

AC 2008-940: INSTRUCTIONAL DEVELOPMENT AND ASSESSMENT OF A TASK-ORIENTED SENIOR LEVEL DATA ACQUISITION PROJECT IN A SIMULATED BUSINESS ENVIRONMENT

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Instructional Development and Assessment of a Task-Oriented Senior Level Data Acquisition Project in a Simulated Business Environment

Abstract

Problem-based learning experiences give technology students a chance to construct their own knowledge base and implement it in an actual application. Some students excel when given this freedom, while others flounder and fail. One reason students struggle is they are accustomed to procedural labs and small-scale analysis problems. They lack experience in applying technical knowledge to open-ended problems. This paper presents the instructional, hardware, and software designs for a ten-week senior level control and data acquisition project that transitions students from small-scale procedural laboratory experiments and individual design tasks to multi-task projects that require coordinated design efforts. The instructional design simulates a business environment where a design team must divide work, complete individual tasks, and integrate separate subsystems to successfully complete a project. To promote the importance of clear written technical communication in a business setting, students report their progress and results in memo form. They then utilize the results of other design team members to produce final technical reports covering the entire project design. This technique uses both instructor and peer evaluations to assess student performance. Based on eight years of student participation, this paper presents the strengths weaknesses of the instructional design.

I. Introduction

Employers value self-motivated workers with management and communication skills who can function effectively in teams. Today's engineers and technologists must have technical proficiency, and also understand the mission and goals of their employer to remain in the workforce. Current engineering technology accreditation requirements recognize these demands and focus on measurable student outcomes. The new requirements seek to develop life-long learning skills, written communication skills, and oral communication skills along with technical proficiencies in all graduates. Satisfying these goals requires new teaching methods that are more student-centered.¹ One technique being applied is project-based learning.^{2,3}

Project-based learning provides enriching educational experiences that help motivate students to become self-learners.¹ Project-based learning experiences give technology students a chance to construct their own knowledge base and implement it in practice. Project-based learning also promotes active student participation in the learning process and outcome, which for some students is a difficult transition. Adopting project-based learning in technical courses requires changes in student behaviors along with new instructional methods. Students whose experiences are limited to procedural lab exercises and who have worked individually or in pairs have difficulty adjusting to the open-ended nature of the process.⁴ Well-designed transitional projects can help all students move from prescriptive lab experiments and projects to project-based learning experiences by developing the necessary skills and behaviors to help them succeed.

Evaluating students in a team is difficult because individual member efforts and contributions are hard to assess. An effective instructional design for project-based learning should include a structure that identifies deficiencies early and includes an intervention procedure to help student maximize their potential for success. The project instructional design should also include individual accountability and personal responsibility as part of the collaborative process.⁵

This paper presents the instructional design, schematics and software flow chart of a team project that helps students transition from procedural lab exercises into project-based learning experiences. During the course of the project, students develop an automated frequency response tester (AFRT) for the audio band using both hardware and software. The instructional design helps students transition to complex systems design by dividing the overall project into subsystems with specific tasks responsibilities. Team members select tasks to complete and periodically report progress by presenting designs, data, and operating subsystems for evaluation. This structure helps assess individual member performance and identify weak team member performance early. Each team member uses the results of the other team members' work to write a comprehensive technical report covering the entire project. This process promotes teamwork and peer assessment of technical content and written work.

II. Instructional Design and Assessment

The AFRT project has four major educational objectives: 1) expand analog circuit design and troubleshooting skills, 2) introduce high-level graphical programming tools, 3) enhance communication skills, 4) and introduce team building and project management skills. The project implementation uses a team-oriented, simulated corporate environment to help students learn fundamental business communication concepts and promote active, self-directed learning. The instructor takes the role of an engineering manager supervising multiple design teams in this model. The instructor divides the class into teams of three to four persons. This project provides the laboratory component for a senior-level electrical engineering technology (EET) digital control and data acquisition course. The course meets for three lecture hours and two lab hours weekly over a 16 week semester schedule. The course schedule requires project completion after ten weeks.

