7-2021

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Abstract

E-learning became the mode of instruction for students worldwide during the COVID-19 pandemic. Instruction was forced onto numerous online platforms quickly, some seamlessly and some not. For those not well versed in online education, the move of all forms of education, including hands-on, laboratory experiential learning, deprived students of new experiences, skills, and knowledge due to a lack of provisions to perform remotely. Uncertain of the pandemic's duration as well as the future of hands-on education, these authors investigated new technology, equipment, and experiments that would provide a hands-on laboratory experience performed by students at a distance.

In response to the laboratory learning dilemma, these authors compiled a distance laboratory kit with physical equipment and components, detailed supplemental instructions, and online communication software to provide a remote live laboratory learning experience for the summer. The new distance learning format was implemented in the summer semester course with students successfully demonstrating a fundamental understanding of electronics while troubleshooting complications with instructor assistance. The instructors determined that the online communication tools provided a timely response between students and instructors to complete work seamlessly and address feedback for course improvements.

While the work was completed in a very challenging environment, the techniques and potential change to the learning environment provides the need to share successful implementation that supports the student's learning experience. This paper documents the successful implementation of college-level hands-on laboratory experiments with electronics performed at a distance by students during the COVID-19 pandemic. While many laboratory classes transitioned to simulation software for experimentation, this course utilized physical equipment and components to conduct experiments and provide valuable experience, skills, and knowledge in the field of electronics off-campus.

Keywords: Active Learning, Laboratory Experiments, Hands-On, e-learning

Introduction

The pandemic outbreak created great challenges for all aspects of life including education. Normal face-to-face, hands-on learning was rapidly shifted to online conferencing, lectures, and assignments with very little time to prepare or adjust [1]. The shift to online learning caused great trouble for teachers as many did not have online platforms prepared or understand how to create and use online platforms [2]. Online learning also posed a great challenge for many students due to the unfamiliar learning environment and increased availability of distractions of learning from home. Recent research provides a better look into highly motivated students finding that they prefer any kind of learning while those that are not as intrinsically motivated found eLearning and the lack of personal interaction with the instructor frustrating [3].

The engineering technology program is reliant on active learning and hands-on exercises [4]. The dilemma that presented itself was in the form of laboratory work, which instructors cut from the curriculum when the semester was pivoted within a week. The cut from curriculum created a challenge for instructors and a deficit for students moving into subsequent courses relying on knowledge built in previous courses [5]. This instructor team investigated ways to bring the laboratory experiments and experience home to the students for the upcoming summer 2020 class. The goal was to provide a similar hands-on laboratory experience that students would receive on campus with electronics and prepare them for their next courses.

Literature Review

The reconfiguration of a course to suit students not prepared for the online environment is a challenge. Consideration into environments for all included preparation of materials for the online environment, a uniform mode for video conferencing, lab equipment, and assignments. An overview of what was done and the evidence-based resources to support those efforts are discussed in the following subsections:

Material Development

In preparation for the upcoming summer semester class, several issues and requirements needed to be addressed. To successfully offer a hands-on electronics course at a distance, an investigation into video conferencing software and equipment was needed to provide a live laboratory experience. The instructors chose to utilize online assignments and instructions to improve the experience for students and instructors [6-9].

The move to a home or living environment that students are familiar with may be referred to as a quasi-informal learning environment. The necessitated move out of the lab and classroom and to the desk or kitchen table provided a less formal environment while following the structured work needed to successfully meet the learning objectives set out in the class. That provided a challenge of how to structure exercises to be done in the home environment [7]. The development work began to consider a uniform format for video conferencing, how to do the experiments in a synchronous environment, and structure class periods the same so students learn the format and then find it easier to follow along.

