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Creating Maker Culture in an Engineering Technology Program*

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Many engineering technology students struggle with theoretical concepts in courses like Control Systems. Maker Culture can provide an attractive option to enhance student learning. In order to help students, Maker Culture was introduced in the Control Systems course in the Electronic Systems Engineering Technology program at Texas A&M University. Laboratories were converted to a makerspace kind of environment. Students proposed their project ideas and worked on their project during laboratory sessions. A Mini-Maker Faire was held at the end of the semester, replacing the traditional project demonstrations and presentations. The most important lesson learned is that a successful implementation requires delicate planning. This paper presents the design of lectures, laboratories, and the course projects to cultivate Maker Culture in an engineering technology program. Evaluation of the effort and analysis of data are discussed.

Keywords: Maker Culture; Maker Faire; Engineering Technology; Control Systems

1. Introduction

Department of Engineering Technology & Industrial Distribution at Texas A&M University offers Bachelor of Science (BS) degrees in several areas of engineering technology (ET). It has been observed many times during outreach or recruiting events that when students and their parents look for majors, many of them oftentimes are confused by engineering technology (ET) as a major, which may be mistakenly thought of as an associate degree program because many community colleges offer two-year associate degrees with similar names. The four-year ET programs are also different from traditional engineering programs. The ET major can cause some confusion among potential employers as well [20, 27]. There has been some debate about whether ET should change its name to applied engineering [34].

Because of their applied nature, it is a common practice for ET programs to focus on hands-on learning. Courses involving more abstract concepts, such as Control Systems, can be challenging to teach in ET programs. Majority of ET courses rely on laboratories to reinforce student learning; however, many cookie-cutter laboratories are more like academic exercises and are not effective. Students simply follow the laboratory instructions without understanding the underlying reasons. These laboratories can only provide limited help for students to make the connection between the abstract concepts taught in the lectures and the laboratory exercises. In addition to the laboratories, many ET courses have course projects for the purpose of motivating students to apply the theories they learn to solve real-world problems.

There are other efforts such as introducing product development [31] and creating high impact learning environment [43] that have been made to motivate students. As one of the attractive ways to enhance student learning [26, 44], Maker Culture is a grassroots movement consisting of mostly tinkers, hobbyists, and engineers, who design and build gadgets while learning by themselves or from one another about software/hardware tools and techniques [1]. It can provide informal and shared learning-by-doing experiences with fun and self-fulfillment for students [17, 21, 33]. Maker Culture also allows for the implementation of several student-centered learning options such as active learning, cooperative learning, peer-led team learning, peer instruction, problem-based learning, challenge-based learning, inquiry-based learning, and project-based learning [19]. Maker Culture is effective in enhancing student learning because it involves high-level learning of "analyze, evaluate, and create" in addition to the lower levels learning of "remember, understand and apply" in Bloom's taxonomy [4, 5].

Maker Faires are events to celebrate Maker Culture. There are also smaller scale Maker Faires called Mini-Maker Faires. Millions of people all over the world participated in Maker Faires every year. Unfortunately, in June 2019, Maker Media, the company that organized the Maker Faires ceased its operations [24]. However, the failure of

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Maker Media should not stop others to carry on the Maker Movement. In fact, the interests to use Maker Culture in educational institutions are increasing [15, 18, 35]. There are several commonly used keywords in Maker Culture: make, design, tinker, build, Do It Yourself (DIY), Do-It-With-Others (DIWO), learn by making, invent, create, and fix [44], these are all relevant hands-on activities for ET students.

Extensive research work has been carried out in the area of Maker Culture [9, 10, 12, 15, 16, 29, 39]. In recent years, many universities are making academic space available for Maker Culture [12, 18]. Wilczynski provided a detailed review of makerspaces at Arizona State University, Georgia Institute of Technology, Massachusetts Institute of Technology, Northwestern University, Rice University, Stanford University, and Yale University [42]. Most of these makerspaces are intended for engineering students; however, makerspaces are not limited to engineering majors. Sheridan et al. discussed how makerspaces can be used to help individuals identify problems, build models, learn and apply skills, revise ideas, and share knowledge with others in areas of art, science and engineering [36]. A thorough review of the literature in Maker Culture was given by Schad and Jones [35].