The project design goal is to construct a PC-based data acquisition system that produces audio band frequency response plots over the range of 20 Hz to 20 kHz. The project specifications define the desired input tester range to be 0-250 mV ac peak and the output range to be 0-12.5 V ac peak. The design specification requires high circuit input impedance ($Z_{in} > 1 \text{ M}\Omega$) voltage measurement to minimize circuit loading effects. The project design specifies circuits that scale and convert ac signs into dc levels that cover the full span of the analog input channels (-5 to +5 V dc). The specification includes frequency measurement to verify the signal source output accuracy. Students develop designs using OP AMPs, a low distortion Voltage Controlled Oscillator, (VCO), (Intersil, ICL8038) and an analog rms converter (Analog Devices, AD536A).

Students use a National Instruments NI 6024E data acquisition card to measure analog signals, generate analog output to drive the VCO, and control the VCO frequency range. Students write software interface and control program, using the LabVIEW graphical programming language. The project specification requires that the program interface have on/off controls, accept an array

of test values, numerically displays correctly scaled voltage and frequency values and generates a frequency response plot when the test is completed.

At the beginning of the course, students receive project documentation in the form of a design specification divided into specific tasks. Each team also receives a design manual that has all component data sheets, application notes, and tutorial documentation. Eight tasks define the project hardware, software, and management requirements. Figure 1 shows the tasks and their interrelationships. Table 1 lists the requirements of each task. Most tasks include both circuit and software design using LabVIEW software.

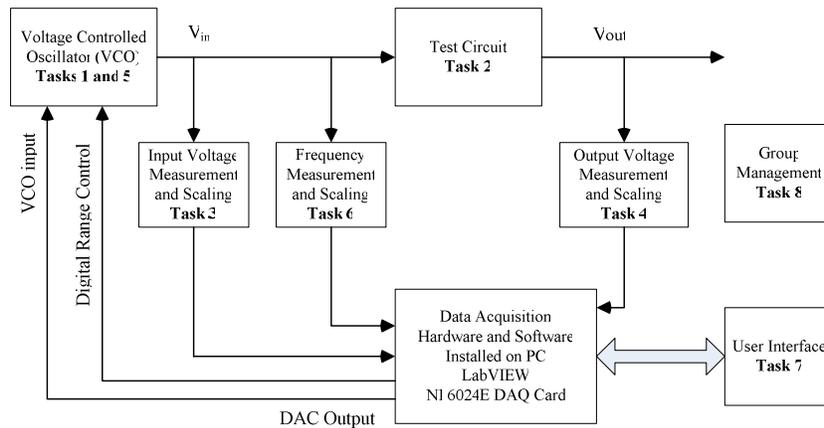


Figure 1. Frequency Response Tester Block Diagram

Table 1- Frequency Response Tester Task Descriptions

Task	Overall Requirements
1	Determine frequency-to-voltage relationships of VCO ranges. Develop LabVIEW software to control ranges and frequency of circuit.
2	Design a bandwidth limited (100-10 kHz) amplifier using OP AMPS and determine its frequency response characteristic.
3	Design a circuit to measure amplifier input voltage. Convert it to dc and scale it to the limits of the DAQ card. Develop LabVIEW software to display correctly scaled values on PC.
4	Design a circuit to measure amplifier output voltage. Convert to dc and scale it to the limits of the DAQ card. Develop LabVIEW software to display correctly scale values on PC.
5	Design a variable frequency voltage controlled sinusoidal signal source to cover the test band of 20-20 kHz in three computer controlled ranges. Measure harmonic distortion of complete circuit.
6	Measure the input frequency of the amplifier and scale to meet the design specification.
7	Using LabVIEW software, develop a user interface and all necessary software to convert measurements into a frequency response plot.
8	Coordinate the design tasks with other group members. Keep group members informed of specification changes.

The task specification includes design criteria, signal flow block diagrams, desired signal levels and a summary of relevant theories. Possible solutions are proposed in general terms. Students are encouraged to explore alternatives and are directed to other resources such as manufacturers' websites. Finally, the task description defines the desired design performance metrics and lists the required deliverables to satisfy completion of the task. Task deliverables include

performance verifying measurements and graphs, design calculations, schematics, and detailed circuit descriptions that verify students understand circuit operation and design. Students demonstrate a working model of the task design as a task completion criterion. Interconnecting all hardware and software tasks produces a complete AFRT system.

