

Interactive Visualization of 3D Electrical Circuit Representations

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Abstract

In this paper, we extend traditional 2D electrical circuit drawings to interactive 3D abstract representations that can be viewed on internet. Since our interactive depictions strongly resemble traditional circuit drawings, classically trained engineers easily adopt to our representations. These 3D representations are especially useful for the people outside of engineering community. Although the abstract nature of traditional drawings still exists in these 3D representations, our representations look more familiar and tangible due to their 3D structure.

1. Motivation

Engineering drawings are never photographs or photo-realistic depictions. In engineering drawings, the goal is to allow the designers to communicate their intentions completely and accurately to the other engineers and crafts-people.

Engineering drawings do not try to reproduce exact images of the 3D objects that are seen by the engineers. Instead, they provide abstract depictions that use previously developed symbols or icons, based on certain conventions and according to the needs of individual engineering disciplines. These abstract icons and symbols usually do not even imitate the shapes of the objects they represent.

A typical example of such an abstraction is the electrical circuit diagram. Electrical circuits are nothing but symbols that are drawn as 2D icons. These 2D icons hardly resemble their real-life counter-parts. Every connection in an electrical circuit drawing is shown symbolically. The beauty of this approach is that the designer does not have to worry about what the electrical elements and the connections do really look like. These elements can come from a variety of manufacturers, but regardless of their manufacturer, when

the specified elements are connected as described in the circuit drawings, the resulting circuit is expected to work as intended by the circuit designers.

While such abstract representations provide functional simplicity and allow ease of communication of ideas among the experts, they may be equally confusing for the novice users such as engineering students. While working in the laboratory, the students build circuits using the actual 3D electrical components, but when preparing their reports, they need to draw the same circuits by using 2D symbols and icons, which typically do not in any way resemble the actual components.

Another issue which is progressively becoming an important engineering challenge is related to the circuit layout. Once a circuit is designed according to the technical specifications, it has to be physically realized on a circuit board. This may not be a trivial problem for circuits with complex topologies and requirements related to space and ambient temperature. If such circuits can be rendered in 3D along with added animation to visualize hot spots, electromagnetic interferences, electric field intensities at various locations on the circuit boards, it would greatly assist the circuit designers in their pursuit of the optimal layout for such circuits.

We extend traditional 2D electrical circuit drawings to 3D abstract circuit representation (see webpage [1] for an example). These 3D circuit representations can be interactively viewed on internet. Since our 3D depictions strongly resemble traditional circuit drawings, classically trained engineers can easily adopt our depictions. On the other hand, these 3D representations are especially useful for the electrical engineering students as well as for people outside the engineering community. Although the abstract nature of traditional drawings still exists in these representations, our interactive depictions look more familiar and tangible due to their 3D structure.

2. Introduction

Electric circuits have been in use for over a century and their complexity increased both in terms of their size and the

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number of different types of components they used. Furthermore, wide spread globalization of the manufacturing business for these components, lead to a slew of visually dissimilar but functionally identical components to populate the market. Thus, we argue that in today's electrical engineering practice, photorealism will hit a roadblock if used for visualization of circuits to aid their design or analysis. To illustrate our point, we took photographs of some commonly used actual circuit components and they are shown in Figures 1, 2 and 3. It is evident from these photographs that photorealism clearly fails to provide the necessary information to enable easy differentiation of circuit elements.



Figure 1. Photographs of a real resistance and inductance.



Figure 2. Photographs of two real capacitors.



Figure 3. A real diode and transistor.

Moreover, due to the above stated reasons, it is not always easy to decipher the main function that a given circuit performs simply based on the photographic images of the circuit board containing various circuit components as shown in Figure 4. A viable alternative to this is a 3D rendering of the circuit by retaining the physical characteristics of individual components but unifying the physical 3D rep-

resentations based on component functions rather than the physical appearance dictated by the manufacturer.

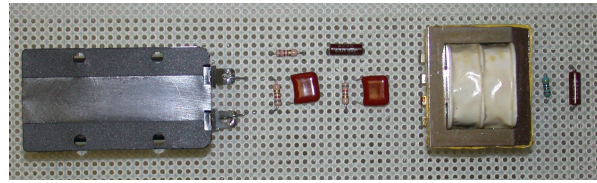


Figure 4. A real circuit.