When planning for the implementation of Maker Culture in a curriculum, other factors such as historical inequalities and cultural differences need to be considered as well in addition to the technical aspects [7, 19, 28, 38]. Hoople et al. found that the presence of experienced practitioners, clear rule of engagement, and a cultural fostering student creativity are critical in student learning in makerspaces [18].

2. Integration of Maker Culture in an ET Curricula

Many researchers concluded that Maker Culture could provide excellent learning opportunities for students [2, 6, 15, 22, 23]. Maker Culture helps in cultivating lifelong learning as well [41]. Large number of presentations at ASEE Maker Sessions in ASEE Annual meetings are the clear evidence of interests in using Make Culture in education among engineering majors [8, 11, 32, 37, 46].

Many aspects of Maker Culture fit well with course projects in ET courses, and majority of students would agree that Maker Culture is fun and interesting. The real question is: Are students learning? [12, 28] Based on the information in the literature, the answer is yes, if the implementation is done correctly. The incorporation of Maker Culture in educational institutions requires careful planning and research [44]. Vossoughi et al. cautioned against the unprepared adoption of Maker Culture into the educational institutions [38]. The structural changes and material and pedagogical resources required to support the adoption of Maker Culture must be carefully considered [3, 30]. While exploring the feasibility of using Maker Culture to enhance student learning [40, 44, 45], the authors learned from their own implementation experience that it was challenging to successfully cultivate Maker Culture in ET programs. A preliminary result was presented at the ASEE Annual Conference in 2020 [45].

The intention of this paper is not about developing a new theory for adopting Maker Culture in ET programs, instead, the focus is on the uniqueness of ET students and the Control Systems course which requires special attention in the implementation. After the initial literature review, the implementation of Maker Culture was started in the Fall semester of 2019 and has continued in the next a few semesters. Each semester, feedback from earlier semesters was collected and used in improving the implementation process.

The final project demonstrations and presentations were planned and organized as a Mini-Maker Faire. To qualify as good demonstrations for their project, students must show a fair amount of knowledge in design, analysis, fabrication, and testing. In Electronic Systems Engineering Technology (ESET) Program within the Department of Engineering Technology & Industrial Distribution, most courses with course projects use about half of the semester for regular laboratories and only about seven weeks for their course projects. Given the time limitation, making a gadget for the Mini-Maker Faire could be challenging for some lower level courses.

In Make Culture, people are supposed to learn many knowledge and skills on their own before they can make gadgets. As students move through the ESET program curricula, they get to know more and more about designing electronic gadgets. Control Systems (ESET 462) is a senior level course. Students typically take this course together with their Capstone I. ESET 462 has two pre-requisites: Electronic Instrumentation and Embedded Systems Software (ESET 369). By the time students take Control Systems, they should have taken most of the courses in the ESET curricula. They should know how to design electronic circuits, complete the board layout, populate the board, program microcontrollers, set up wireless communication systems, and design instrumentation systems. They have learned how to conduct engineering test and conduct statistical analysis. In ESET 462, they learn how to analyze and design control systems. In summary, they are well-equipped to start their capstone projects. Therefore, the Control Systems course is one of the best choices for Mini-Maker Faire. The course projects in this course can also help students to get ready for their capstone projects. Students in other courses may also be able to participate in Mini-Maker Faires, but more careful planning is needed.

The implementation plan required changes to be made in lectures, laboratories, and course projects. The focus of this paper was on the details of the execution and the effect on ESET 462.

The Maker Culture was introduced to students in lectures at the beginning of the semester. Students were informed that in the second half of the semester, they would design and fabricate products based on their own ideas using the knowledge they learned throughout the semester and what they learned in courses they had taken. Project guidelines, in Appendix A, were provided to students so that they know the specific requirements on projects, team formation, and the rubrics for project evaluation. They were told that there would be a Mini-Maker Faire at the end of the semester, and they would be evaluating their teammate and other teams. Participation and contribution from each team member was expected in order for students to receive a good project grade.

Students brainstormed for product ideas and reviewed the skills and tools that might be needed. For the additional knowledge they needed, students were expected to conduct research or to learn by themselves or from one another. This self-learning part was important because it would help students understand the value of life-long learning. Several lectures were devoted to Maker Culture, importance of life-long learning [41], and project related discussions. Students delivered presentations of their project ideas during lecture hours.