Dividing the project into tasks benefits the project instructional design in several ways. Learners new to the design process are sometimes overwhelmed and intimidated by large projects. Individual tasks define and limit the scope of each design subsystem to a manageable size which is less intimidating. The project specification is an example of how complex systems can be divided into workable tasks demonstrating the process to students. This gives student experience for future project-based learning assignments that require design skills and open ended problem solving. Each task description provides fundamental background information and points students to other resources to give learners a starting point for further investigations. Students are expected to explore these resources and attempt designs based on their own findings. The tasks have well defined, yet open-ended, results requirements. The list of required deliverables and items to present for evaluation clearly specifies instructor expectations. This eliminates student confusion about what should be reported and simplifies assessment. Defined tasks help instructors manage and monitor team member progress. Individual performance is checked three times during the project, allowing the instructor to identify students who need additional assistance and guidance.

The project is implemented over a ten week schedule as the laboratory component of a senior-level data acquisition and control course with two scheduled lab hours weekly. An open lab policy gives students more time to test and troubleshoot designs outside the scheduled time. Students receive supporting instruction in the course lecture that covers relevant project topics. The course instructor randomly selects groups of three to four students to form project teams and distributes the design specification documents during the first laboratory meeting. Group members meet and review project specifications and tasks, select a team leader, exchange contact information, and determine task assignments. Each team member selects at least two tasks to accomplish. The instructor receives a summary sheet from each team listing contact information and task assignments. At this time team members receive the expected work schedule and the assessment criteria.

The project assessment plan consists of five components: individual task technical evaluation using a memo format, informal oral task/project presentations, individual formal technical reports, peer assessment of technical and self-management skills, and self-assessment of technical and self-management skills. For the first assessment component, each team member reports task progress to the instructor three times during the project schedule in the form of a business memo with task deliverables attached. The instructor assesses student work based on three criteria: 1) adherence to schedule milestones, 2) technical and grammatical correctness, 3) completeness of presented work when compared to the expectations defined in the task documentation. Students receive individual scores for each criterion. The average team score for criterion 1, adherence to schedule milestones, is used as a team performance measure that impacts each student's individual score. This links individual member performance to the team's performance. The instructor's written comments and interaction during scheduled lab time is an

important element to encourage improvements in team members' work product as the project progresses.

For the second assessment component, students demonstrate their completed tasks to the instructor and explain their designs in the lab. This allows the instructor to verify the operation of individual subsystems, and test student knowledge of their work. The final oral assessment consists of an informal presentation of project operation by group members. The project assessment plan checks student written communication using an individual technical report covering all tasks and their progress memos with attached circuit descriptions. Team members write individual versions of the technical report using other members' task deliverables. This method provides peer evaluation and utilization of technical data, simulates large-scale systems design, and promotes collaborative learning.⁶

Peer and self-assessment complete the project assessment plan. At the completion of the project, students fill out self-assessment and peer assessment questionnaires covering different facets of the project learning objectives. Students are asked to evaluate themselves and their group members on contribution to team efforts, and on how the project improved specific technical skills, communication skills, and managerial skills. The instructor compiles this information and shares the average peer assessment and self-assessment scores with individual students. The average score on the peer assessment is included in the student technical report grade.

III. Typical Circuit Designs and Software Flowchart

This project's hardware designs give student experience in signal conversion, digital interfacing, analog scaling, and linearization using low cost devices. The bandwidth-limited amplifier shown in Figure 2 is the test circuit for the AFRT project. Teams build and test this circuit using laboratory instruments at specified test frequencies to establish a reference response plot.

