Rapid Change of Instructional Modes in a Studio-based Learning Environment: A response to Covid-19

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Abstract

At the University of Virginia, we have heavily invested in studio instructional techniques for our introductory course work in Electrical and Computer Engineering. This method of course delivery relies heavily on direct interaction between lecture and laboratory learning methodologies, and team-based activities throughout. In addition, these courses include a final project that involves printed circuit manufacture.

The events of Spring 2020 led to a sudden cessation of on-grounds classes and an immediate switchover to a complete online learning scenario; this completely upended the studio scenario. In this paper, we demonstrate how we adapted the studio classroom to the new environment. This scenario involved a switch to student-owned test equipment, rewriting experiments, and rethinking project completion goals. Our experiences in this emergency have led us to reconsider some aspects of studio teaching that are becoming a part of our standard content delivery, as we have started a partial ramp-up of in-person classes.

Keywords

Studio instruction, hardware, project-based

Background

Studio based instruction has become a hallmark of our instructional delivery methodology in Electrical and Computer Engineering, especially for core material [1]. This approach also incorporates a breadth-first approach which links concepts in circuits, electronics, and signals at successively deeper levels of understanding with each iteration. An important part of this approach is a learning studio, in which laboratory experiments are incorporated directly into our lecture sessions, implementing a hands-on project-based learning environment as in Figure 1.

Clearly this approach requires an in-person class approach, with a heavy emphasis on direct interaction with students. What happens when an event such as the pandemic of 2020 necessitates a cessation of direct contact with the students and a switchover to a remote learning environment? In the balance of this paper, we describe our approach for our core classwork, and discuss our adaptations as classes began a partial return to in-person classes. We also discuss our approach for the Fall 2020 Capstone Design course.

Figure 1 Studio Instruction

Spring 2020 Approach

In the Spring of 2020 we were faced with approximately a week's notice to switch classes to a full remote delivery format. At this point, the hands-on techniques that we had worked to develop required a rapid re-thinking! We did not have a sufficient supply of test equipment to ship out a laboratory set up to each student , so we looked at possibilities for devices that the students could use on their own that would still be inexpensive enough for us to acquire for the approximately 125 students we had enrolled across our three primary courses. Our investigations led us to the *Analog Discovery 2* from Digilent Inc.[2] This device enabled us to continue most of our hands-on work for the balance of the semester. Devices, along with a sufficient supply of parts, were shipped to each student. A typical instrumentation amplifier experiment is shown in Figure 2 below.

