LightUp: A Low-Cost, Multi-Age Toolkit for Learning and Prototyping Electronics

Zain Asgar
Stanford University
520 Galvez Mall
CERAS 232
+1 (650) 736-0966
zasgar@stanford.edu

Joshua Chan
Stanford University
5208 Lodestar Way
Elk Grove, CA 95758
joshchan@stanford.edu

Chang Liu
Stanford University
520 Galvez Mall
CERAS 232
+1 (650) 736-0966
changliu@stanford.edu

Paulo Blikstein
Stanford University
520 Galvez Mall
CERAS 232
+1 (650) 736-0966
paulob@stanford.edu

ABSTRACT
LightUp is a constructionist platform to teach novices about electronics, and also a low-cost rapid-prototyping platform for more advanced users. The LightUp kit contains many basic electronic components attached to magnetic building blocks and a connection base. Various project-based educational materials are also included. Initially designed as an interactive and transparent learning tool, the concept behind LightUp is to provide a "low threshold, high ceiling" learning experience for self-motivated individuals who want to better understand the complex electronics inside the devices they rely on every day. In addition, LightUp also serves as a user friendly, low-cost prototyping tool for people who do not have a strong engineering background but still want to build electronic circuits. This paper gives an overview of the LightUp platform, the construction process and future developments and implementations.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—Input devices and strategies, interaction styles; K.3.1 [**Computers and Education**]: Computers Uses in Education

General Terms
Design, Experimentation

Keywords
Tangible interfaces, constructionism, education, engineering education, electronics.

1. INTRODUCTION
Advancements in technology have led to the miniaturization of electronics into increasingly complex integrated circuits in devices we use regularly, such as radios and TV. The relatively accessible circuits in yesteryear's devices have been replaced by a bewildering maze of black boxes. Tinkerers with an interest in electronics could take things apart and immediately learn before, but are now turned away by the very complexity that powers the things they use every day. Similarly, our observations of novice users revealed that the tangle of alligator clamps, wires and tiny components on current breadboards used for prototyping is intimidating. Bearing these points in mind, it is timely and necessary to create easy-to-use, tangible and modular electronics toolkits that enable complete novices to learn by doing (i.e. building working circuits) and people with non-technical backgrounds to utilize electronics in their own projects. To fill this gap we created LightUp, a platform for learning about and exploring electronics. It consists of an acrylic baseboard with a grid of metal contact points, and building blocks, which can be arranged using magnetic contacts that allow for an easy and intuitive connection scheme. The overview and some sample modules are shown in Figure 1.

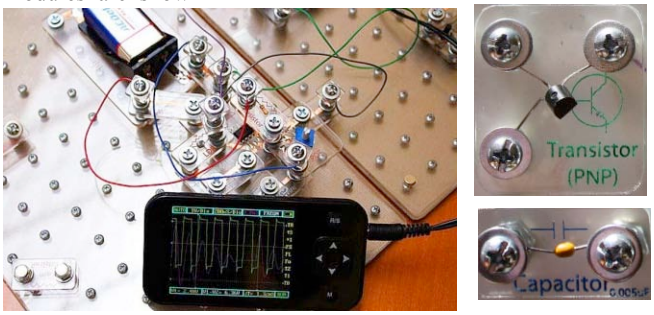

Figure 1. Basic RC circuit and some components.

2. RELATED WORK
There are existing products on the market that fulfill at least some of these objectives. Elenco's Snap Circuits [2, 3] teach children about basic electronic principles through modular pieces, while breadboards allow hobbyists to build quick prototypes before finalizing a circuit. However, Snap Circuits™ connectors are not always easy to join, and the large size and low count of the pieces, as well as the size of the baseboard constrain the complexity of the circuits beyond the very basic. In addition, the premium price charged for expansion kits prevents it from becoming a viable tool be-yond the educational toys market. Finally, it does not interface well with standard microcontroller platforms. In our research in customer testimonies posted online, many beginners expressed frustration with deciphering cryptic circuit schematics, connecting elaborate wire mazes on breadboards, and working with a hot soldering iron. While all of these are valuable and necessary to the craft and science of electronics, these mundane details often get in the way or even create a fear of learning about circuits, especially for absolute beginners. Breadboarding is a useful tool in the hands of an experienced experimenter, but can quickly confuse a novice who is not prepared to learn the complexities of electronics. Other tools such as littleBits [8], although flexible and modular, are also

IDC 2011, June 20-23, 2011, Ann Arbor, USA.

too advanced for novices and relatively expensive for use in schools in large numbers. LightUp bridges this gap between beginners and advanced users, providing an initial learning platform and basic prototyping tool [4, 5] that is much more approachable than breadboards, while being extremely low cost.

3. TANGIBLE LEARNING

Learning about electronics is challenging enough in its own right, and aspects of the process that don't directly contribute to learning should be minimized or removed [6]. On the other hand, oversimplifying electronics has its own unintended consequences for learners. Replacing electronics lab with a lecture or on-screen virtual activity separates core circuitry concepts from their tangible realization; for example, drawing a schematic of a LED/switch circuit on the whiteboard and verbally explaining how it would behave in real life versus building, debugging, and learning from the actual circuit.

