

# CircuitAssistant: An Introductory Circuit Development Teaching Assistant

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## ABSTRACT

The CircuitAssistant is a teaching aide developed to aide entry level Electrical Engineering Students learn proper circuit layout and etiquette. The CircuitAssistant will be used to assist Teaching Assistants (TAs) convey circuit layout principles. This will replace the conventional breadboard, which offers students a development platform to quickly design basic circuitry. The CircuitAssistant has all the same functionalities as a conventional breadboard, but offers guidance and feedback when designing basic circuits. Preliminary results show potential for the system, but a larger scale user study needs to be preformed to verify the results.

## Categories and Subject Descriptors

D1.4 [Control Structures and Microprogramming]:  
Microcode Applications; J.6 [Computer Applications]:  
Computer-Aided Engineering

## General Terms

Computer-Aided Design, Computer-Aided Learning, Interactive Learning

## Keywords

GUI, Breadboard, Development Platform

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## 1. INTRODUCTION:

The purpose of the CircuitAssistant is to help students learn how to use a breadboard and to teach student good circuit etiquette. This project was created as a development platform for the EE101 Laboratory [2]. <sup>1</sup> The platform is to be used to aide the Teaching Assistant, help student develop, and understand circuits. This paper will cover the motivation for such a product and how the platform was designed. The design of the platform has been broken up into two parts software, which consists of software on the PC, and Hardware which consist of the breadboard and microcontroller. This paper also covers the user study test and results. The participants for this study were chosen to fit in two user groups, an expert user group and a novice user group. The expert user group was chosen to critique the platform and the usability requirements: Learnability, Flexibility, and Robustness. The novice users were chosen to provide quantitative data used to measure how well the system is able to teach entry level Electrical Engineering Students. We hypothesize that, using the CircuitAssistant will teach novice user to use a breadboard correctly and efficiently.

## 2. PURPOSE:

As mentioned earlier the purpose of the CircuitAssistant is to help entry level Electrical Engineering students learn how to properly use a breadboard and in the process learn some proper circuit layout techniques. Since this is a learn tool we propose to use and test the CircuitAssistant in a laboratory setting, with users of varying levels of expertise in the field of electrical engineering. Doing a quick survey of the class sizes for 5 different universities, <sup>2</sup>. Looking at the website for these 5 universities they report having class sizes from 15 to 45 students per class. Some of the universities have larger class sizes and this means that students get very little one on one time with the professor or teaching assistant. Due to the lack of interaction, students don't get the assistance they need to fully understand the course material.

<sup>1</sup>EE101 is the Introduction to Circuits class at UC, Santa Cruz

<sup>2</sup>University of Pennsylvania[6], Purdue [4], Calvin College [1], North Carolina[3], and UC Santa Cruz[5]

As a teaching aide the CircuitAssistant can be used to give students feedback on their circuit designs so they can ask more direct questions to the professor or teaching assistant.

The CircuitAssistant is intended to be a teaching aide rather than a replacement and as such is meant to help student learn good engineering habits. For this reason the CircuitAssistant emphasizes good circuit etiquette and proper circuit layout techniques. It is our believe that teaching students the correct way to layout a circuit in the beginning of their engineering career is easier than trying to correct bad habits later on.

### 3. SYSTEM OVERVIEW:

The CircuitAssistant consists of two parts: a Software side and a breadboard side. The Software side and the breadboard work together to provide feedback to the user. The Software is used to display and create a new circuit diagram, see figure 2. The Software will allow users to virtually add components to the breadboard and evaluate the circuit. When you evaluate the circuit the Software will give you feedback on whether a complete circuit has been created and if the circuit you designed in Software matches the circuit on the breadboard.

The breadboard is the hardware side of the system. It is the device that the students will build their circuit on, see figure 6. The breadboard is equipped with an Arduino Uno32 used to translate the data from the breadboard to the PC. The breadboard has 10 rows that the students can use to build their circuit. An additional 2 columns are provided for Power and Ground to complete the breadboard layout. The layout of the breadboard corresponds to the GUI, in figure 3.