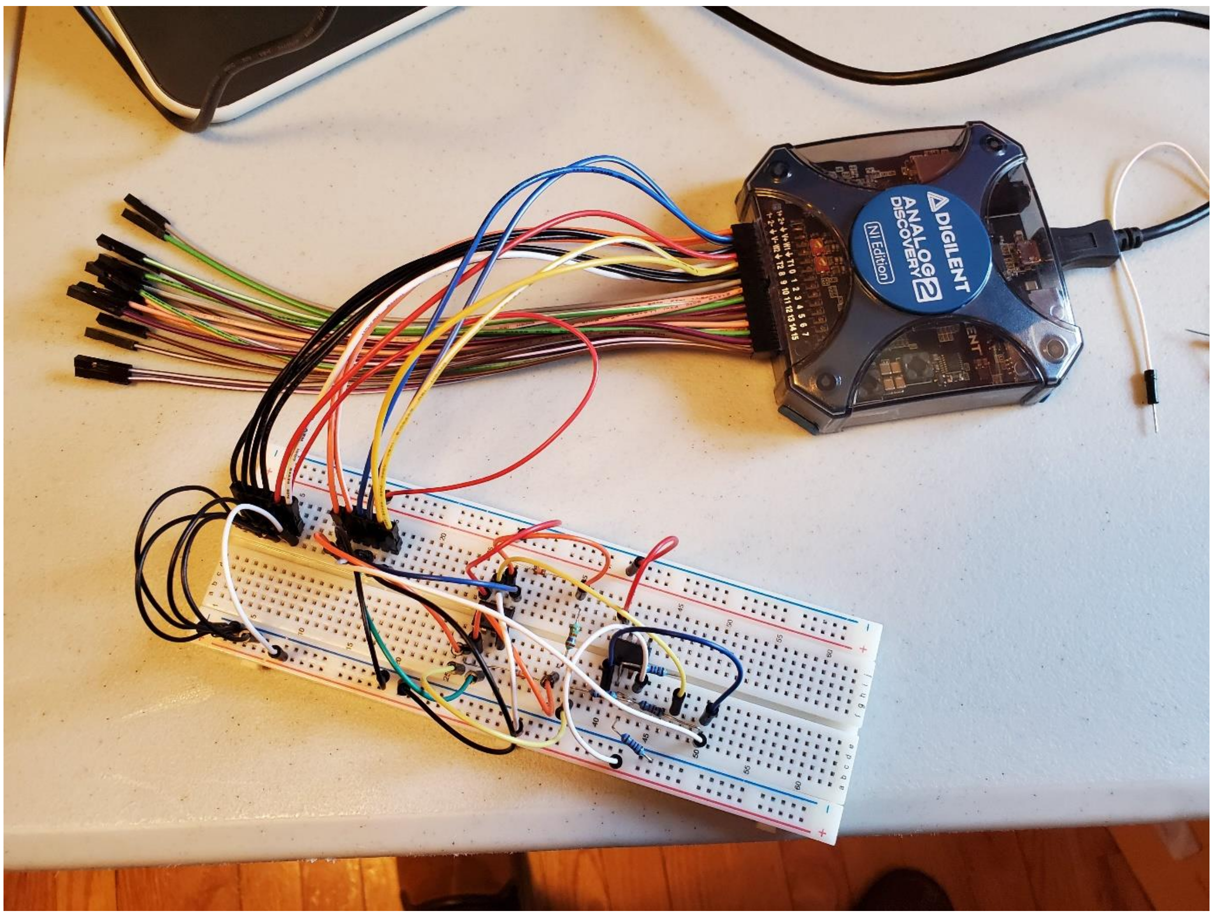

Figure 2 Breadboard with wire connections

Student comments were very favorable and they especially appreciated the user interface. It should also be noted that software ran under Windows, Mac, and Linux; no virtual machines were required. We were also impressed with the dual function generators, and built-in Bode plotting abilities, which were features not present in our previous laboratory equipment.

Fall 2020

On balance we were favorably impressed to the point that we made a decision to adopt this device for our classes, whether being offered remotely or in-person. Note that this decision needed to be made prior to a decision for the course delivery method for the fall was know.

However, there was a drawback. From Figure 2, we can see that the wiring was bulky and unwieldly to decipher; this made for messy setups, and made debugging by remote video sessions virtually unmanageable. Over the summer we developed a solution to this problem that has ameliorated the situation. This is an adapter, Figure 3, that cleans up the wiring considerably.