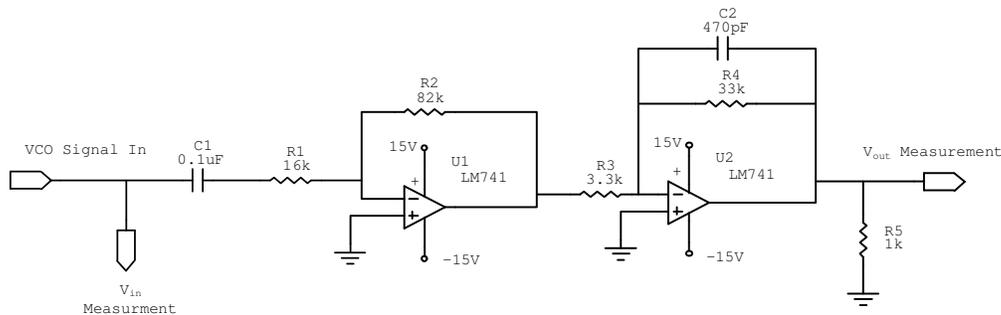


Figure 2. Band Pass Amplifier for System Testing: $A_v=50$, $f_L = 100$ Hz, $f_H = 10$ kHz

The circuit has an overall voltage gain of 50 with lower and upper cutoff frequencies of 100 Hz and 10 kHz respectively. The project specification sets the values of C1 and C2 along with overall gain and frequency limits. Students use design formulas to compute all resistor values. This circuit takes a sinusoidal input signal from the VCO. Additional design tasks develop the input and output voltage measuring circuits.

Figures 3 and 4 show schematics of typical input/output voltage measurement circuits for the AFRT project. Both circuits use an AD536A True RMS Converter circuit to change the ac input signal into an rms equivalent dc value.⁷ In the input voltage measurement circuit, an LF351 OP AMP amplifies the ac signal to achieve full scale input into the AD536 for an input level of 250 mV. Two LM741 OP AMPs' form a scaling circuit that produces an output voltage range of -5 to +5 V dc over the input voltage range of 0-250 mV ac peak. The output voltage measurement circuit has an input