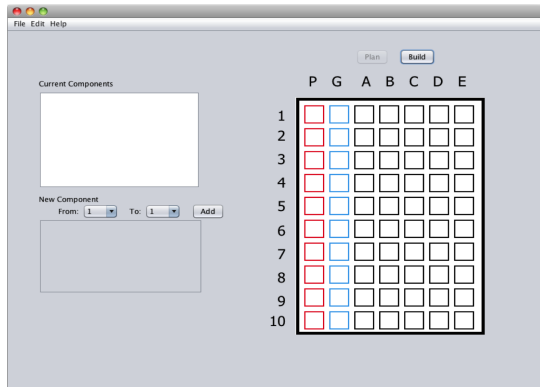


Figure 1: This is the pop up window asking which type of component you want to add

#### 3.1 Software:

The Software side of the CircuitAssistant has two different modes. The two modes being the Plan stage and the Build stage. When users open the CircuitAssistant GUI they will start in the Plan stage. The Plan stage is where student will design their circuit. This is done so that students can design their circuit without risking breaking equipment. The Plan stage also provides useful feedback that can assist students in their circuit design.

Students use the GUI by adding circuit elements to the virtual breadboard on the right hand side of the CircuitAssistant GUI, see figure 1. To add a circuit element the student can select the two rows the circuit element is plugged into by selecting the Rows in the drop down menus. To add the component the student will then click the “Add” button. When the “Add” button is hit a pop up window prompts the user to select the circuit type. The user can then choose one of the three options; a wire, resistor, or a capacitor, see figure 2. The user can then repeat this process until they have created the circuit they wish to design.

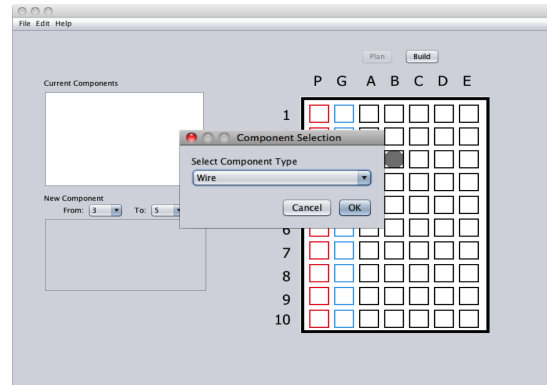


Figure 2: This is the pop up window asking which type of component you want to add

A sample design can be found in figure 3. In this design a resistor is added from row 3 to row 5. A second resistor is added from row 5 to row 7. The way to tell the component type is to look at the Current Component window. In this window the components placed on the virtual breadboard are displayed in the format, component type: Row - Row. Therefore taking a closer look at the Current Component window shows that the two placed components are resistors. The codes for the components are as follows: Wire = W, Resistors = R, and Capacitors = C.

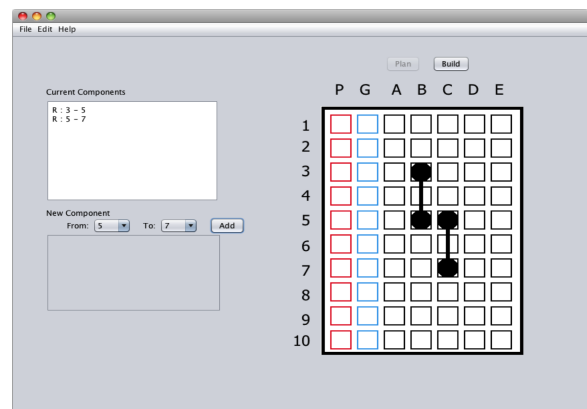


Figure 3: This is the GUI when a resistor has been added across Row 3 and Row 5

Figure 4 shows the circuit designed in figure 3 with connections to power and ground. Connecting power and ground to the circuit creates a completed circuit and this is indicated by the green components. When a complete circuit

has been designed the circuit turns green otherwise it will stay black.

In order to help students learn from the CircuitAssistant a few features have been added to the system. For example users aren't able to connect power directly to ground. An error message will appear informing the user that they have created a short circuit. If this was a real system this could have catastrophic repercussions. The CircuitAssistant doesn't let users plug a single circuit component into the same row. In a breadboard this has no effect because current can bypass the circuit element.

Once the circuit has been designed, the user is able to enter Build Mode. Build Mode is where the user can build the physical system using with the help of the CircuitAssistant. Once the user enters Build Mode they will notice the completed circuit turn from Green to Gray. This indicates that no components have been plugged into the CircuitAssistant Hardware yet. As components are added one by one the gray components turn from gray to black. Figure something, is an example of the circuit in build mode, it should be noted this circuit has an error as described below.