Uniform Video Conferencing

Live video conferencing is essential for immediate instruction, signoff, and troubleshooting during laboratory experiments. In a standard laboratory environment, students are given instructions and procedures at the beginning of the lab with tips for successful completion before starting individual experiments. As the experiments progress, students demonstrate experiment completion and understanding, known as signoffs. These signoffs demonstrate student understanding of the experiments to instructors. A webcam is required to visually interface with the student and for the student to demonstrate lab exercises and measurements to achieve lab signoffs. If students run into issues, an instructor can also provide guidance. With social distancing limitations and the closing of campus, live communication between students and faculty would be essential to give direction, complete activities, and address issues in a timely manner to achieve a quality laboratory experience.

Established, readily available, and user-friendly video conferencing would provide greater possibilities for success of a live laboratory [10, 11]. A video conferencing software would create a live meeting for each class for instant communication between students and instructors. The instant communication and feedback would reduce waiting time, reducing frustrations and fatigue [12]. A video conferencing software that was established and effective with few issues would also reduce complications and frustrations during procedures. The software would need to be readily available and cost-effective for students, and allow the sharing of computer screens, video, and audio for communication and instruction. Furthermore, the software would need to allow meeting attendees to break into small groups. Small groups allow students to collaborate with each other as previously done in person and troubleshoot problems without the presence and need of the instructor [13]. Additional smartphone compatibility could provide further resources for communication in the event of computer and equipment issues. Finally, the instructors realized that video fatigue was something to consider and needed to make modifications to the materials and approach to reduce that issue [14].

Equipment

The move to remote learning requires consideration of the equipment and components used to support laboratory hands-on learning instead of computer simulation. To provide a hands-on laboratory learning environment, a laboratory parts kit had to be created to provide both components and equipment to perform experiments. This course already utilized a predetermined laboratory kit from previous classes. In face-to-face laboratory environments, students would use laboratory equipment provided by the university in conjunction with their kit. However, under the new constraints, market-ready equipment and components had to be identified to provide a similar experience at a distance. The needed equipment included a function generator, oscilloscope, digital multimeter, and a power supply. Adding more components to the kit would increase cost, therefore, finding low cost, low volume products was another factor in the search. After identifying equipment satisfying requirements, several would be ordered for testing. Once the equipment list was finalized and validated, it would be added to the parts kit. The parts kit provides the student with the necessary equipment in a list before shipping for convenience, thus reducing student frustration with the learning conditions and allowing them to move forward while building their knowledge [15]. A full list of parts and equipment can be found in Appendix A with new equipment and components labeled “NEW”.

Assignments

Assignments related to the laboratory activities are constructed using scaffolded learning techniques originally presented by Vygotsky [16] and others [17, 18]. Following the tenets of those investigating this kind of learning, the instructors developed daily activities with specific procedures, images, and submissions for students [19]. The instructions give visual and descriptive information for safe and successful completion while the submissions would provide immediate feedback. This course already utilized an online platform known as LON-CAPA [20] for instruction and submission; however, assignments and instructions would require modification for new equipment and components that align with the changed environment. A user friendly and modifiable software for instructors to change information as needed and consideration of lower bandwidth within individual home environment was important for course success.

Shipping and Delivery

Shipping and delivery were a major issue throughout the entire process, causing delays and requiring larger lead times than usual [21]. Equipment, especially from overseas, had more than 2-weeks of lead time and arrival times were often nebulous with extended delays. To combat shipping delays, experiments were organized with the more readily available equipment first. Experiments requiring equipment with long lead times were placed towards the middle and end of the course to combat the shipping issue. Some students received their equipment after the course started and days before needed, creating some concerns for the course in a short time frame.

Course Preparation

Course preparation includes verification of equipment, components, software, and procedures that were key to successful understanding and implementation. Months before class began, equipment and software were investigated simultaneously to determine the best solutions and give ample time for testing and verification. After identifying the necessary software, components, and equipment, testing was conducted to determine equipment, video conferencing, and communication functionality. Testing identified issues to improve experiments as well as supplemental information that would be needed for using the new equipment, components, and software.