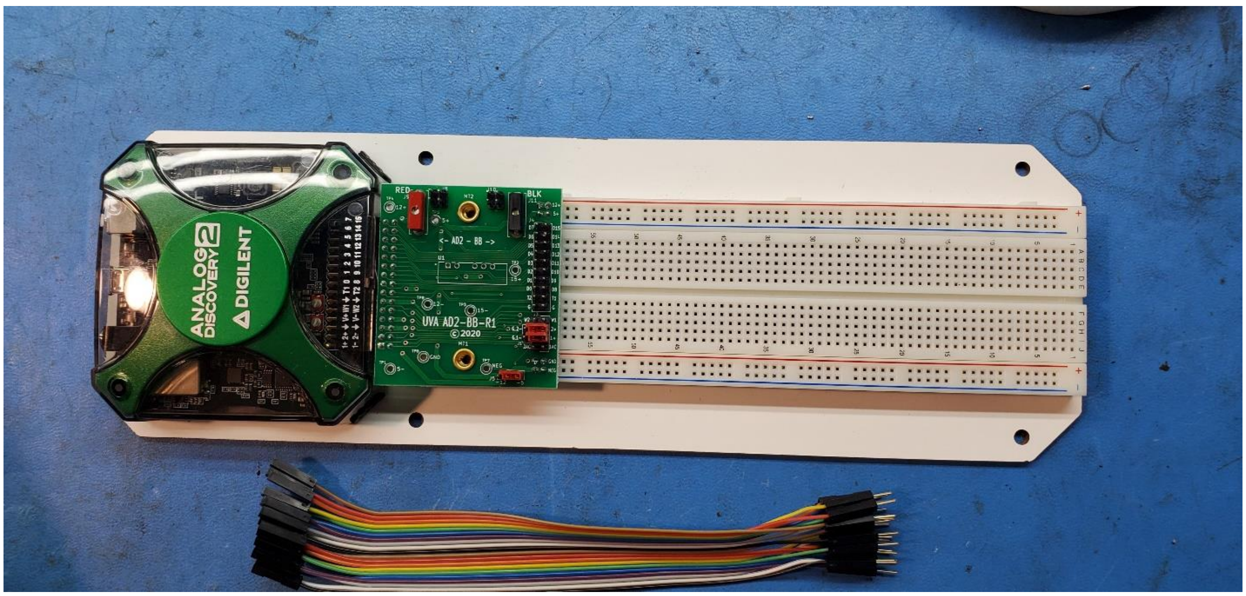

Figure 3 UVA Breadboard Adapter

Our adapter plugs directly into the Analog Discovery, and brings all of the signals to a strip conveniently located directly on a solderless breadboard. Additionally, the power and ground voltages are distributed along the upper and lower rails, which facilitates neat student layouts. The adapter and breadboard are mated to a fiberboard backing strip, adding rigidity to the connections, and facilitates storage in a backpack. In 100-piece quantities, we were able to get this device fully assembled for approximately $40.00, including parts and labor. We adopted it for the Fall of 2020 and student comments have been very favorable. We have now moved entirely to student-owned test equipment while maintaining the studio instruction modality. This device is now also in use at two other Universities.

Management of Project Work

An integral part of our course work is a final project that builds on material throughout the semester. In the final course of our sequence, that project takes the form of an ECG measurement subsystem. In Spring 2020, in-person classes were suspended before students could assemble their designs, although the bare circuit boards had arrived at our facility. We could not ask the students to assemble them at home, with soldering etc. involved. Rather than abandon the project we had the students develop assembly documentation. This involved calculation and simulation of all subcircuit functions, then writing a document that included drawings and directions in a format specified by our local electronic supplier. The students submitted an overlay of their board designs, with component values on each location; parts that required specific orientation were labeled. In addition, each team submitted a spreadsheet that correlated part values, vendor part numbers, and reference designators. The supplier did the actual assembly work according to the student specifications. This was a team-based project, and we had each team specify a designated tester. The assembled boards were then mailed to designee, and the other teammates assisted in writing the final report and doing the documentation.

This approach, while developed in an ad hoc fashion, actually turned out quite well. Forcing the entire design process to be completely specified before the assembly began encouraged the students to be more thorough than we had observed in the past, when there was no “safety net”. We felt that this was actually a very realistic engineering exercise. The students also had very favorable comments on the process. We have continued this approach for the Fall, and plan to do so for the Spring of 2021 as well.

Extension to Capstone Projects

At the University of Virginia, Capstone is a one-semester 4.5 credit hour course, offered in the fall semester only, forcing us into a remote experience, with minimal direct student interaction with the instructors. We had 20 Capstone teams to manage and considered tools for managing group progress, that would include a measure of accountability, and still not be cumbersome for teams to use. We settled on *Gitkraken*, which is part of the *Github* ecosystem; the full professional version is available to educators at no cost [3]. This tool lets the instructor establish a team area, with a graphical user interface as shown in Figure 4. The board is arranged in columns, and descriptive cards may be added to each column. The board owner can view all team areas, but individual teams can only access their own area.