**we need a picture of the BUILD MODE**

Once the user has added all the components correctly they will notice that the components turn from Gray and Black to Green. This indicates that the circuit they designed in the Plan Stage have been built on the CircuitAssistant Hardware. If the user accidentally adds an component incorrectly they will see an error in the Mismatch Window in the bottom left corner of the GUI. They will also notice the some of the rows will turn red. The rows the in incorrect component was plugged in. Figure something depicts the error in the Mismatch Window and red rows.

refer to the same picture as build MODE

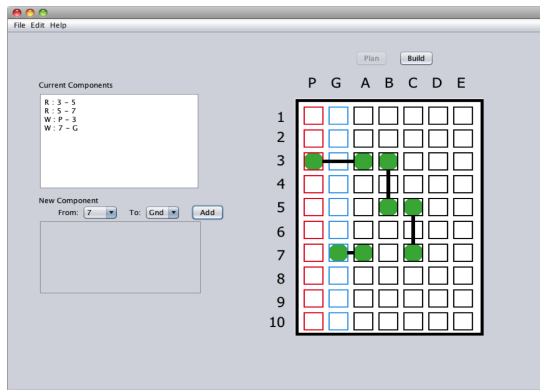


Figure 4: This figure shows a completed circuit

**3.2 Breadboard:**

talk about the hardware: how it works, what it does, how to do it

For our Pilot Study and User Study we had a setup similar to that in Figure 5. Figure 5, shows the CircuitAssistant

on the bottom left corner, next to the CircuitAssistant is a laptop running the CircuitAssistant software. In the back of the picture is an oscilloscope that was used to debug the CircuitAssistant Hardware.

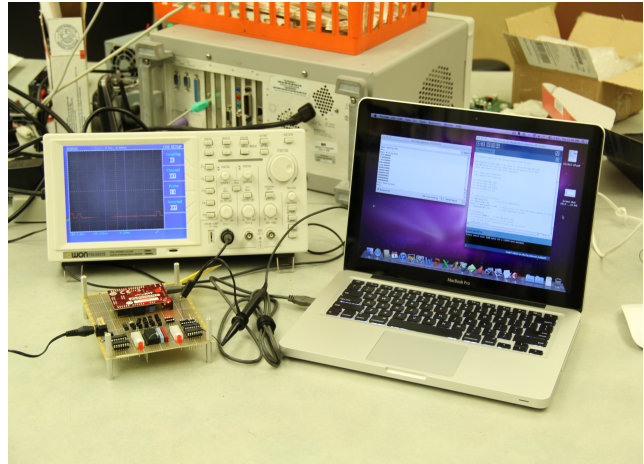


Figure 5: This is the full System setup

Figure 6 shows a close up of the CircuitAssistant Hardware. The hardware consists of an Arduino Uno32, some LEDs, and the breadboard. The part of the CircuitAssistant the user will interact with can be seen in the front of the picture. The "breadboard" consists of two columns Power (red) and Ground (blue). It also consists of 10 rows that are to the left of the Power and Ground columns.

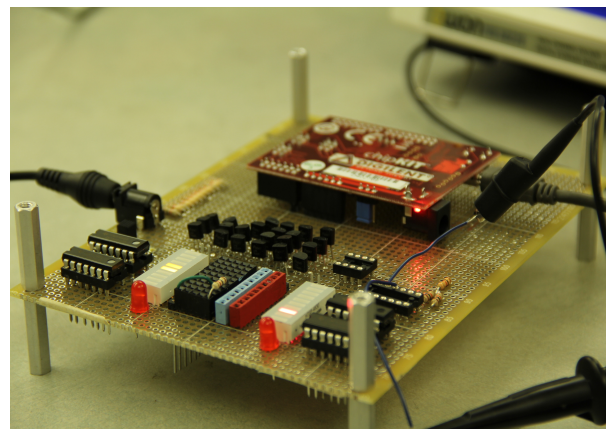


Figure 6: This is the Breadboard hardware

As seen in figure 5 the CircuitAssistant hardware is attached to the computer. The CircuitAssistant hardware will periodically check if anything is plugged into the "breadboard". It will sweep the whole breadboard and then send a matrix full of data that tells the computer where circuit elements are located. An example can be found in figure 7. Observing figure 7, shows that a circuit element is plugged into rows 1, 3, and row 5. If we take a closer look at figureboardFig, we can see a resistor is plugged from row 1 to row 5 and a wire is being plugged into row 1 and 3.

```

/dev/tty.usbserial-A100A9TF
Begin Writing Data
10101000000
01000000000
10101000000
00010000000
10101000000
00000100000
00000100000
00000010000
00000000000
00000000000
00000000000
Begin Reading Data
Autoscroll No line ending 9600 baud

```

Figure 7: This is the terminal Output

## 4. USER STUDY:

Our hypothesis is that using our product will teach novice user to use a breadboard correctly and efficiently. These user tests will be done to test/verify this hypothesis.