Students learned essential skills such as using a sensor to measure some variables and programing a microcontroller to control certain variable in laboratories during the first half of the semester. In the second half of the semester, students designed and built their own products as course projects. The project part was the most challenging one, which required significant changes in project evaluation. In traditional course projects, students are expected to make a functional product. In Maker Culture, whether students' products work or not is not as important as what they have learned in the process. The project evaluation rubric must reflect this Maker spirit. Several students commented that it was quite unique that the focus was on learning instead of a good prototype. They expressed that this provided a new type of motivation.

In Maker Culture, communication is more informal. Formal presentations and project reports had to be added to the course project requirements to help students improve on their communication and writing skill, which are important parts of the ABET student outcomes. To address this issue, an abstract was required, which was reviewed by the instructor to make a preliminary decision to approve or disapprove the project, followed by a brief in-class presentation for project ideas. A final report in the IEEE conference paper format was required. These additions to the Maker Culture practice are necessary for ABET accredited programs.

3. Mini-Maker Faire

A Mini-Maker Faire was organized at the end of the semester, replacing the traditional final project demonstrations and presentations. To make the final project presentation more like a real Mini-Maker Faire, instructors from two separate courses coordinated to hold the project demonstrations and presentation sessions together. The idea was to promote interaction among students across different courses. Since the room used for the Mini Maker event was not big enough for all the students involved to present at the same time, the plan was to have two different groups of students coming at different times with some overlapped in time. The final project presentation session for ESET 369 was held from 8:10 AM until 10:20 AM on December 2nd, 2019. The final project presentation session for ESET 462 was held from 9:30 AM until 10:30 AM on the same day. The time was purposefully overlapped to increase the impact by mixing students from two different courses like a Mini-Maker Faire. The goal was to gain experience from this event and eventually to organize a program-wide Mini-Maker Faire. This was the first attempt by the ESET program to have more than one course's presentations to be held together at the same location.

Student teams set up their posters and demonstrations in the room. The instructors of the two courses participated in the Mini-Maker Faire. Students listened to each project team's presentation and watched their demonstration as well. Student peer reviews also were conducted. It was noticeable that students were sharing their experiences with other teams, learning from each other and teaching each other.

Over one hundred students participated in the Mini-Maker Faire. Due to the active engagement of all the students involved, many project teams took longer time to finish their presentation. Peer review also took longer than expected. One of the consequences was that students ran out of time for peer review and student survey.

A typical project in ESET 462 would include some sensors, actuators such as motor, and electronic circuit built on a breadboard, a controller implemented in a micro-controller or LabVIEW. Two students' projects are included in the Appendix (E and F) [13, 25]. Both projects had working prototypes.

4. Assessment

The presentations at Mini-Maker events are typically more informal. However, the assessment of course projects need to be more rigorous. In addition to the instructor, peer reviews by other teams (review form in Appendix B) and peer reviews within each project team (review form in Appendix C) were added to the assessment. This provided a way for teammates to identify the high and low performers.

An end-of-semester student survey was conducted. The survey form is included in Appendix D. The survey results, with the sample size of 16, are summarized in Table 1, where Q1, Q2 represent Question 1 and Question 2 and so forth.

Using the average and standard deviation, the confidence interval for each question is calculated using Eq. 1

$$\left(\bar{X} - t_{\frac{\alpha}{2}, n-1}\frac{s}{\sqrt{n}},\ \bar{X} + t_{\frac{\alpha}{2}, n-1}\frac{s}{\sqrt{n}}\right) \quad (1)$$

The sample size is n = 16. With 95% confidence level, $\alpha = 0.05$, $t_{\frac{\alpha}{2}, n-1}$. The 95% confidence interval are given as follows

Q1: (2.75, 3.75); Q2: (2.97, 3.91); Q3: (3.25, 4.25); Q4: (3.66, 4.34); Q5: (3.29, 4.21); Q6: (3.41, 4.35); Q7: (3.37, 4.25); Q8: (2.46,3.66); Q9 (2.42 ,3.16); Q10: (3.70,4.42).