LightUp features a transparent configuration so almost every component included is fully exposed to the user. This is evident most literally in our choice to mount all of the included electronic components on top of clear acrylic blocks to be visible to the learner. Users learn about basic electronics as they build circuits by putting together single components, as opposed to the level of "black-boxed" circuit boards, or wire mazes on breadboards. Lastly, the ability to design circuits in 3D, i.e., stack up pieces such as resistors or capacitors, creates a more intuitive way to build parallel circuits (Figure 2). The difference between series and parallel becomes evident when the former is confined to the plane of the baseboard and the latter rises above the board.

4. IMPLEMENTING LIGHTUP

LightUp uses magnets to connect the circuit building blocks, which makes it easy to use and intuitive from the learner's perspective. All the components are built on top of generically shaped blanks, which span one or more grid sections. The components provided range from simple resistors, capacitors and wires to transistors and integrated circuits. LightUp is extremely affordable to make, since even repurposed electronics can be used, and the kit is engineered so that accidental connections are unlikely to damage anything or harm the user.

One of the advantages of the LightUp platform is that it is possible to build more complex circuits as well, using the same components. This makes it suitable as a platform for people without a strong electronics background who want to build more complicated circuits, as they won't feel as threatened as by other less transparent prototyping platforms such as breadboards. It is also fairly easy to create custom components as users can use blanks similar to the existing blocks in the kit and add their own components. Under-development kits include transition pieces that would allow the connection to platforms such as Arduinos and GoGo Boards, so that users could create circuit and 'shields' for them with ease. LightUp is a "low threshold, high ceiling" [1,7] platform as it is simple to use and expandable in many ways.

5. USER FEEDBACK AND FUTURE WORK

Our preliminary user feedback has been very positive, with many students commenting on the ease of use and simplicity of LightUp's form and function. While it allows users to build and share circuits, there is a problem that comes up in preserving past work, as one must eventually deconstruct finished circuits in order to free up parts for new creations. One solution that we have been developing is to have a simple computer vision system with a low-cost webcam that would automatically take pictures of the system and reconstruct the circuit, for sharing, debugging, or later reuse. Also, this system enable learners to create time-lapse sequences of their creation for automatically generating tutorials, or as a research tool to understand how the gradual building of a circuit reveals rich detail of the learner's preconceived notions about circuits and thought process.

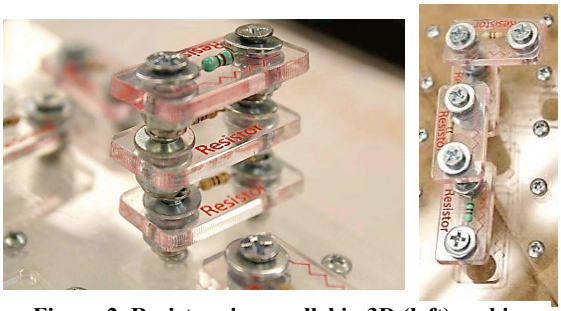

Figure 2. Resistors in parallel in 3D (left) and in series (right)

6. CONCLUSION

The LightUp platform provides a low-cost, user-friendly and tangible way for people to learn about electricity and electronic, and is able to grow with users as they progress from absolute novices to experienced prototypers. While existing educational toys and prototyping tools exist for electronics, we believe that LightUp combines the best attributes of each into a platform that has value both as a learning and rapid prototyping tool.

7. REFERENCES

[1] Papert, S. 1980. *Mindstorms : children, computers, and powerful ideas.* New York: Basic Books.

[2] Moor, S., & Piergiovanni, P. 2003. Experiments in the classroom: Examples of inductive learning with classroom-friendly laboratory kits. *Proceedings of the American Society for Engineering Education Conference*, Nashville, TN.

[3] Snap Circuit. http://www.snapcircuits.net/

[4] Laerhoven, K., Schmidt, A., and Gellersen, H.W. 2002. Pin&Play: Network objects through pins, *Proceedings of UbiComp '02*, Göteborg, Sweden, 219-228.

[5] Sankaran, R., Ullmer, B., and Ramanujam, J. 2009. Decoupling interaction Hardware Design using libraries of Reusable Electronics, *Proceedings of Tangible and Embodied Interaction 2009* (TEI'09), Cambridge, UK.

[6] Perner-Wilson, H. and Buechley, L. 2010. Making textile sensors from scratch, *Proceedings of Tangible and Embodied Interaction 2010* (TEI'10), Cambridge, MA, 349-352.

[7] Blikstein, P., Buechley, L., Horn, M., and Raffle, H. 2010. A new age in tangible: Computational Interface for learning, *Proceedings of the International Conference for then Learning Sciences 2010* (ICLS 2010), Chicago, IL.

[8] Bdeir, A. 2009. Electronics as material: littleBits. *Proceedings of Tangible and Embodied Interaction 2009* (TEI'09), Cambridge, UK.