Historically speaking, we do not know exactly when and by whom the first 2D icons for various circuit elements were used for creating circuit drawings. Some of the current standard symbols for drawing circuits are shown in Figure 5. However, we know for a fact that these were not standards until 1930's, i.e., standards were not established even 50 years after the American Institute of Electrical Engineers (AIEE), the predecessor of Institute of Electrical and Electronic Engineers (IEEE), is founded in 1884.

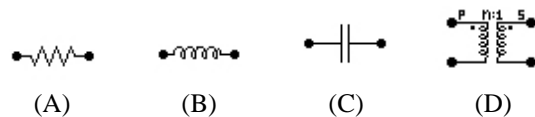


Figure 5. Standard symbols (2D abstract depictions) of some circuit elements: (A) Resistance, (B) inductance, (C) capacitance and (D) transformer..

Until 1920's, even circuit drawings were very rare in publications. The engineers generally used pictures of the actual instruments. Based on their appearance in publications, we speculate that the early icons must have been introduced in the later part of the 19th century by scientists or electrical engineers. They simply used icons that strongly resembled their 3D counter-parts to effectively communicate their ideas by representing circuits with abstract depictions. Figure 6(A) and (B) illustrate such a resemblance that is common in early circuit drawings. In the figure (A) all X 's are not inductances; they represent resistances. Note that how much these coil-looking icons for resistance is influenced by actual resistances at the time shown in (B). C In the circuit drawing shown in Figure 6(A) is a capacitance, which also resemble its actual 3D counter-part. Moreover, the shapes that look like resistances are actually springs.

Six years later, in 1879, the same publication, *The Electrician*, started to draw the circuits in a more abstract manner and changed the icon for resistance to a rectangle as shown in Figure 7 [5]. However, the icon for capacitance is not changed, the symbol called it "the induction plates" is, in fact, a capacitance. Moreover, the symbol called it

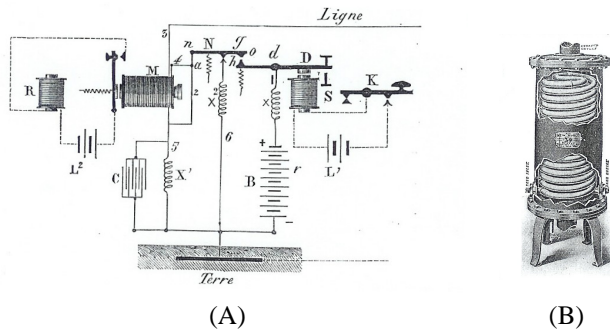


Figure 6. (A) A typical circuit drawing from The Electrician in 1873 [3, 2] and (B) A 3D depiction of an actual resistance at the end of 19th century; from American Electrician [8].

“the induction coil” represents inductance and resembles its actual 3D counter-part.

In 1880’s, circuits were still not drawn very abstractly. As shown in Figures 8 and 9 the rectangular icon seems to be used internationally. In 1890’s standards still not emerged as seen in two examples from *American Electrician* in 1899 shown in Figures 11 and 10. Transformers are abstractly depicted in one issue [10] and realistically depicted in another issue [11] and neither of the depictions is the same as current standard symbol for transformer.

With the beginning of the 20th century, the current 2D icons for resistance and inductance seems to be adopted by all electrical engineers. However, the current 2D icon of capacitance has not been accepted as a standard until 1930’s [13]. However, after 1930’s these symbols became internationally standard symbols for electrical engineering field and these 2D icons have remained unchanged since then except for a few new additions to represent the later-discovered non-linear circuit elements¹.

These 2D icons or symbols are still an integral part of electrical engineering. Even widely used network design and analysis software such as Matlab [16], Pspice [18], Psim [17] and Atp [19] use the same type of icons to represent circuits as shown in Figures 12, 13 and 14.

These abstract 2D circuit representations provide functional simplicity and allow communication of ideas among the experts. However, these representations are confusing for the novice users such as engineering students. While working in the laboratory, the students build their circuits

¹To name a few non-linear circuit element additions before and after 1930’s: in 1904, John Ambrose Fleming discovered two-element vacuum tube diode to detect radio waves [14]. In 1906, Lee de Forest introduced triode by adding a third electrode into the vacuum tube. The triode is used both as an amplifier and a switch [14]. In December 1947, Walter Brattain, John Bardeen and William Shockley discovered transistor action at Bell Laboratories [15].