As part of the user test we need to find the correct participants. We are trying to find two groups of participant an expert user group and a novice user group. We believe this will give more information than just an expert user group or just a novice user group. More detail will be given later for the testing environment and the users background requirement for this study.

The user study will go over the method in which we tested our participants and the tests we wish for them to perform. A detail description of the test plan can be found in section 4.3. In order to better evaluate the test plan a pilot study was done. This pilot study consisted of 2 users one male and one female. The female was a novice user and the male an expert user. For this test we had the two users work together as a team. The results from this test can be found in section 4.3.

### 4.1 Participant Profile:

As mentioned earlier two major groups will be formed for the purpose of this test. The two groups will be defined as an expert user group and a novice user group. The participants in the expert user group meet the following criteria.

1. Have an advanced knowledge of circuit
2. Senior level undergraduate EE/CE
3. Circuit board layout experience

On the other hand the novice user group has the following criteria.

1. Little to no breadboard experience
2. Understands basic circuits
3. Not EE/CE

On top of the requirements for the two specific user groups, everyone must also fit the general user requirements. The general requirements are as follows.

1. UCSC Student

2. Age range 18 - 30 (most college students)
3. Engineer

Because the participants profile is very limiting we will not need to collect any personal data for each of our participants. A few simple yes or no questions will be asked of each participant before the testing begins. Questions like, "are you within the ages of 18-30?", will be asked of the participants. As long as the participant is able to fit within the general requirements and within one of the two group requirements they will be allowed to participate in the study. This also means that our experiment can be conducted under the Category II IRB.

### 4.1.1 Persona

Based off of our participant profile we have create two ideal user persona. Our first persona is a 2<sup>nd</sup> year Electrical Engineering Student with no formal circuit design experience. They have taken the required physics classes so they have been introduced to Electricity and Magnetism. This student is a male, 20 years of age and hasn't taken any engineering courses only general education classes, physics, and math. His father is an Electrical Engineer so he has very limited exposure to engineering but, his father and himself have both worked on small project together. So he has experience soldering and has a limited knowledge of circuit components such as resistor, capacitors, etc. Our persona is also very excited to take EE101 after struggling though physics he hopes to finally take some engineering classes.

Our second persona is a 3<sup>rd</sup> year Computer Engineering Student. He has a very limited background in circuit design but, has a lot of experience programming microcontroller. No one in his family is an engineer but, got interested in engineering in high school. His high school had an after school robotics club, this is where he learned how to program. He has finished taking physics and has taken a few engineering courses but most of them are programming courses. He is reluctant to take hardware design classes as he has little experience with hardware.

### 4.2 Two user groups:

As mentioned earlier our user study will consist of 2 distinct user groups, an expert user group and a novice user group. Of our 11 participant study we will have half of them be expert users and the other half novice users. We believe that both groups will have something to add to our study.

The expert user group consisting of Senior level engineers have taken several circuit design classes and have participated in several circuit design project. This being said they have a lot of experience when it comes to designing electronic circuits. Therefore it is our belief that the expert user group will be able to provide useful feedback on our CircuitAssistant system. Because the expert users have a lot of experience with circuit they will be able to critique our circuit design techniques and compare our techniques with ones they have learned. This comparison will be very useful in analyzing the usefulness of our product. In order to gage the usefulness of our product the expert users will be asked to complete a questionnaire and asked to comment on the design and the implementation methods.



