' through to 'c'.

Speed could be found using frequency measurement blocks but to improve the level of understanding of students, the models discussed here are developed almost from scratch using very few built in function blocks or library toolboxes. The approach used provides inter disciplinary understanding that is applicable in different courses – Concepts of High Level Programming, HDL, Microprocessor/Controller etc. Readily available

functional blocks/toolboxes cannot demonstrate these without having a corresponding separate application.

One of the important requirements in industries and professional organizations is to design complex systems, properly document the technical details, electrical circuit design to meet the required standards. One such procedural requirement is the naming conventions used. When there are multiple circuits in many different sheets and are interconnected like the one discussed here the naming convention, terminology plays an important role. To demonstrate the same, the “off-Page Connectors” used here are named based on the page number they are sourced from and by using the short form of the type/components name. This provides for easy understanding, interlinking or assembling of circuits in design and development and also for documentation purpose, so that the design documentation can easily be read and understood by a third party. This also demonstrates modularity and hierarchy.

Ability to work as an individual and in a group is also one of the requirements that students should understand and develop so as to be able to work effectively in an organization. Modular and Hierarchical approach demonstrated through the electrical circuit design for speed measurement through multisim provides ample opportunity to work either as an individual or work as a group. As an example, a Divide by 3 may be designed by a student, divide 4 by another, astable multivibrator by one student, two 4-bit counters by other etc. based on the size of the group. After individually developing the respective circuits, students may be assembled together as a group to integrate all the modules of the circuit. Here there is also the opportunity to incorporate group lead that takes care, plan the design and development of the required speed measurement.

This approach may also be implemented in academics across different labs and semesters by careful planning of different components design across various labs or semesters. As an example, Design of counters may be designed as part of digital lab, programming, counting logic in programming course etc. Similarly, the same may be applied in the same course as in different steps in different weeks and assembling them during the semester or at the end of the semester to form a mini project based on the complexity of the setup. The speed measurement setup discussed here and the level measurement



discussed in [7] have been done during multiple weeks in a step wise manner. The Week by week organization is as follows.

- In the first week LabVIEW Introduction, “Numeric”, “Boolean” type programming had been covered.
- Second Week “Structures” – Case, for and while have been covered along with logic for determining the +ve and -ve edge.
- Third Week additional application examples along with timer – timing, local variables, Graph, File I/O with Data Logging have been covered.
- Fourth week speed measurement setup requirements along with simulation only model of speed measurement is covered. (Case 'a').
- Fifth week, Hardware components for Data Acquisition (DAQ) like myRIO have been demonstrated and used for acquiring sensors signal.
- Sixth week, the actual measurement of speed is done using myRIO & LabVIEW. (Case 'b').

The theoretical aspects of LabVIEW have been conducted as an Add-On course for Hands on programming practice.

To demonstrate the effectiveness of using NI tools, and to cover the general requirements of the lab completely within the stipulated time, considering the skill levels, only some experiments were done using NI tools, and the others were done using traditional training setups.

Multisim based electrical circuit simulation (case 'c') was considered as mini project for fast learning and enthusiastic students in earlier regulation and is being implemented for all as Seventh week work in the later regulations in Industrial Instrumentation Lab.

The required hardware setup had been developed by lead students who have shown keen interest in design and development with the help of faculty and lab technician. This gave students opportunity to develop, test setups and cater to the needs of other students. Some of the standout contributors are some of the co-authors of this and the level measurement paper of [7].

These setups offered various benefits as compared to readily available setups. The NI tools were the only one big investment made, which had been used for 8 of the 15 experiments in total. Labview, Multisim, myRIO had been used across multiple experiments providing reuse cost benefit, flexibility along with all the above-mentioned simulation and design features.

Seamless connectivity of NIs tool suites and interconnectivity could be performed using integration of LabVIEW, Multisim and myRIO/ELVIS II+. This Integration of the myRIO, LabVIEW and Multisim has been demonstrated using a simple example of liquid level measurement in [7]. Similar setup could also be used to demonstrate integration of ELVIS ii+, LabVIEW and Multisim but is not presented here.

Some of the other design simulations or development methods are Microcontroller or Field Programmable Gate Array - FPGA based measurement setups. An equivalent structural/C program shown in figure Fig4(c) of case 'b' could be used to implement in microcontrollers in embedded C or assembly programming. If an operating system is used, it takes care of the concurrent execution and the process 1 and 2 could be run concurrently under the control of an operating system. If an operating system is not present, the concurrent process 1 may be designed and configured as a hardware timer using interrupts and the concurrent process 2 could be run as the main program.