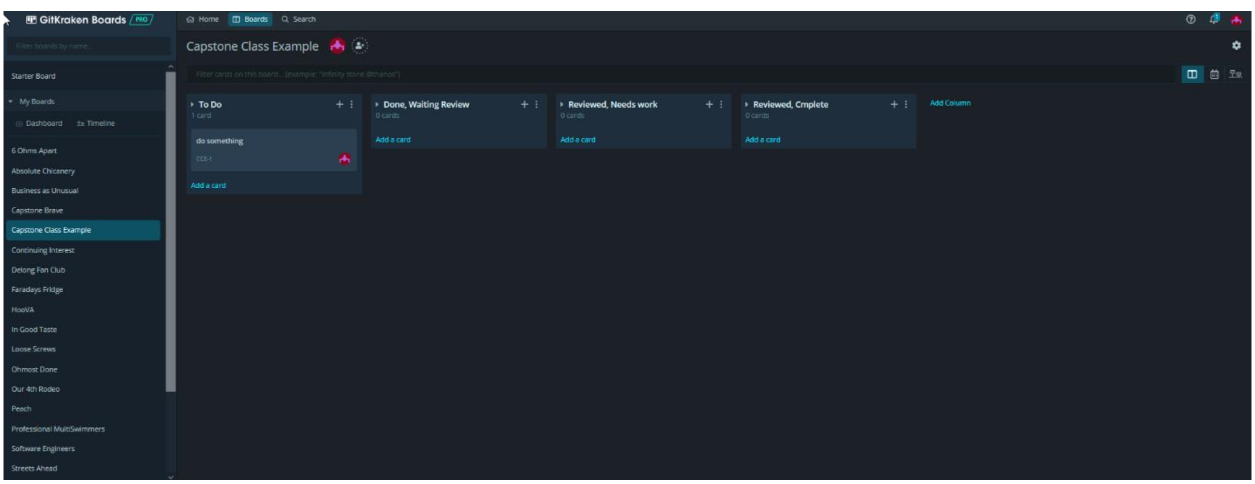

Figure 4 Starting “*Gitkraken*” Board

For the setup we created 4 columns, “To Do”, “Done, Waiting Review”, “Reviewed, Needs Work”, and “Reviewed, Complete”. In addition, we can assign students to each board, and we have one board per team; each board is private to that team. In our initial team meeting, we establish tasks for each team member and complete a card in the "To Do" column. For example, and initial task might be to create a block diagram and assign that task to a team member. In Figure 5 a task was created and assigned to "Harry".

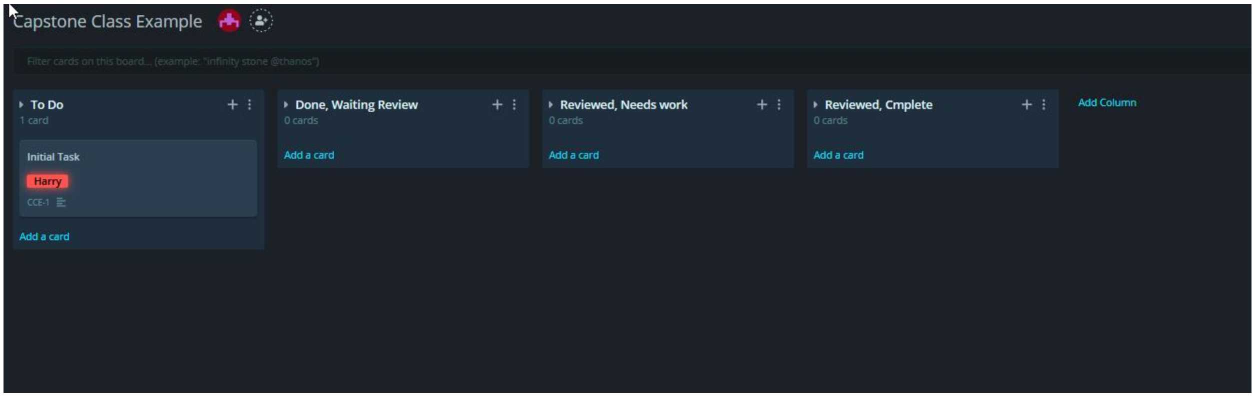

Figure 5 Assigning a task

Each card has fields for file uploads, due dates, and comments as seen in Figure 6