**Table 1: Motor Geometry Summary**

Participant	User Group	Gender	Beginning Task
E1 (1)	Expert	Male	Task 2
E2 (2)	Expert	Female	Task 1
E3 (3)	Expert	Male	Task 2
E4 (4)	Expert	Male	Task 1
E5 (5)	Expert	Male	Task 2
N1 (6)	Novice	Male	Task 2
N2 (7)	Novice	Female	Task 2
N3 (8)	Novice	Male	Task 1
N4 (9)	Novice	Male	Task 1
N5 (10)	Novice	Male	Task 1
N6 (11)	Novice	Male	Task 2

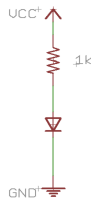
The novice user group will provide a different type of feedback. Most of the novice users have never used a breadboard in their entire life. Therefore the novice users will be very useful when evaluating if our product teaches users how to correctly and efficiently use a breadboard. This will be tested by comparing the circuit the user creates in Task 1 and in Task 2. These tasks will be defined in the Testing Procedure Section. We will evaluate the errors, etiquette, and time it takes the novice user.

### 4.3 Testing Procedure:

To evaluate our product a User Test Plan was created. This test plan hopes to evaluate the usefulness of our product as a teaching aide. In order to evaluate this we plan on assigning two tasks for our participants. Task 1 will involve using the CIRCUITAssistant to help design a simple circuit, circuit 1 as seen in figure 8. Task 2 will involve designing a similar circuit, circuit 2 as seen in figure 9, on a standard breadboard. These circuits were chosen because of their simplicity and because they are real circuits that students will be asked to create in Lab 1 of EE101. Therefore we thought that these circuits would be a good test for our participants. We plan on randomizing the order of the tasks, this will be done because we believe that the second circuit regardless of which circuit it is (1 or 2) will be easier for the participant. A breakdown of all of our participants can be found in Table 1. Each participant will be referred to by their number, names will not be used in this paper or in this study.



**Figure 8: Circuit 1**



**Figure 9: Circuit 2**

### 4.4 Definition of Success:

With the proposed Test Plan we have a few measures of success that we are trying to measure. As mentioned earlier our hypothesis is that, using our product will teach novice users the proper way to use a breadboard correctly and efficiently. In order to test this a few measures of success must be defined. These are listed below

1. Did our Novice user learn anything?
2. Was it faster to do Task 1 first?
3. Doing Task 1 first meant less errors?

The first measure of success is only for the novice users, we are assuming the expert users will not learn anything new when using the CircuitAssistant. We want to see if the novice users learn about breadboard etiquette, how a breadboard works, and/or how to design a circuit with a breadboard. If our novice users learn any of these three skills then we will consider the test a success. Another important measure is the time it took to complete the tasks. Since we believe that our system will help users build a circuit efficiently we believe that performing Task 1 first will mean a fast combine time to complete Task 1 and 2. Our final measure of success is the number of errors in the circuit. In accordance with our hypothesis we believe that users who perform Task 1 before Task 2 will have less errors in their circuit as compared to users who perform Task 2 before Task 1.

### 4.5 Pilot Study:

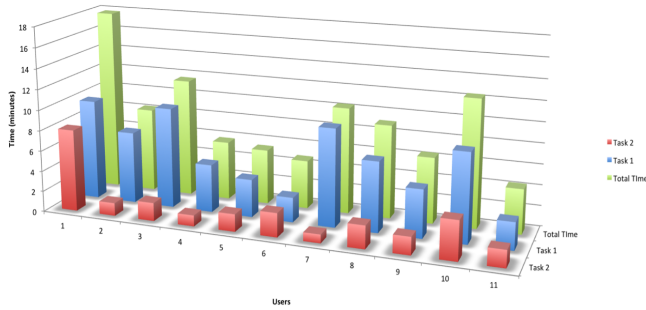
In order to run a smoother User Test, a pilot study was done. For the user study 2 participants were chosen, one female and the other male. The female student was classified as a novice user and the male student was classified as an expert user. From this point on the female user will be referred to as user  $\alpha$  and the male user will be referred to as user  $\beta$ . When conducting the pilot test we had a few goals as listed below.

1. Should users work in groups?
2. How much do we need to teach users?
3. Could a novice user use our system?
4. Was our questionnaire sufficient?
5. What is the role of the expert/coach?

When we conducted this experiment we asked our two users to work together (1) and gave very specific instructions on how to use the system (2). When the users were working together we found that only one student could work on the breadboard at a time and therefore only one user could participate at a time. This meant that the second user wouldn't be involved in the design process. During our study we found that user  $\beta$  conducted the experiment himself and user  $\alpha$  sat beside him and watched. We believe that this would be a problem no matter who our users were. This is because only one user is able to interact with the device at a time. Therefore we have determined it would hurt the study if participants were to work together. During this part of the study we found that too much information was given to the users  $\alpha$  and  $\beta$ . Both users didn't have any questions on how to use the system, this is a problem when evaluating using the coaching method. We were hoping they would have more questions on how to use the system. We have therefore concluded that it would be better to give the participants less instructions on how to use the system and let them ask the "coach" for help.