In the following semester, Spring of 2020, based on the feedback and lessons learned in Fall semester of 2019, it was decided that the Mini-Maker Faire should be held for individual courses first and then be combined the following semester. In the middle of the semester, the course project plan was disrupted by the Covid-19 pandemic. Students had to make changes to their projects so that they did not need to meet in person. Placing orders of hardware components was not allowed by ESET program and students were not allowed to come to laboratories to work on their projects. Despite all the constraints, students were able to complete their course project. The Mini-Maker Faire was changed to a virtual format using video presentations. Student survey was conducted; however, Question 9 was deleted since the Mini-Maker Faire was canceled.

The 95% confidence interval for the nine questions are calculated using Eq. (1) with $t_{\frac{\alpha}{2}, n-1} = 2.01$.

Q1: (3.48, 4.07); Q2: (3.66, 4.18); Q3: (3.20, 3.72); Q4: (3.97, 4.44); Q5: (4.33, 4.67); Q6: (3.50, 4.04); Q7: (3.57, 4.14); Q8: (3.63,4.12); Q10: (3.56, 4.16).

The peer reviews within project teams (form can be found in Append C) were useful in assigning grades according to each member's contribution to the project. There were a couple of teams with apparent issues among the teams. There were students giving each other the lowest scores in the peer review within the project teams. The issues were reflected in the qualities of the projects as well. Based on this observation from Fall 2019, the instructor started to ask students to report any such problem during the project in Spring 2020. There was no similar issue afterwards.

5. Analysis and Lessons Learned

The survey results in Table 1 shows that the implementation in the first semester was not very successful. There were only two questions that received 4.0 or higher out of 5.0, these are Questions 4 and 10. Question 4 was about writing. Since students were required to write a final project report in IEEE style, it is not surprising to see a relatively high score in this category. Question 10 indicated that students thought the projects were relevant to the material they learned in the course. From the survey results, in particular from Question 8, it was clear that more effort needed to go into the lecture part. For example, more time should be spent in lectures for project discussions.

There were many lessons learned in the first trial of a Mini-Maker Faire. The first one is the organi-

Table 1. Survey results summary for Fall 2019

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Average	3.25	3.44	3.75	4.00	3.75	3.88	3.81	3.06	2.79	4.06
Std	0.93	0.89	0.93	0.63	0.86	0.89	0.83	1.12	0.70	0.68

Table 2. Survey results summary for Spring 2020

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q10
Average	3.78	3.92	3.46	4.2	4.5	3.77	3.85	3.88	3.86
Std	1.03	0.91	0.9	0.82	0.58	0.93	0.99	0.86	1.04

zation of the Mini-Maker Faire. Because the room was too small and some teams took longer to set up and finish their presentations, this caused a chaotic situation. Many teams were struggling because of the shorter time available to them. They had to go through other teams' presentations and evaluate them in a short period of time. This probably had a negative impact on the quality of peer reviews. The Mini-Maker Faire was scheduled on the last day of regular class, thus the student survey must be done at the Mini-Make Faire. Since many students ran out of time for peer review, which was required, they opted to not participate in the voluntary student survey. As a result, the sample size was low, out of fifty students only sixteen completed the survey.

Despite of the negative impact from Covid-19, the survey results, in Table 2, show some improvement from Fall 2019 to Spring 2020. The sample size was significantly increased from sixteen to forty-nine.

Out of the nine common questions between the two semesters, significant improvements can be seen in Q1, Q2, Q4, Q5, and Q8. The responses to Q3 and Q10 were slightly worse in Spring 2020, and Q7 didn't change much. Many students giving low scores indicated in their comments that it was mainly due to the impact of Covid-19. Considering the significant impact from Covid-19, the overall survey result in Spring 2020 was satisfactory.

Even though the survey results from Spring 2019 were less than satisfactory, the instructor did notice that students were learning abstract concepts such as difference equation and digital PID controller design in virtually every project. Students appreciated the improved performance when a PID controller was properly implemented and tuned. Peer teaching and peer learning occurred quite often as well during the project time. Students were sharing their problems and success stories in designing circuits and programming micro-controllers.