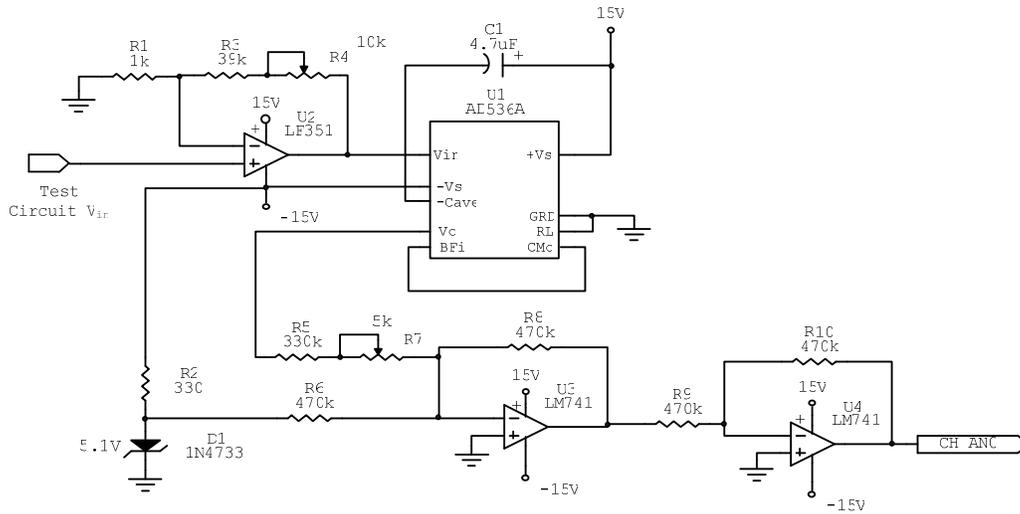


Figure 3. Input Voltage Measurement Circuit

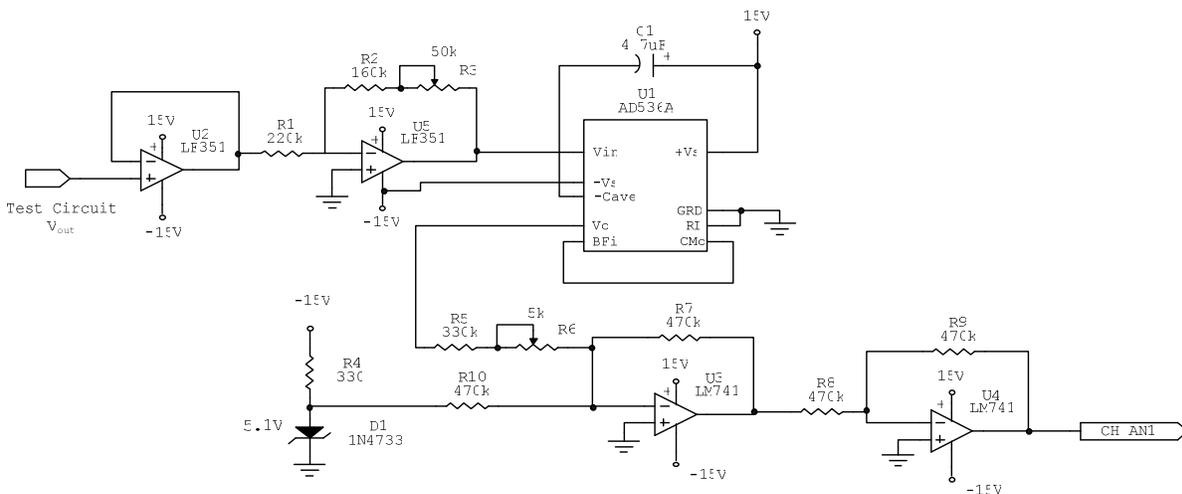


Figure 4. Output Voltage Measurement Circuit

voltage range that is greater than the rating of the AD536A. The LF351 OP AMPs U2 and U5 provide high impedance input to reduce circuit loading and attenuate the voltage level to the operating range of the AD536A. The remaining circuitry scales the True RMS converter output to the desired analog input channel range. Students design and construct the input/output

measurement circuits using block diagrams that generally define the function of circuit stages. Lecture material and device application notes give students the necessary background to complete these tasks.

Students construct a voltage controlled sinusoidal oscillator with three digitally controlled ranges to provide the test amplifier input signal. Figure 5 is a typical schematic for this project task. An Intersil ICL8038 function generator is used for the VCO sinusoidal source.⁸ The project design documentation specifies that the VCO will operate over three ranges to improve accuracy and resolution. These ranges cover the entire audio band and are 0 – 400 Hz, 0 – 4000 Hz, and 0 – 40 kHz. The values of R10 and C1, C2, C3 set the free-running frequency of the VCO. The voltage at pin 8 of the device controls the frequency output. The lowest allowable voltage at this pin is 7 V dc with respect to ground.⁸ The highest frequency occurs at the lowest value voltage value. The lowest frequency occurs when pin 8 is at 15 V dc. The devices U3, U4, and Q1 scale