Verification of Equipment

Equipment testing provided identification of experiments that could be achieved under the new constraints. Small and affordable electronics equipment, including a Hantek 2D42 [22] function generator, oscilloscope, and digital multimeter, were identified and ordered for testing. Upon delivery, previous laboratory experiments were conducted by instructors with the new equipment to determine and understand functionality as well as troubleshoot issues quickly. Furthermore, the testing identified areas of improvement for experiments as well as additional components and software needed for further testing. For example, an electric motor experiment would require a small electric motor, batteries, and connectors, normally provided in lab, to be added to the kit to incorporate the experiment into the distance course.

Video Conferencing

Video conferencing and communication testing were critical for comprehension and troubleshooting of laboratory procedures. After investigating several conferencing software, Microsoft Teams [23] was chosen due to its unique capability of team breakouts, multiple chat channels, file uploading, ease of access for students with Microsoft accounts provided by the university, and mobile phone compatibility. The software was first tested with IT professionals to grasp the full potential of the software. Once achieving a thorough understanding, a communication protocol was created by instructors to create a flow of communication during live, online laboratory experiments similar to face-to-face experiments. The communication protocol included initial instruction and tips, breaking off into teams, and communicating with instructors and classmates after beginning experiments. Testing the communication protocol was conducted with faculty and IT professionals to gain feedback and troubleshoot problems that could arise during live meetings. Multiple meetings improved the instructor's understanding of the software and laboratory procedures to create the best learning environment for students.

Communication

Communication with students before the start of class was essential for a smooth transition. Students intending to take the course in this new environment were contacted weeks in advance to communicate expectations as well as computer and software requirements. Furthermore, detailed information and instructions were communicated to guide students to the needed software and equipment for the best experience and prepare for the fast-paced summer course that lay ahead, a full semester course in 4 weeks.

Supplemental Information

Supplemental information was important to the understanding and application of equipment, software, and components [24]. Procedures with detailed photographs and instructions provided clear direction for students. The use of video instructions further improved students' ability to use equipment and software as well as build electrical circuits for testing. The supplemental information was made available in advance to each scheduled meeting, giving students ample time to review and become familiar with equipment and material as well as ask questions. The supplemental information also provided safety procedures for students to follow including wearing safety glasses, assembling and powering circuits, and taking measurements.

Implementation

The preparation by instructors created an ideal start for the distance laboratory experience. Many students had acquired their parts, equipment, and software in time, creating a smooth start for the class. Furthermore, preparation provided insight into expected issues that were easy to solve. As the class progressed, some issues were discovered along the way with the new equipment and procedures that required adaptation and additional supplemental instruction.

Experiment Demonstration

Demonstrating the communication protocol and software was necessary for a successful transition. The first lab was new, created to demonstrate the communication protocol and flow of experiments including initial instructions, conducting experiments, and communicating in real-time. The lab instructors walked through Microsoft Teams [23] and its functionalities, including video and screen sharing, uploading documents, breaking into teams, and communication through chat channels. Once demonstrated, the students were instructed to break off into their assigned teams to begin chatting, uploading and sharing documents, and communicating based on the communication procedure. Once in their teams, students remained working through the laboratory procedure to understand the software and communicate with instructors. At the end of the procedures, instructors confirmed with students their understanding of procedures for future labs before concluding.

All laboratory experiments followed the same procedure of communication. Students were introduced to experiments at the beginning of labs with tips on how to succeed. Students then broke into their teams to begin work. Once reaching a checkoff point or in need of assistance, the student team would notify the instructors through the main class chat channel and an instructor would join the team to sign off or assist individuals in each team. Students could share their screen, use their webcam, or upload photos to demonstrate experiment completion or troubleshoot problems. In many instances, uploading photos were the best solution to resolve wiring issues with circuits and eventually obtain a signoff. Each signoff was recorded through a shared online spreadsheet by instructors to track student progress as well as electronically recorded in the LON-CAPA assessment program.