6. Conclusions and Future Work

In theory, Maker Culture is definitely a good fit for ET students. One can integrate the Maker Culture in ET curricula to enhance student learning. Despite the natural fitting of Maker Culture in ET programs, from the limited experience of Maker Culture implementation in a Control Systems course in ESET program, careful planning and implementation in multiple semesters are recommend. Any mistake in the implementation can cause the result to be less desirable. This paper provides other educators with an example that includes both successes and lessons learned in creating Maker Culture in ET. Although the first effort in the Fall semester of 2019 was less than ideal, improvement steps were taken based on the lessons learned and the results from the following semester show some improvement despite the negative impact from Covid-19.

Future work includes organization of Mini-Maker Faire with multiple courses and collaboration with Prairie View A&M University. The combination of different course is something that is worth trying after the successful Mini-Maker Faire for individual courses. A potential solution to the large number of teams when multiple courses are involved is to select a few representative ones from each course within the ESET program to participate in the program-wide Mini-Maker Faire. How to implement Maker Culture when courses are delivered online [14] in situations such as during the Covid-19 pandemic is another topic that is worth studying.

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Appendix

A. Project Guidelines

Control Systems Course Project (Mini-Maker Faire) Guidelines

The course project requires your team to design a gadget and you need to have a prototype ready by the last week of the Fall semester (Before the reading days).

Project requirements

1. Design a product that has potential commercial value or that has potential use in your daily life.
2. It must have a micro-controller (use of myRIO or other equivalent device needs to be approved by the instructor).
3. The prototype must have at least one sensor and one control action (for example, controlling motor speed, turn something on/off).
4. Use at least one thing you learned in Control Systems (PID control, transfer function, stability analysis, digital system, etc.).
5. This project can be a part of your capstone project.

Team formation

This work should be carried out in teams of four. Please talk to your classmates and form your own team by October 3. The project leader should send an email to the instructor with the following information: A name for the team and the team members' names. Teams with five members should receive approval from the instructor. Your team may be assigned extra work.

Mini-Maker Faire

1. Participation in the event is mandatory.
2. The event will be held in the last week of the Fall semester (The exact event date will be scheduled and announced before the end of October).
3. A poster presentation is required for each team. If you miss the event, this will result in zero credit for both peer evaluation and instructor's evaluation of the project.

Project report

1. An abstract containing no more than 500 words must be submitted through eCampus before October 12th. The abstract should contain a brief description of your project.
2. A project report is mandatory and due by the 1st reading day.
3. A video recording of your demo must be submitted together with the report.
4. Project report should follow the writing style and formatting rules of the IEEE conference. https://www.ieee.org/conferences_events/conferences/publishing/templates.html
5. The report should be submitted through eCampus.

B. Project Evaluation

	Instructor	Non-team member	Teammates
Originality/Significance	10		
Complexity	10		
Functionality	10		
Demo/Poster	15		
Report	15		
Contribution to your team			15
Peer review (by non-team members)		15	
Abstract	10		

(Peer Evaluation Guide: A+: 15, A: 13, B: 11, C: 9, D: 7, F: equal or less than 5)

C. Peer Evaluation

	member name	member name	member name	member name	evaluator name
Team member's					Your name
teamwork spirit					
personal effort					
timeliness					
technical competence					
overall contribution					

1–10: being the worst and 10 being the best. You only give evaluation to your teammates, not to yourself.
Add columns if necessary.

D. Student Survey

5: strongly agree, 4: agree, 3 neutral, 2, disagree, 1: strongly disagree

1. Did you learn something new on your own during the course project? ____
   Additional comments: ____________________
2. Did you course project involve critical thinking? ____
   Additional comments: ____________________
3. Was your project intellectually challenging for you? ____
   Additional comments: ____________________
4. Did your project involve writing? ____
   Additional comments: ____________________
5. Did your project involve reading? ____
   Additional comments: ____________________
6. How relevant was your project to lifelong learning? ____
   Additional comments: ____________________
7. Do you prefer a course project that you choose over a course project that is assigned to you by the instructor? ____
   Additional comments: ____________________
8. How much do you know about Maker Culture? ____
   Additional comments: ____________________
9. Overall, was the Mini Maker Faire successful? ____
   Additional comments: ____________________
10. Were you able to apply what you learned in this course to your project? ____
    Additional comments: ____________________

E. Student Project 1: Object Detection Platform Robot

Detection of objects is a common feature for many control systems such as conveyor processor of the automation industry. There are many object sensing technologies, such as limit switches, inductive proximity switches, capacitive sensors, ultrasonic proximity sensors, photoelectric sensors, etc. This project utilizes an ultrasonic sensor and a DC motor to detect objects within a set distance. In the presence of an object the motor will come to a halt and sound off a buzzer to inform the user that there is object in front of them. This project is completed with the use of the myRIO embedded device and LabVIEW. The conceptual diagram and the prototype are shown in Fig. 1.