Each week team members meet, via zoom, with the instructors and tasks are added for each member. As tasks are completed, the student moves the card from the "To Do" column to the "Done, Waiting Review" column. During the meetings, the instructor and the students examine the cards in the "Done, Waiting Review" column, and decide whether the card can be moved to the "Reviewed, Complete" column, or if it needs to go to the "Reviewed, Needs Work" column. Students can move cards from the "To Do" column or the "Reviewed, Needs Work" one to the "Done, Waiting Review". Only instructors can move cards to the "Reviewed, Complete" column. We also allowed students to create additional cards in the "To Do" column as additional job needs emerged during the project.

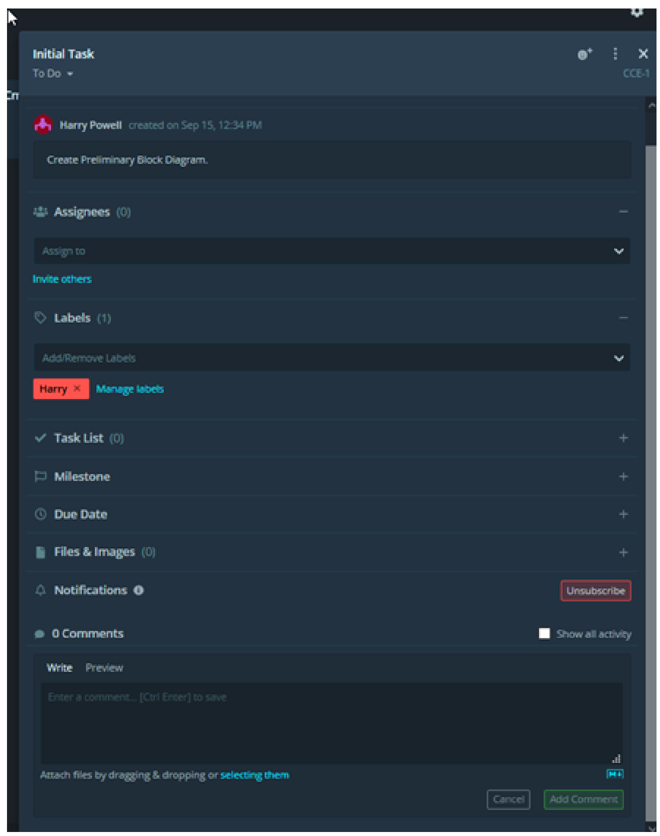

Figure 6 Task Description

This approach proved to be an effective compromise in maintaining student progress, and not involve an undue amount of overhead. Students comments about using it were positive. Most appreciated the graphical nature of the interface, and we were impressed by the "at a glance" view of overall team progress. It also allowed team members to track each other's progress, a useful feature, as some students were remote while others were local and had more laboratory access.

An example board for a team that is nearly complete is seen in Figure 7.