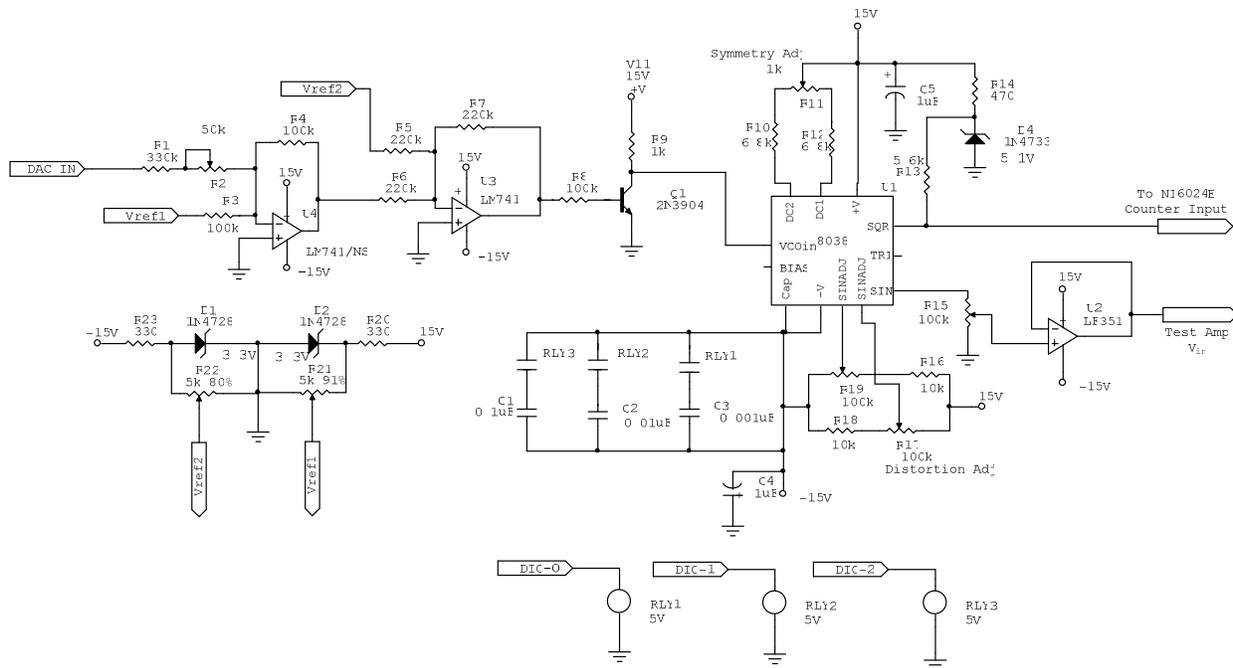


Figure 5. Computer Controlled VCO Sinusoidal Signal Source Circuit

the data acquisition card's (DAQ's) analog output from the range -10 to $+10$ V dc to the operating range of the VCO, 7 - 15 V dc. The three SPST relays, (RLY1, RLY2, and RLY3) with coils connected to the DAQ digital outputs, control the range of the oscillator. Adjusting R11, R17, and R19 control the signal symmetry and distortion. The potentiometer R15 controls the test signal level that is buffered by the voltage follower, U2. As part of this task, students use a low frequency spectrum analyzer to determine the harmonic content of the oscillator sinusoidal output. They use this data to determine the total harmonic distortion as a function of frequency.

Most design teams choose the integrated digital counters of the NI 6024E to measure the test frequencies. Figure 6 shows the external connections necessary to measure frequency using these counters.⁹ A high-level LabVIEW Sub-Virtual Instrument (Sub-VI) causes counter 0 to produce a high output for a predetermined time interval. Counter 1 accumulates VCO signal

transitions for this period. The VI uses the accumulated counts and the gate period to determine signal frequency. The digital counters require TTL compatible signals developed from the VCO circuit to measure input frequency.

Team members develop the control and data acquisition software using LabVIEW. The flow chart in Figure 7 gives an overview of the software design. An array of test frequencies on the

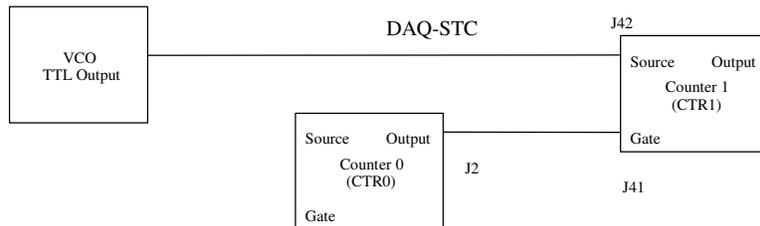


Figure 6. NI 6024E External Frequency Measurement Connections

system front panel determines the test points. When the test starts, the software determines the correct VCO range through a window comparator implemented in LabVIEW. A case statement selects the correct VCO scaling function and activates the correct range relay based on an identifier produced by the comparison. The software then writes the correct voltage value for the desired frequency to an analog output. A 0.2 to 0.5 second software delay assures that steady-state values will be read for each test point. The software then reads voltage and frequency test data and scales the readings to show actual values at each point. When all test frequencies have been processed, the program computes the gain in dB and generates a semi-log plot of the results.