The equivalent structural/C program shown in figure Fig4(c) of case 'b' could be also implemented in an FPGA without the operating system as a set of hardware components when the application program is synthesized into equivalent hardware components offered by the FPGA using C or HDL language-based tools. Students of Third or final year could employ this microcontroller or FPGA based approach for the same. The full implementation details of microcontroller or FPGA based designs are out of the scope of this paper. Interested reader can refer to reference or equivalent papers for the respective implementation details.

These methodologies help the instructing faculty in training the students to understand and develop skills required for industries. The student feedback survey had been positive, students showed improved understanding and skill levels. The academic achievement for Batch of 2016 is around 88% and 2017 Batch stood at 90%. There has also been

improvement in the level of feedback from batch to batch with improved experience, organization and adaptability of the faculty. The discussion has been focused on technical aspects for use by engineering education fraternity up to this section and detailed questionnaire, assessment and observation is presented in the next section.

#### 4. Assessment & Observation Of Survey

Survey places a vital role in analysis of the proposed techniques and the assessment gives estimation whether the proposed methods met the desired objective or not.

A survey has been conducted involving the students to assess and ascertain the proposed way of education in industrial instrumentation lab. The assessment is carried out for Students of Dept of EIE. The lab course had been introduced under SVEC-16 regulations and had been conducted for two batches – 2016 Batch and 2017 Batch respectively. A set of questions that cover all the aspects about learning, practicing and best practices implemented in laboratory that are prepared by the faculty and survey was overseen by the student volunteers through Google Form.

The questions used for assessment are given below.

- Q1. Did the experiments of the lab meet all objectives and requirements of the course?
- Q2. Were you satisfied with the flow and organization of the experiments in the lab?
- Q3. Did the experiments based on NI tools – LabVIEW, Multisim, myRIO improve your skills compared to traditional experiments?
- Q4. Did the LabVIEW programming improve your ability to apply programming skills for instrumentation and measurements?
- Q5. Is problem solving and proving solutions to problems incorporated in the experiments and is it appropriate?
- Q6. Did the experiments in lab encourage and improve your ability to work together in a group?
- Q7. Do the traditional measurement setups provide flexibility to change the design specifications or meet the full requirements of a laboratory?
- Q8. Did the experiment improve your ability to work in a multidisciplinary environment?
- Q9. Do you feel the knowledge and skills you acquired in this lab will be helpful and applicable for other courses or in your future job?
- Q10. Do you recommend the modeling, design, simulation and measurement approach employed for speed measurement using NI tools as the proper way for incorporating in the measurements & Instrumentation laboratories?
- Q11. Did you enjoy and feel motivated to do the experiments?
- Q12. For better, fast understanding & practice would you spend extra time or come to extra sessions?
- Q13. What is your opinion about the complexity of the content in laboratory experiments?
- Q14. How was your interest in the laboratory experiments before the course?
- Q15. How was your interest in the laboratory experiments after the completion of the course?
- Q16. Rate the amount of effort you put in to learn?
- Q17. Rate the amount of skills you gained through the experiments in the lab?
- Q18. Which method do you feel would benefit your career development?
- Q19. Which kind of method would you use to fully utilize the given lab time of two and half hours?
- Q20. Which kind of method would you use to develop skills in measurements and instrumentation?

The assessment that is performed and presented here focuses on NI Tools based experiments along with general assessment of lab, comparison with traditional setup based experiments. Non random sampling approach is employed for the survey for studying the learning, understanding levels, & practical learning. The batch of 2016 had 33 student responses and the batch of 2017 had 48 responses.

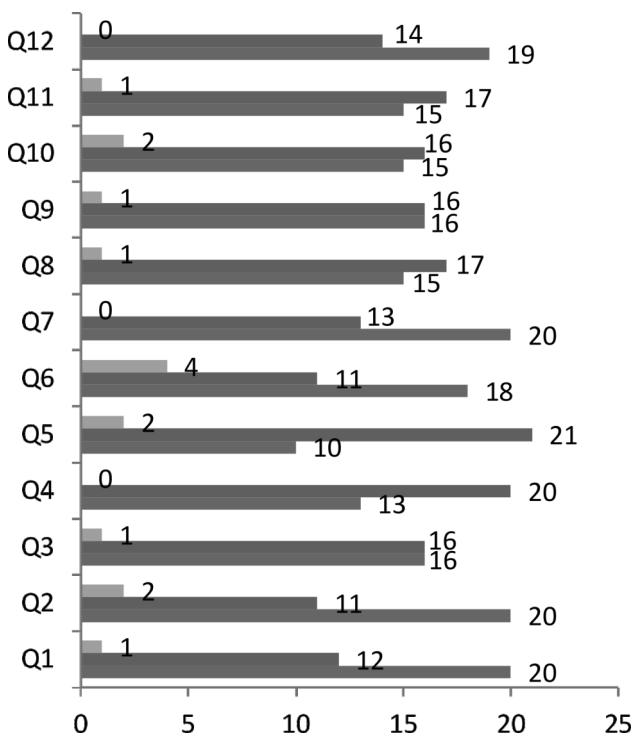
The student responses for Questions 1 to 12 are shown in figure Fig.10. The response for question 13 is shown in figure Fig 11. The responses for questions