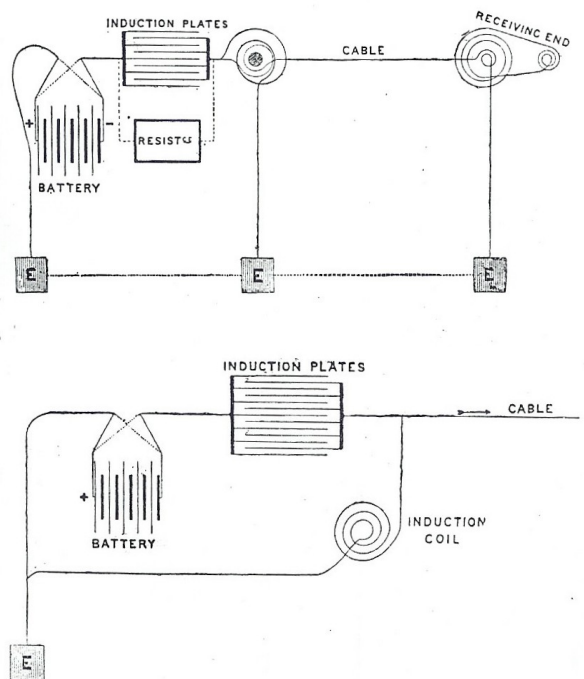


Figure 7. Two circuit drawings from The Electrician in 1879 [4, 5].

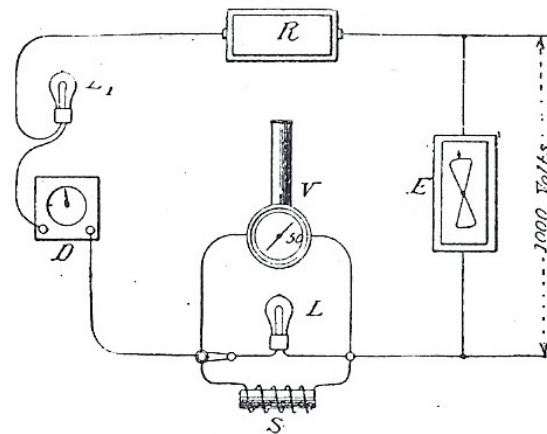


Figure 8. A circuit drawing from The Electrician in 1887 [7].

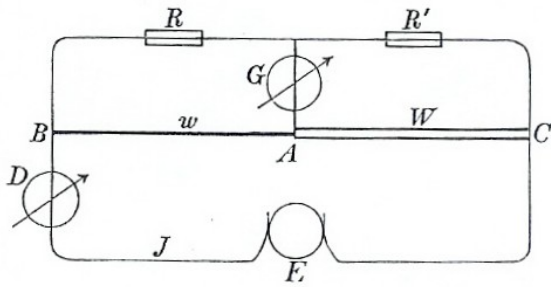


Figure 9. A circuit drawing from 1885 *Electrotechnische Zeitschrift*, an *Electrical Engineering journal in German language* [6].

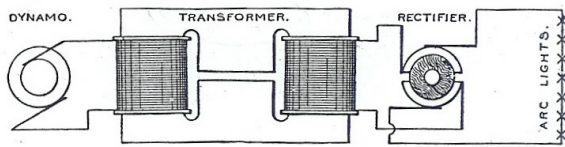


Figure 10. A circuit drawing from 1899 April issue of *American Electrician* [10, 11].

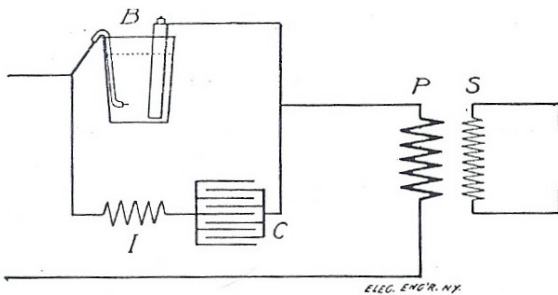


Figure 11. A circuit drawing from 1899 June issue of *American Electrician*[10, 11].

using the actual 3D electrical components, but when preparing their reports, they draw the same circuits by using 2D symbols and icons. We observe that interactive 3D representations can be a viable alternative representation for circuits. These interactive representations of the circuits can be useful for novice users if they retain the 3D characteristics of individual components but unify the physical representations based on component functions rather than the physical appearance dictated by the manufacturer.