Since user  $\beta$  did most of the designing, we asked user  $\alpha$  to design a circuit on her own. We found that she didn't have any trouble designing the circuit. The only caveat is that she was able to observe user  $\beta$  before trying to design the circuit on her own. Both users were asked to answer a questionnaire,

**Figure 10:** This is a bar graph representing the time it took to complete each task.



it is regrettable to say that only user  $\beta$  answered the questionnaire, but he had some useful feedback on his experience in EE101 and how this system would have helped. Finally from this experiment we found the the “coach” should act like a TA, but the problem is that the level of involvement of TA’s varies quite a bit. From this study we decided it would be more beneficial to us, as the testers, if we impersonated a less than helpful TA when explaining the system. But, be more helpful when specific questions are asked.

A summary of our finding can be found below.

1. No groups.
2. Teach as little as possible.
3. Yes
4. Yes, ask participants to comment on experiment
5. Act as a TA

## 4.6 User Study Results:

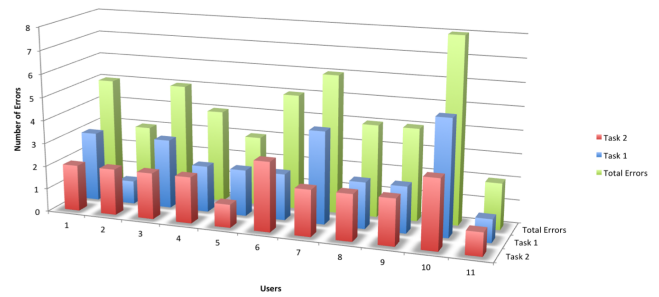
As indicated in the participant profile section, we had 11 participants in this study and of those 11, 6 were classified as novice users. A majority of the users were male, only two users were female, one expert and one novice user. From the user testing we were able to collect both Quantitative and Qualitative data as presented below.

### 4.6.1 Quantitative Data

In accordance with our user testing plan we measured the time it took for each of our users to complete Task 1 and Task 2. It was also recorded which Task we asked the participant to perform first. Figure 10, is a bar graph of all the user timing data. In the figure, the red indicates the time it took to perform the 2<sup>nd</sup> Task, the blue indicates the time it took to complete the 1<sup>st</sup> Task, and the green indicates the time it took to complete both Tasks. In this plot the Expert users are users 1-5 and the novice users are users 6 - 11.

As expected it took participants longer to complete Task 1 as compared to Task 2. This was due to the fact that the using the CircuitAssistant requires more steps than a traditional breadboard. In a traditional breadboard the user can start plugging circuit elements directly into the circuit. In the CircuitAssistant users are required to plan out their circuit before they begin building it. With simple circuits like the

**Figure 11:** This is a bar graph representing the number of Error of each user.



circuit build for this user study, a circuit plan and layout don’t need to be done if the user is “advanced”. But, for more complicated circuits is is recommend if not necessary to plan the circuit layout before beginning the build phase.

An unexpected results is the the expert users on average took longer to complete both tasks as compared to the novice users. On average the Novice user took 7:53 minutes to complete both tasks. While the expert users took 9:45 minutes on average to complete both tasks. This figure is a little deceiving because 2 of the 5 expert users were purposely took longer on Task 1. These 2 users trying to learn more about they system and “break the system” or find “bugs” in the system. On that note, User E1 who took the longest of all the users, Novice or Expert, was not trying to find bugs in the system, he merely had trouble building the circuit and wasn’t listening to the feedback provided by the GUI.

More statistical analysis showed that amongst all participants, participants who begun with Task 1 took less time to complete both tasks. On average users who began with Task 1 took 8:22 minutes to complete both tasks. While users who began with Task 2 took 9:01 minutes to complete both tasks.

Another statistic that we kept track of was the number of error each user made during the experiment. Figure 11, shows the number of errors in Task 1 in blue, the number of errors in Task 2 in red, and the total number of error in Green. On average users made 2.5 errors on Task 1 and 2 errors on Task 2. The errors that participants performed on Task 2 were mainly circuit etiquette errors. Circuit etiquette errors consisted of not cutting the leads for the circuit components and plugging circuit components into the power and ground rails. On the other hand errors related to Task 1 were related to people plugging circuit components into the incorrect pins and circuit etiquette. It is somewhat understandable that participants had more errors in Task 1 as users normally placed 2 extra components into the circuit board during task 1, those components being wires from Power and Ground.