14 to 17 are shown in figure Fig12. The responses for questions 18 to 20 are shown in figure Fig 13.

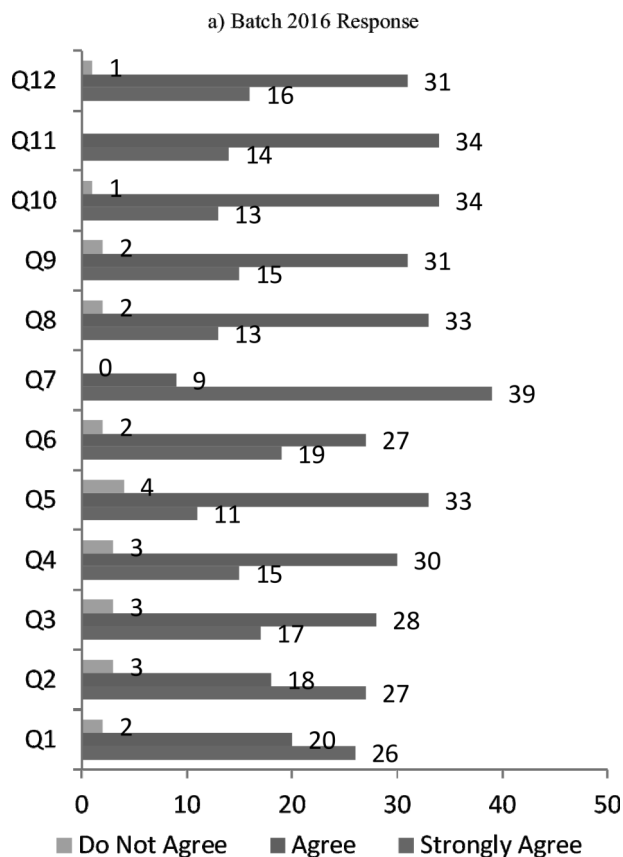
Based on the student responses of Batch 2016 and 2017 to the Question Q1, it has been observed that all the required objectives had been met as most students strongly agree or agree. Only 1 or 2 students disagreed. Students have also been satisfied with the organization and flow of experiments in the lab, observed through the response for Question Q2 with only 2 or 3 students who disagree.

Almost all the students strongly agree that NI tools based experiments are the preferred way for measurements & instrumentation, full lab time usage from responses to Questions Q19 and 20 shown in figure Fig.13 and that they provide flexibility for design changes, or meeting all laboratory requirements from response to Question Q7 shown in figure Fig 10. Most strongly agreed that NI based tools or combination with traditional method would benefit for career development based on response from Question Q18 demonstrated using figure Fig. 13.

Students were asked whether they would recommend modeling, design, simulation and



a) Batch 2016 Response



b) Batch 2017 Response

Fig.10 Student Responses for Questions 1 to 12

measurement approach as in Question Q10. It is observed from the response in figure Fig 10 that most of the students have agreed to recommend.

From response to Question Q11 in figure Fig 10, it is observed that motivation level of the students is good. Q14, Q15 were focused on the student's interest before and after the lab. The responses in figure Fig 12 indicate that their interest had increased after completion of lab.

Questions Q16 addressed the amount of effort student had put in. The responses from figure Fig 12