Student Progress

Tracking student progress identified student comprehension of concepts, materials, and equipment in real-time to promote student success [25]. In normal laboratory environments, student progress is visual. However, at a distance this becomes more challenging, requiring the need for tracking progress. Each laboratory experiment has checkpoints for demonstration requiring signoff before students continue. These checkpoints were utilized to track student progress and understanding individually using a shareable online spreadsheet, also ensuring no academic dishonesty could occur [26]. The spreadsheet identified students' pace and understanding as well as students that may require assistance and guidance from instructors. If students appeared to fall behind, instructors communicated with specific students to provide additional help. Several students encountered various issues with equipment, components, and software that were able to be resolved through immediate communication with instructors to assist remotely and work through the issues.

Course Outcome

Effective research and preparation provided a hands-on learning experience at home for students to become familiar with physical electronics systems and equipment. Throughout the course, students faced several issues with the software, components, and equipment that were able to be addressed quickly through live communication. Every student completed all laboratory experiments in the fast paced, distance electronics course while using physical equipment and components instead of simulation software. Students learned the fundamentals of electronics and demonstrated their pragmatic understanding through the completion of experiments by building and measuring electrical circuits at home with physical components. The fundamental knowledge gained from the course can be applied to future courses with the experience of using physical equipment. Wang & Goryll [27] demonstrate that the fundamental knowledge of electronics can be gained face-to-face or online using physical equipment. Wang & Goryll [27] results show similar knowledge retention and testing results while adhering to the Accreditation Board for Engineering and Technology (ABET) outcomes. Student attitude towards laboratory experiments in either face-to-face or online environments also showed no significant difference

[27, 28]. With this new knowledge, students can also pursue hobbies and projects relevant to the field of electronics using their equipment.

Lessons Learned

With the potential of future disease outbreaks and the increase in online education, the need for online learning is necessary to provide a laboratory experience remotely with physical equipment. Furthermore, online learning can provide an opportunity for students unable to attend a physical university location. While challenging, hands-on laboratory learning can occur at a distance. The success of distant, hands-on learning requires the use of many resources, supplemental instructions, and additional time. The benefit of a distance lab kit with small, handheld equipment creates the possibility of conducting electronic experiments anywhere for students, especially after successful completion of a course.

To improve this electronics course, the instructors are continually investigating new equipment and software. Identifying equipment that has multiple functions is continually being investigated while instructions and supplemental information are being improved. It is important to have plans for assessing issues and ways to get around them during laboratory procedures. Additionally, it is recommended that experienced personnel for a topic are instructing a distance laboratory course in the event of issues arising. Other courses requiring large equipment may be able to implement remote control of physical equipment in a lab as presented by Gustavsson et al. [29].

References

[1] C. M. Toquero, "Challenges and Opportunities for Higher Education Amid the COVID-19 Pandemic: The Philippine Context," *Pedagogical Research,* vol. 5, no. 4, 2020.

[2] Y. K. Dwivedi *et al.*, "Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life," *International Journal of Information Management,* vol. 55, p. 102211, 2020.

[3] S. Keskin and H. Yurdugül, "Factors affecting students' preferences for online and blended learning: Motivational vs. cognitive," *European Journal of Open, Distance and E-Learning,* vol. 22, no. 2, pp. 72-86, 2020.

[4] A. Mehrabian, W. W. Buchanan, and A. Rahrooh, "Innovation is the name of the game: A case study of an online course in engineering and technology," in *Proceedings 2014 ASEE Gulf-southwest section conference*, 2014.

[5] R. A. Machado, P. R. F. Bonan, D. E. d. C. Perez, and H. Martelli JÚnior, "COVID-19 pandemic and the impact on dental education: discussing current and future perspectives," *Brazilian oral research,* vol. 34, 2020.

[6] P. Bell, B. Lewenstein, A. W. Shouse, and M. A. Feder, *Learning science in informal environments: People, places, and pursuits*. National Academies Press Washington, DC, 2009.

[7] M. Brown, "The effects of informal learning environments on engineering education," Rutgers University-Graduate School of Education, 2019.