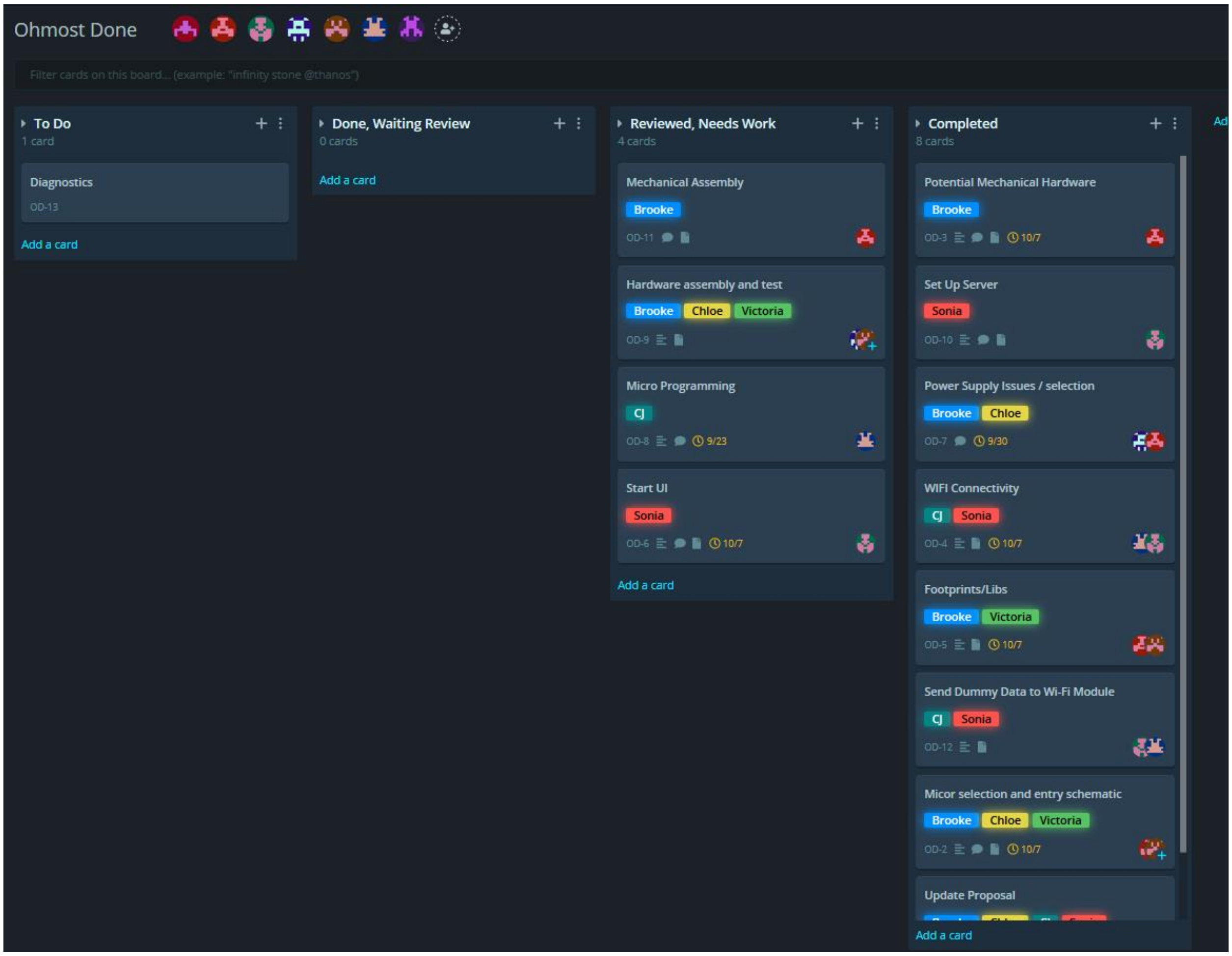

Figure 7 Example Board

It is very intuitive, and by inspection we can see that most of the cards are in the "Completed" column. While not as effective as full in-person team meetings in the laboratory, this allowed for most teams to remain accountable, and we had very few complaints about non-productive team members. Our initial assessment is to continue use of this tool, even after we return to an in-person setting for class in the future.

Additionally, students followed the same board manufacturing process that was used in the spring of 2020, creating manufacturing documents and test plans. The printed circuit assembly was done by the same local manufacturer as we used for our other course work Student feedback was positive in this respect, and most stated that the experience gained earlier from this approach was an enabling factor, and represented the type of real-world engineering process that they would encounter after graduation.

In spite of the challenges of managing a “mostly-remote” Capstone, we had a number of teams taking on very ambitious projects and completing them on time. Among the projects was a robotic plant watering device that used machine vision to assess plant growth and move the plant to the optimal location for light, complete with a user interface that would run on a mobile device. Another was an automatic door locking system that assessed a person’s body temperature, and logged entrance into the building as a measure for protecting against Covid-19, seen in Figure 8.

Figure 8 Typical Capstone Project - Protective Door Entry System

Another notable project was the design and construction of a brushless direct current motor, complete with a microcontroller, power electronics, and user interface, for use in an instructional power laboratory, shown in Figure 9. Note that the students did all of the magnetic design and assembly as well.