As the bar graph in Figure 11, shows users normally had the a few more errors on the CircuitAssistant. Several par-

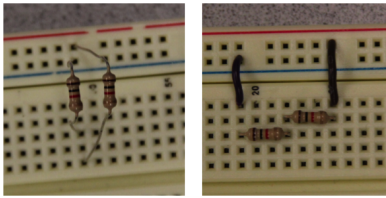


Figure 12: Images from User Quiz

Participants claimed they were unable to figure out which pin were which. They recommended numbering the rows so the that pins could be more easily identified.

Looking at all the data that we have collected there seems to be a few trends. First of all, users who preformed Task 1 first take less time to complete both tasks. From this we can deduct that users who preformed Task 1 first have a better understanding of what they are doing in Task 2. We aren't completely confident with this statement as the number of participants in our study was very limited. In order to get more conclusive results we will need a larger test group.

#### 4.6.2 Qualitative Data

As part of the evaluation process we asked participants to fill out a quiz and questionnaire to help us gage their understanding of breadboard etiquette and get their feedback on the system, respectively. One particularly interesting result we got from the quiz was related to two different circuit layouts, as seen in Figure 12. The first question on our User Quiz referred to the images in figure 12, and asked participants which they considered a "better" circuit. Everyone of our 11 participants choose the image on the right of Figure 12, but no one created a circuit that looked similar to that image. Almost all of the circuit created in Task 2 more closely resembled the image on the left of Figure 12.

Needless to say this was not the result we were hoping for. We hoped that all the users who preformed Task 1 first would create a circuit similar to the right hand side of Figure 12. We believe that users were being lazy, because half of our users asked if they needed to design a "pretty" circuit. The TA told these students to design the circuit any way they wished. The result was, everyone created a circuit that didn't meet the circuit etiquette criteria.

From the questionnaire we learned the most users would either recommend this system to others or use it themselves. This was dependent upon the participants experience with breadboards. Experienced participants found this system to be to limited for their applications, while novice users found it useful. We also received bad reviews, a few users found the system very confusing and not intuitive. These users recommended a tutorial or a video that demonstrated how to use the CircuitAssistant properly. It should be noted that most of these users were those that jumped right into the CircuitAssistant software without asking the TA how to use it.

As mentioned earlier, users suggested numbers should be added on the CircuitAssistant Hardware to indicate the row. Many users complained they couldn't find the correct pin.

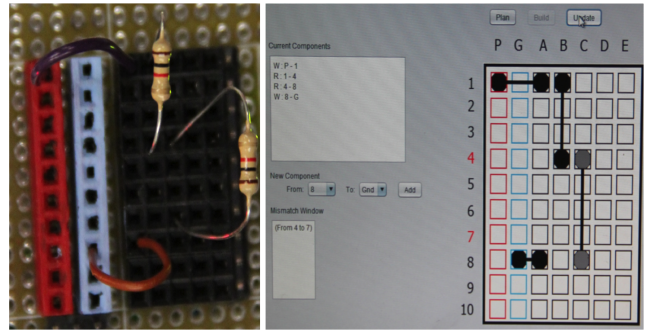


Figure 13: This is terminal output for the correct incomplete circuit

The Error count also supports this, as several of the errors that occurred in Task 1 were due to participants placing a component in the wrong pin.

#### 4.6.3 In Depth User Study

Now that the results for the whole user study group have been presented, we are going to do an in depth study on one of the users. The user that we choose is User N4, who is male and perusing a degree in Computer Science. User N4 has a very limited knowledge of circuits. In the user study when N4 was given the schematic for the two test circuits (figures 8 and 9) he wasn't sure what to do with it. With the TA's (coach's) assistance he was later able to understand what the icons represented, ex. what the (VCC) icon represented.

User N4 was chosen for the in depth user study because he is the closest user to our user persona. User N4 has almost no experience with circuit, he has only heard about these circuit elements, eg. resistors, capacitors, etc. He is also interested in learning about circuits but never took EE101 and has no experience with breadboards. The only criteria that he didn't fit is that he is not in the Electrical or Computer Engineering major.