[8] D. Kotys-Schwartz, M. Besterfield-Sacre, and L. Shuman, "Informal learning in engineering education: Where we are—Where we need to go," in *2011 Frontiers in Education Conference (FIE)*, 2011: IEEE, pp. T4J-1-T4J-7.
[9] A. Manuti, S. Pastore, A. F. Scardigno, M. L. Giancaspro, and D. Morciano, "Formal and informal learning in the workplace: a research review," *International journal of training and development,* vol. 19, no. 1, pp. 1-17, 2015.
[10] W. Smith, R. Rafeek, S. Marchan, and A. Paryag, "The use of video-clips as a teaching aide," *European Journal of Dental Education*, vol. 16, no. 2, pp. 91-96, 2012.
[11] K. Woelk and P. D. Whitefield, "As Close as It Might Get to the Real Lab Experience—Live-Streamed Laboratory Activities," *Journal of Chemical Education,* vol. 97, no. 9, pp. 2996-3001, 2020.
[12] F. F.-H. Nah, "A study on tolerable waiting time: how long are web users willing to wait?," *Behaviour & Information Technology,* vol. 23, no. 3, pp. 153-163, 2004.
[13] J. F. Rhoads, E. Nauman, B. M. Holloway, and C. M. Krousgrill, "The Purdue Mechanics Freeform Classroom: A new approach to engineering mechanics education," in *121st ASEE Annual Conference & Exposition, Indianapolis, IN. June 15-18, 2014,* 2014.
[14] L. Fosslien and M. W. Duffy, "How to combat zoom fatigue," *Harvard Business Review,* vol. 29, 2020.
[15] M. Vovk, O. Emishyants, O. Zelenko, O. Drobot, and L. Onufriieva, "Psychological Features of Experiences of Frustration Situations in Youth Age," *International Journal of Scientific & Technology Research,* vol. 8, no. 1, pp. 920-924, 2020.
[16] L. Vygotsky, "Interaction between learning and development," *Readings on the development of children,* vol. 23, no. 3, pp. 34-41, 1978.
[17] M. Y. Doo, C. Bonk, and H. Heo, "A Meta-Analysis of Scaffolding Effects in Online Learning in Higher Education," *International Review of Research in Open and Distributed Learning,* vol. 21, no. 3, pp. 60-80, 2020.
[18] K. Kouicem and N. Kelkoul, "Constructivist Theories of Piaget and Vygotsky: General Teaching Implications," 2016.
[19] I. Gustavsson, T. Olsson, H. Åkesson, J. Zackrisson, and L. Håkansson, "A remote electronics laboratory for physical experiments using virtual breadboards," in *Proceedings of the 2005 ASEE Annaual Conference*, 2005, pp. 12-15.
[20] "Lon Capa Purdue University." Lon Capa. https://loncapa.purdue.edu/adm/login (accessed March 25, 2020).
[21] K. Nikolopoulos, S. Punia, A. Schäfers, C. Tsinopoulos, and C. Vasilakis, "Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions," *European journal of operational research,* vol. 290, no. 1, pp. 99-115, 2020.
[22] "Hantek 2000 Series." Hantek. http://hantek.com/products/detail/13174 (accessed March 25, 2020).
[23] "Microsoft Teams." Microsoft. https://www.microsoft.com/en-us/microsoft-teams/group-chat-software?&ef_id=CjwKCAiAl4WABhAJEiwATUnEF_dlBJmZmS4qQHTEu868DNG8IZyhAXCUTxFrCtnyqzODL3VhcQRkyBoCIoQQAvD_BwE:G:s&OCID=AID2100233_SEM_CjwKCAiAl4WABhAJEiwATUnEF_dlBJmZmS4qQHTEu868DNG8IZyhAXCUTxFrCtnyqzODL3VhcQRkyBoCIoQQAvD_BwE:G:s&gclid=CjwKCAiAl4WABhAJEi

wATUnEF_dlBJmZmS4qQHTEu868DNG8IZyhAXCUTxFrCtnyqzODL3VhcQRkyBoCIoQQAvD_BwE (accessed March 25, 2020).