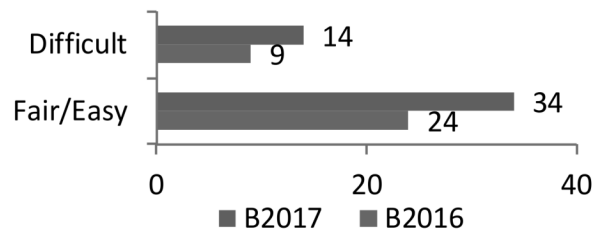


Fig.11 : Student Responses for Question 13

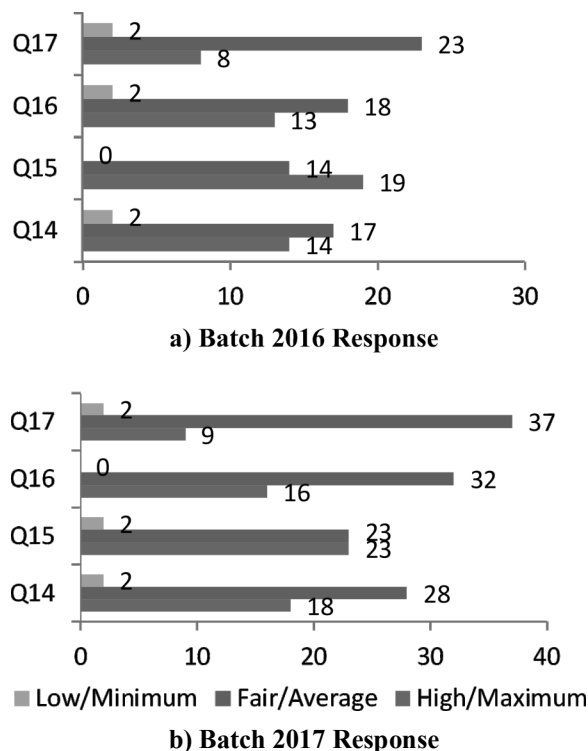


Fig.12. Student Responses for Questions 14 to 17

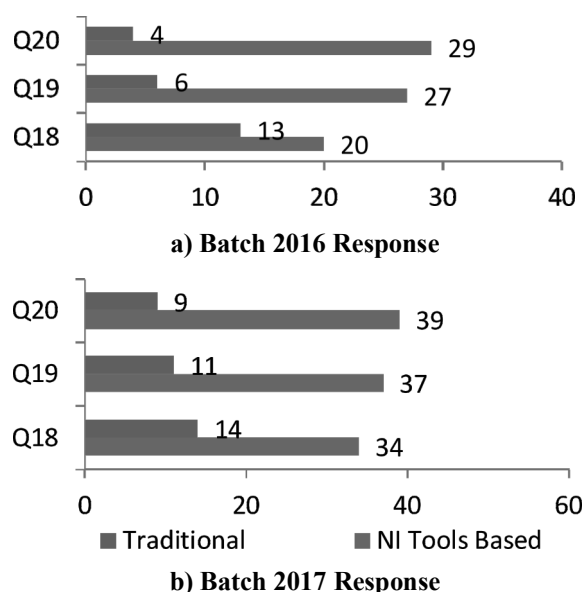


Fig.13. Student Responses for Questions 18 to 20

indicate that they made fair amount of effort in learning and doing the lab.

Many students agreed that experiments based on NI based improved their skills in programming, measurement & instrumentation problems from responses to Questions Q3 & Q4 using figure Fig 10. Q17 indicate the overall skills they have gained through the lab. From the response in figure Fig 12

students agree that they have gained considerable overall skills through the lab.

Also responses from Q8 and Q9 of figure Fig 10 indicate that experiments conducted in the lab improved their ability to work in a multidisciplinary environment and that the knowledge and skills acquired would benefit in other courses or their future job and responses to Question Q5 from figure Fig 10 indicate that student agree that problem solving & providing solution is satisfactory.

Question Q13 addressed the student's opinion on the complexity and content in the laboratory. Around 72% of the students of both the batches considered the complexity and content to be appropriate – Fair/Easy as shown in figure Fig 11. Around 28 percent of students considered it to be difficult. This could be attributed to the wide range of students, their interests, programming skills and abilities.

## 5. Conclusion:

The paper demonstrated procedures/standards that are generally followed in industries and any professional organization for documentation purposes.

Also demonstrated are the possibilities for instilling the concepts of modularization and hierarchy by distributing the different functionalities, subsections of a model, software/hardware to develop individually and then also bring together the different subsections/circuits models to make the student to work as a group to perform measurement of speed.

Employing the methods discussed in this paper for Lab experiments and projects provides an opportunity to students in understanding the ways of modeling, simulation using the various software tools, integrating and developing the required hardware along with professional practices, standards, procedures, ability to work as an individual and in a group. This project-based learning approach allows the students to do and learn and gives a better exposure to design thinking methodology and holistic development of students. This approach clearly demonstrated that it meets all the objectives and outcomes as compared to traditional method. A similar approach could be employed for various other measurements and other courses.

From the student's survey, analysis and assessment we concur that NI tools based experiments are the preferred way for meeting the course objectives and developing skills in programming for Measurements and Instrumentation.

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