Looking at User N4's test results show that he preformed Task 1 (using CircuitAssistant) before preforming Task 2 (standard breadboard). Before preforming Task 1 User N4 had some general questions on how to build the circuit and how to use the GUI. The questions related to the GUI were how to connect the power supply to the circuit. The TA

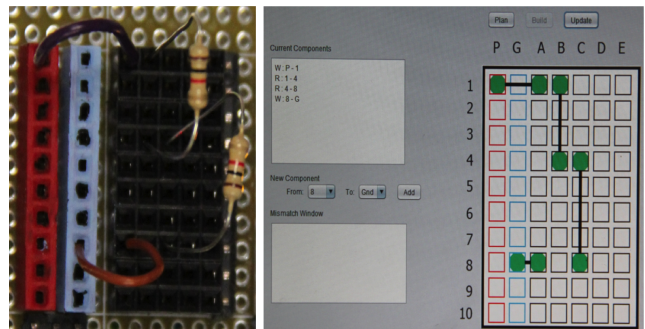
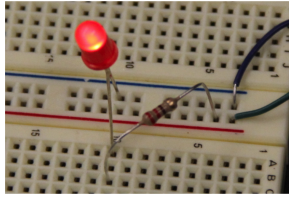


Figure 14: This is terminal output for the correct completed circuit



**Figure 15: This is an image of the completed circuit for Task 2**

then explained to the user that the RED column was the power supply. Once the user got a better idea of task and the GUI, he began to layout the circuit. He then finished designing the circuit as seen in figure 14. The user then noticed that the circuit turned green and was informed by the TA that the green circuit meant, a complete circuit was created.

The next step the user performed was to continue into the build phase. Once in the build phase the user was informed that the circuit will turn gray. As circuit elements are added the corresponding circuit element would turn black. This process was performed, until an error occurred, as seen in figure 13. Figure 13, show the incomplete circuit to the left and GUI interface to the right. Looking at the GUI interface, the user noticed that Rows 4 and 7 were highlighted in RED. This indicates that something was plugged into the 4<sup>th</sup> and the 7<sup>th</sup> rows. It was then pointed out to the user that the Mismatch Window also recognized an error in the placement of the component. Based off the information provided by the GUI the user plugged the resistor from row 4 to row 7. In the plan stage the user was supposed to plug in the resistor from row 4 to row 8. It is hard to see in figure 13, but the image to the left shows the bottom resistor being plugged into row 7 rather than row 8. As the image shows it is hard to distinguish which pin the resistor is plugged into. This is the reason why user N4 has trouble plugging the resistor into the correct pin, he had trouble distinguishing the pins.

Figure 14, is an image of the completed circuit and the GUI, indicating the correct circuit was built. While in the build phase the user can place components one at a time. As the components are placed and when the user hits the update button, the GUI is updated. Once all of the components have been properly placed the circuit will turn green as seen in figure 14. Once again it should be noted that the circuit picture in figures 13 and 14 are different picture. But, it is hard to tell and this was the cause of user N4's error as well as other users in the study.

User N4 had no trouble with Task 2, he didn't have any question either. The only error that was documented was his circuit etiquette. He did manage to cut the leads of the components but plugged the resistor and the diode into the Power and Ground rails. It is believed that his success with Task 2 was partly due to the questions asked and the things he learned during Task 1.

## 5. CONCLUSION

After carrying out this experiment we understand that a more in depth and larger user study must be carried out in

order to get solid results. Right now we have a few trends from our user study but it is hard to support these results with such a small user group. But, this user study wasn't a total waste of time, we were able to get a lot of useful advice to improve upon the existing system.

As such we have some future goal for this project, we want to increase the dimension of the CircuitAssistant hardware. Currently we are limited to a 10 row system. We believe that we need to create at least a 100 row system in order for our product to be useful. We also need to find a better way to explain how the CircuitAssistant system works. We cannot rely on a TA to explain the system to new users, instead we need a video or tutorial to help users understand what the CircuitAssistant is doing and what it can do.

As previous mentioned the data that we received is not enough to make a confident statement as to the success or failure of the CircuitAssistant, but many students said they would either use the system themselves or recommend this system to others. Due to the insufficient amount of data, we believe this is our best bench mark for success at this point. We hope to implement the suggestions we received from the user study and perform the user study once more with a much large user group.

## 6. REFERENCES

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