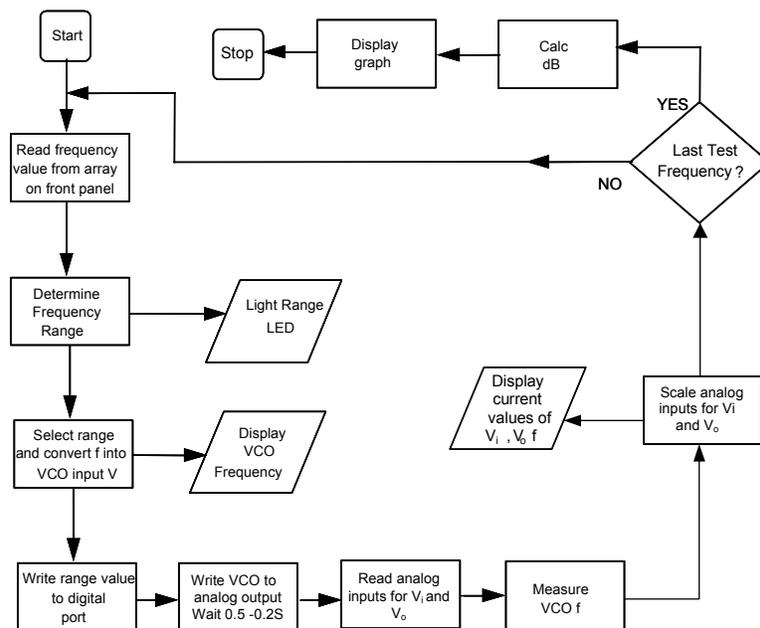


Figure 7. Software Design Flowchart

IV. Results and Discussion

Eight years of results have been recorded for this project; six using LabVIEW and National Instruments hardware, and two using other hardware and software. All students graduating from the EET program take part in the project since it is a required course. Eighty-seven students took part in the project and formed 24 project groups over its eight-year history. Twenty of the 24 teams presented successful projects for instructor evaluation. The remaining four teams presented partially operational designs.

Figure 8 compares individual performances measures for the three assessment instruments. This compilation shows team members performing better in scheduling and individual progress memo writing than in technical report writing.

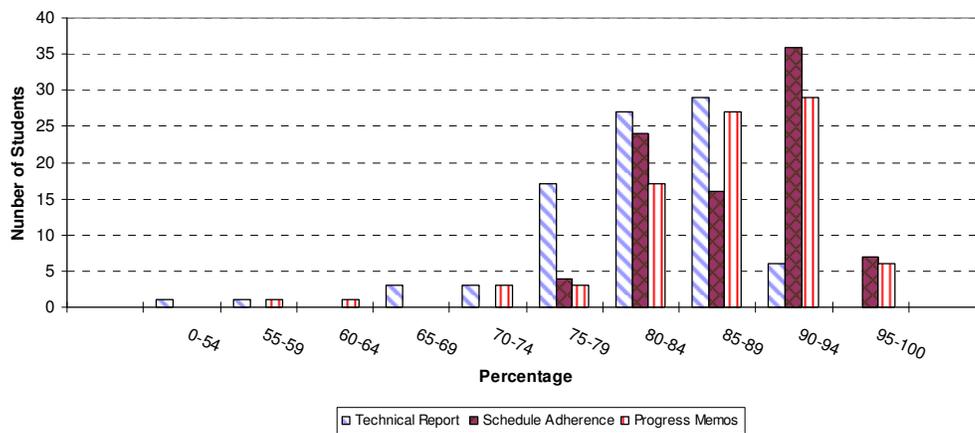


Figure 8. Individual Student Performance Distribution for Project Assessment Instruments

This is not unexpected since the technical report includes all aspects of the project and team members have only developed subsystems. There is correlation between the length and detail of the task exposition in the technical report and team members' involvement in designing the task. Students report the tasks they design more thoroughly than those designed by other group members.

Peer and self-assessment was added to the project to measure individual project contributions and introduce reflective practices to the assessment process.¹⁰ The most recent class of students who participated in the project completed peer and self-assessment surveys. The survey instrument measures technical, communication, and managerial skills. The survey contains six items in each area. Figure 9 compares the self, peer, and instructor assessments of the fourteen students in the class. In most cases, self, peer and instructor evaluations of performance agree within a range of 10 percentage points. Two occurrences of low peer evaluations were traced to specific group member performance deficiencies. In these cases the instructor assessment and self assessment rank student performance higher than group peers. A peer assessment has been added to the project assessment process to fairly compensate members for their contribution within teams.