[24] J. A. Schmidt-McCormack, M. N. Muniz, E. C. Keuter, S. K. Shaw, and R. S. Cole, "Design and implementation of instructional videos for upper-division undergraduate laboratory courses," *Chemistry Education Research and Practice,* vol. 18, no. 4, pp. 749-762, 2017.

[25] B. Norwich, "Improving learning through dynamic assessment: a practical classroom resource," ed: Taylor & Francis, 2014.

[26] K. A. Gamage, E. K. d. Silva, and N. Gunawardhana, "Online delivery and assessment during COVID-19: Safeguarding academic integrity," *Education Sciences,* vol. 10, no. 11, p. 301, 2020.

[27] C. Wang and M. Goryll, "Design and implementation of an online digital design course," in *123rd ASEE Annual Conference and Exposition*, 2016: American Society for Engineering Education.

[28] T. M. Hall Jr, "A quantitative analysis of the effectiveness of simulated electronics laboratory experiments," *Journal of engineering technology,* vol. 17, no. 2, p. 60, 2000.

[29] I. Gustavsson *et al.*, "A flexible electronics laboratory with local and remote workbenches in a grid," *International Journal of Online and Biomedical Engineering (iJOE),* vol. 4, no. 2, pp. 12-16, 2008.

Appendix A: Distance Parts Kit

The parts kit described in this paper include a variety of items for ECET 224 at Purdue University. The following table is the Bill of Materials (BOM) for the provided kit. Following the table, specific information and photos of each item are provided.

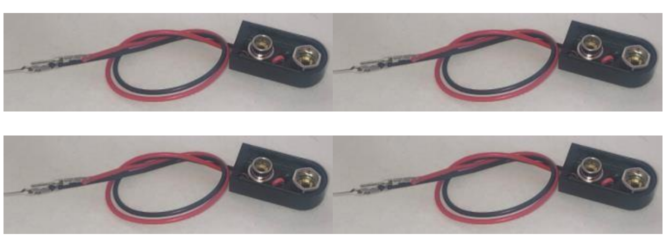
Table 1: BOM provided by third party eeinabox.com

Quantity	Description
1	Arduino Mega Microcontroller
1	Velcro Strip
1	USB A to B Cable
1	Plastic Backboard 17cm x 15 cm (custom to course)
5	Rubber Feet
1	10 k ohm Potentiometer
1	220nF Film Capacitor
1	1uF Film Capacitor (105)
1	FQP30N06L MOSFET, TO220 pkg.
4	TL081 Op Amp
1	Assembled Voltage Shield (custom to course)
1 set	Banana Jack to Mini-Grabber
1	Full Size Breadboard
20 pcs.	1 pin, 6" Jumper Wire Kit (10 pcs. M/F, 10 pcs. M/M)
5 each	6.8, 68, 100, 220, 330, 470, 560, 680, 820, 1k, 2.2k, 3.3k, 4.7k, 5.6k, 10k, 22k, 47k, 270k, 1M ohm resistors
19	Plastic zip lock bags for resistors with labels
1	Needle Nose Pliers
1	Flush cutters
1	140-piece jumper wire kit
1	Safety Glasses / Side Shields
2	9V Battery (NEW)
4	Battery Connector (NEW)
5	Alligator Clip Jumper Wires (NEW)
1	7 function DMM (NEW)
1	6V DC Motor with Encoder (NEW)
1	6V Lantern Battery (NEW)
1	Hantek 2D42 Handheld Oscilloscope Kit (NEW, provided by the university)

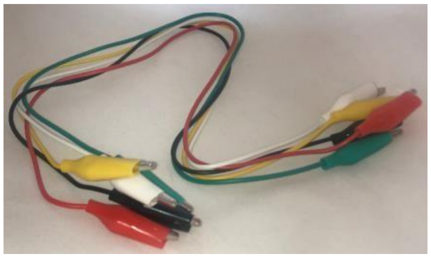
(2x) Oscilloscope Probes, spring loaded grabbers on left, BNC connector on right side. Only use these on an oscilloscope.