F. Student Project 2: Beehive Smoker

This project involves preventing bees from swarming or becoming overly agitated by listening to the sound levels of the overall hive. When a beehive becomes aggravated or becomes Africanized, the hive will produce a louder than normal buzzing sound, which is an indication that the beehive needs to be smoked in order to prevent swarming. If the sound level is above a threshold (swarming conditions), a smoker connected to a sound monitor and controller will determine the amount of smoke to be released to calm down the bees. The conceptual diagram and the prototype are shown in Fig. 2.

A digital filter was implemented to get rid of the noise in the sound signal and a PI controller was used to set off smoker. An LED was used instead of an actual smoker during project demo.

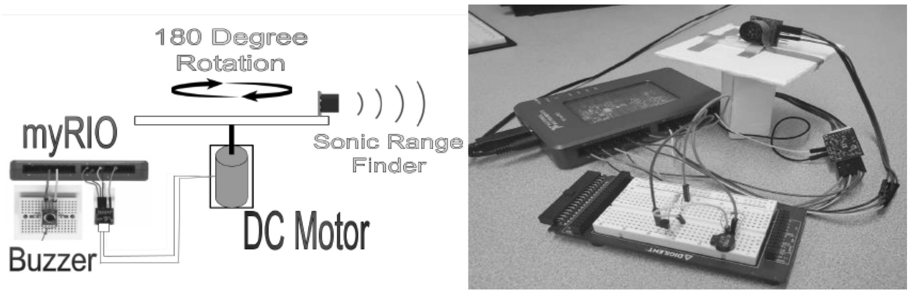

Fig. 1. Conceptual diagram and prototype for ODPR.

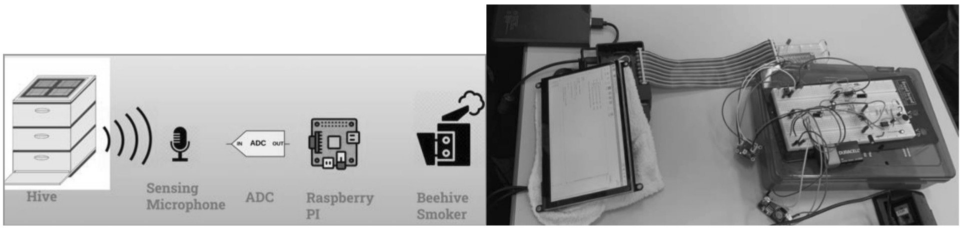

Fig. 2. Conceptual diagram and prototype for Beehive Smoker.

Wei Zhan is a Professor of Electronic Systems Engineering Technology at Texas A&M University. Dr. Zhan earned his DSc in Systems Science from Washington University in St. Louis in 1991. From 1991 to 1995, he worked at University of California, San Diego and Wayne State University. From 1995 to 2006, he worked in the automotive industry as a system engineer. In 2006, he joined the Electronic Systems Engineering Technology faculty at Texas A&M University. His research activities include control system theory and applications to industry, system engineering, robust design, modeling, simulation, quality control, optimization, and educational research.

Byul Hur received his BS degree in Electronics Engineering from Yonsei University, in Seoul, Korea, in 2000, and his MS and Ph.D. degrees in Electrical and Computer Engineering from the University of Florida, Gainesville, FL, USA, in 2007 and 2011, respectively. In 2017, he joined the faculty of Texas A&M University, College Station, TX. USA, where he is currently an Assistant Professor. He worked as a postdoctoral associate from 2011 to 2016 at the University Florida previously. His research interests include Mixed-signal/RF circuit design and testing, measurement automation, environmental & biomedical data measurement, and educational robotics development.

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