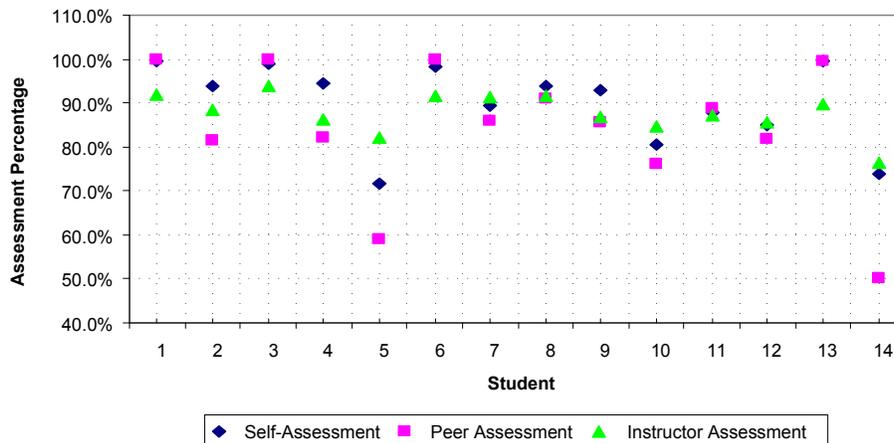


Figure 9. Comparison of Assessment Processes in Frequency Response Tester Project

In observing student performance over the project history, several interesting points and areas for continued instructional design refinements have been discovered. One area of concern is that group members have difficulty writing and applying information from circuit design descriptions. This is evident in the comprehensive technical reports that require group members to use peer materials. To help eliminate this deficiency, model circuit descriptions will be taken from technical publications and given to students for review. The instructor will review the key points of the model materials so that these characteristics and concepts can be included in student work.

Student surveys of the project instructional design indicate that more tutorial information and exercises are necessary to prepare students to use LabVIEW. In the past, a one hour tutorial was presented on the software and a short homework assignment was given to evaluate student understanding. Team members were expected to use LabVIEW software’s online help feature and the instructor as resources to learn the necessary programming skills. Future implementation of the project will include a series of programming assignments related to the necessary topics of analog input/output and digital port control to develop necessary skills. An additional textbook will be included that teaches LabVIEW and includes a student version of the program.

Most students underestimate the time needed to integrate individual tasks into a working system. Previous design projects encountered in the program construct circuits that require a single breadboard to complete, while this project requires several. Students must develop skillful breadboard construction techniques and use test points for the final calibration for efficient and timely project completion. Circuit documentation is critical during the integration phase. All schematics must be correct and clearly labeled. Software must be debugged using dummy inputs prior to system assembly.

The most important observation involves how a failure or delay of a critical task subsystem seriously impacts the teams’ ability to complete the project. The tasks are designed such that most work can be completed independently, but all tasks must be completed on schedule. The task-oriented nature of the instructional design, and the repeated student interaction and feedback

help identify individuals who are struggling with their tasks. Then they can receive the necessary support required to complete the task. As an additional completion aid, working designs are being placed on printed circuit boards and will be made available to remaining team members in the event that an individual fails to meet task requirements in a timely fashion, so project development can continue.

Future implementations of this project will include enhanced project management instruction and practical application of scheduling. Many EET students take project management as a technical elective and project management software, such as Microsoft Project, is available to students. In the future, team leaders will be responsible for developing project progress charts that show a detailed breakdown of the processes necessary to complete the individual tasks. They will also be required to allocate time to each task. This process should help teams self-assess their design progress and utilize concepts developed in other courses.

V. Conclusion

Teaching design and troubleshooting of complex integrated hardware and software systems is challenging and requires modification of student behaviors. This task-oriented frequency response tester project helps students transition from procedural lab experiments conducted individually or in pairs, to a multi-stage design project using project teams. The use of instructor evaluated peer designs and circuit descriptions in developing individualized project technical reports emphasizes the importance of clear and correct technical communications to all team members. Close and periodic evaluation of task performance identifies student deficiencies which can be corrected with supplemental instruction. Eight years of results show that most groups using these instructional materials were able to complete the project design and meet or exceed the project assessment criteria. Addition of self and peer assessment produces a more reflective learner, fairly rewards group member participation, and aids in effectively evaluating student contributions to the project effort. Future instructional materials will develop and enhance pre-existing project management skills, giving learners a real-world context for their application.

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