(1x) USB Cable (A to B)

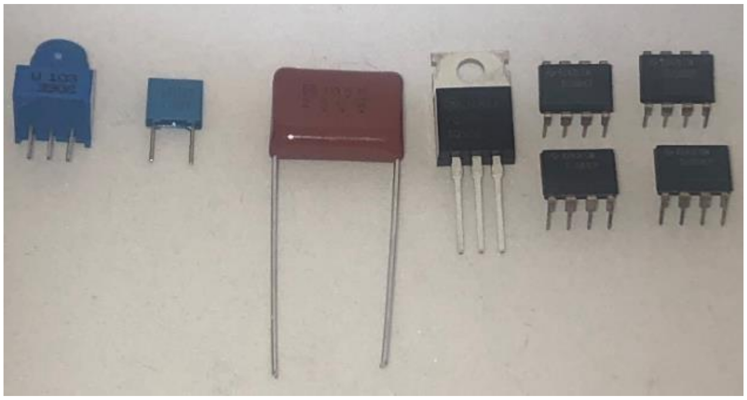
(2X) 9V Battery (NEW)



(4X) 9V Battery connector (NEW)



(5X) Alligator clip jumper wires (NEW)



From left to right.

(1x) 10kΩ potentiometer (pot), ¼ watt, (103 printed on body), value is read with 10 + three zeros added to the value to indicate the value.

(1x) 220nF capacitor, 63V (22K marked on body)

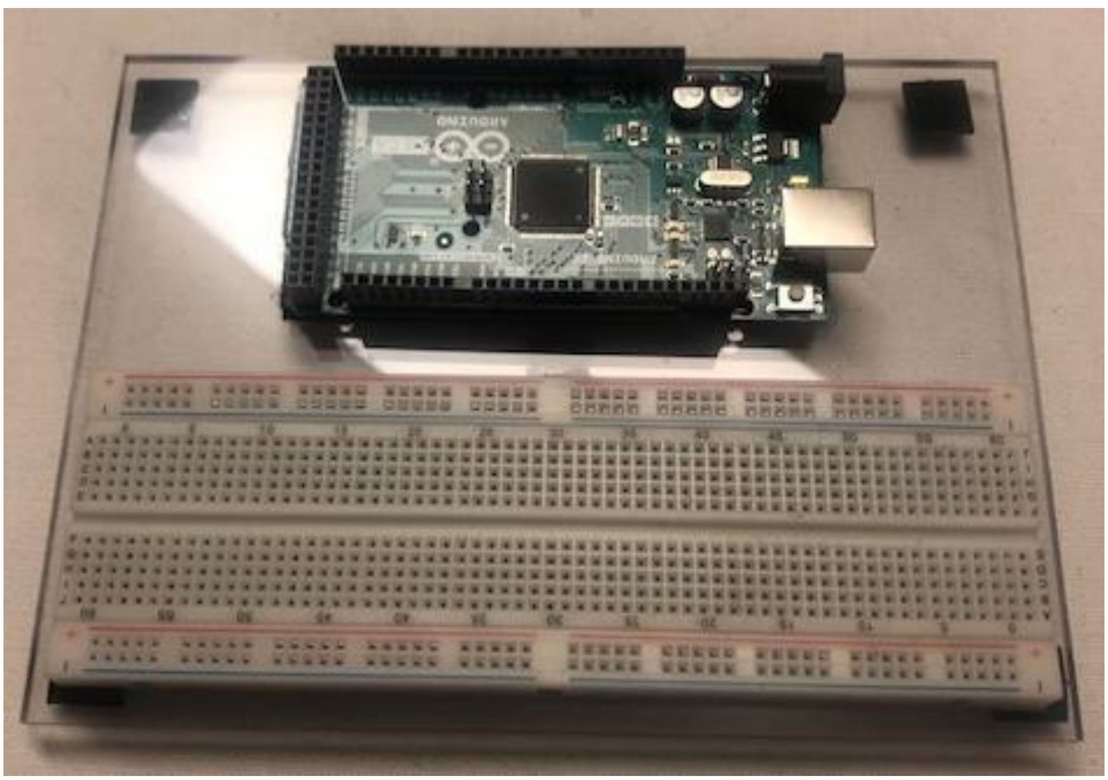
(1x) 1uF capacitor, 250V (105K marked on body)