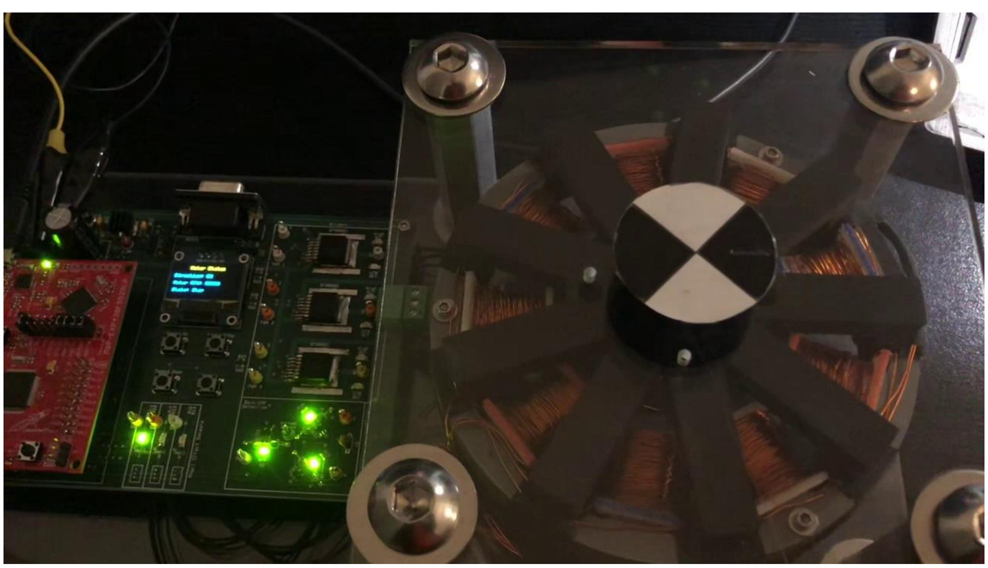

Figure 9 Typical Capstone Project – BLDC Motor

Summary and Conclusions

The pandemic has created unique educational challenges, especially for engineering courses that rely on hands-on, project-based learning. In addition to the student engagement issues that all disciplines face, we must deal with issues related to laboratory skills, project management, tool availability, and remote debugging. However, challenges can become opportunities, and we have endeavored to make this the case. Lessons learned from switching to student owned experimental hardware and distant laboratories have steered us in a direction in which this becomes the more normal approach. Techniques that have emerged during our Capstone class have provided us with a toolset that will enable us to enhance this class for the future.

References

[1] Dr. Harry Powell, Dr. Ronald Williams, Dr. Maite Brandt-Pearce, and Dr. Robert Weikle, "Restructuring an Electrical and Computer Engineering Curriculum: a Vertically Integrated Laboratory/Lecture Approach," presented at the ASEE, Southeast Conference, Gainesville, Fla., Apr. 2015.

[2] "Analog Discovery 2: 100MS/s USB Oscilloscope, Logic Analyzer and Variable Power Supply," *Digilent*. https://store.digilentinc.com/analog-discovery-2-100msps-usb-oscilloscope-logic-analyzer-and-variable-power-supply/ (accessed Dec. 08, 2020).

[3] "Free Git GUI for Windows, Mac, Linux | GitKraken," *GitKraken.com*. https://www.gitkraken.com/ (accessed Dec. 09, 2020).

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Dr. Powell is a Professor of Electrical and Computer Engineering and Associate Chair for Undergraduate Programs. After receiving a Bachelor's Degree in Electrical Engineering in 1978 he was an active research and design engineer, focusing on automation, embedded systems, remote control, and electronic/mechanical co-design techniques, holding 16 patents in these areas. Returning to academia, he earned a Ph.D. in Electrical and Computer Engineering in 2011 at the University of Virginia. His current research interests include machine learning, embedded systems, electrical power systems, and engineering education. Dr. Powell is a member of ASEE, IEEE, and ACM.