(1x) FQP30N06L MOSFET, TO220 package

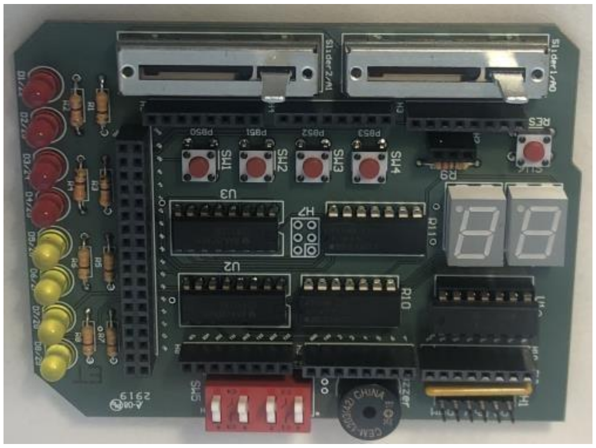
(4x) TL081 Op-Amp

(1X) 6V DC motor with encoder (NEW)

(1X) 6V Battery (NEW)



Assembled unit: Arduino Mega Microcontroller, clear plastic backboard, Velcro, 5x rubber feet, breadboard

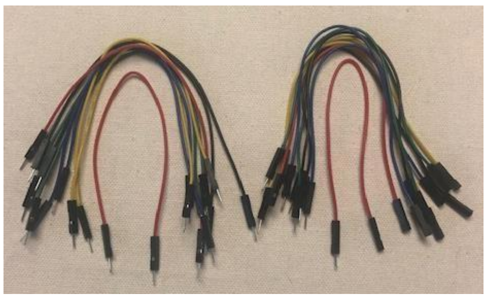


(1X) Assembled Voltage Shield (installed on microcontroller)

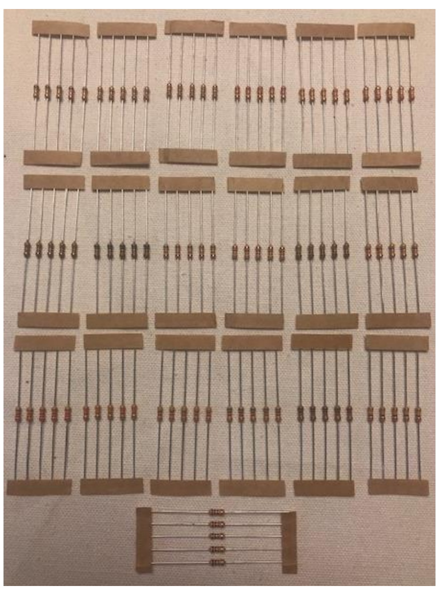
(1X) 7 function digital multimeter (NEW)

(1X) HandTek 2D42 Handheld Oscilloscope/Function Generator/DMM with charging cord, (1x) DMM probe set, (1x) Oscilloscope probe, and (2x) Function generator Probes. (NEW, provided by the university)

(1X) DMM (Digital Multi-Meter) Leads, (Red/Black), banana jacks on left side, spring loaded mini-grabbers on right



(20 pieces) 6” jumper wire (10 Male/Male, 10 Male/Female) used for connecting the microcontroller to your breadboard



(5 of each value) resistors (6.8, 68, 100, 220, 330, 470, 560, 680, 820, 1k, 2.2k, 3.3k, 4.7k, 5.6k, 10k, 22k, 47k, 270k, 1M)

(19x) plastic zip lock bags for resistors with labels

(1X) Needle-Nose Pliers

(1x) Flush Cutters

140 pc. Jumper Wire kit, used to wire circuits on your breadboard

(1x) safety glasses or side shields for prescription glasses