Based on this observation, we extend traditional 2D electrical circuit drawings to interactively viewed 3D circuit representations. Figure 15 shows interactively created perspective and parallel views of the 3D representation of the circuit shown in Figure 4. This example can be interactively viewed on internet [1]. As seen in this example, we have improved the quality of visual representation without changing the nature of 2D icons; our top perspective views or parallel projections look exactly like 2D circuit drawings. Since our interactive 3D representations strongly resemble traditional circuit drawings, classically trained engineers can easily adopt our representations. On the other hand, these interactive representations are especially useful for the electrical engineering students as well as for people outside the engineering community. Although the abstract nature of traditional drawings still exists in these 3D representations, our interactive rendering approach looks more familiar and tangible due to their 3D structure.

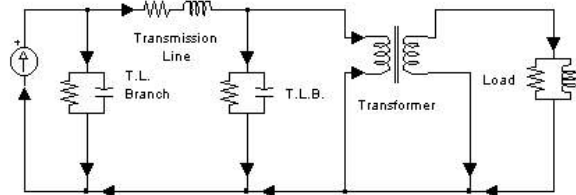


Figure 12. The 2D abstract representation of the circuit in Figure 4 drawn in a well-known, extensively used commercial program Matlab Power System Blockset [16].

3. Methodology

The choice of 3D shapes for individual components is critical to make images created by parallel projection closely resemble traditional 2D circuit drawings. Since, 2D icon of inductances is 2D coil, as a 3D icon of inductances we simply use 3D coils. Similarly, 2D icon for resistance is a 2D zigzag shape, for 3D icon we use a 3D zigzag shape. 3D icons for capacitors turned out to be a problem. For capacitors we first used two rectangular shaped thin plates,

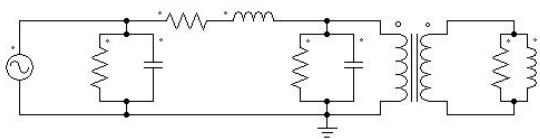


Figure 13. The representation of the same circuit in PSPICE package [18].

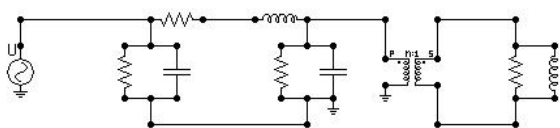


Figure 14. The representation of the same circuit in ATP package [19].

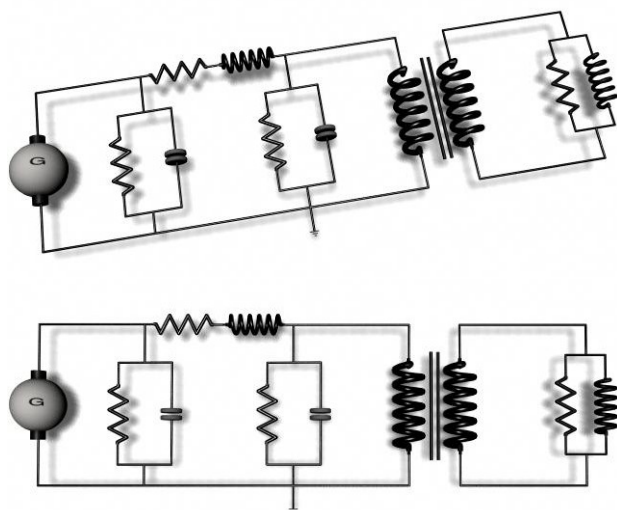


Figure 15. Our 3D abstract depiction of the same circuit with side and top views (both are perspective projections).

but the resulting circuit, when viewed using parallel projection, did not look like a 2D drawing of a circuit as shown in 16. We, then, improved 3D icon for capacitor using two circular shaped thin plates. As seen in Figure 18, this choice not only gives for better visual representation under parallel projection, but also provide a better resemblance to real capacitances which usually have circular shapes (see Figure 2). Each component is modeled in Maya and circuits are constructed by connecting these components in Maya. We then export the circuit representations as either VRML or Macromedia files.

We simply use a parallel light source with a direction perpendicular to the plane of the circuit board for illumination. This light source allows us to obtain a shadow directly under each element. To compute the shadow we simply use a shadow map with very low resolution and obtain a very soft shadow with gaussian low-pass filtering. Since this shadow does not change depending on the position of the circuit element, we can simply bake this shadow and add it as a texture map. Making the shadow softer is especially useful when the circuit is viewed with parallel projection; it creates a soft gray halo around each circuit element.

The diffuse color of each circuit element is chosen to be pitch black and diffuse reflection coefficient is chosen to be zero. Since specular reflection is essential to see the shape of the objects, specular color is white and specular coefficient is very high. These choices guarantee that (along with the shapes of circuit elements) silhouettes of circuit elements are black. Additional examples are shown in Figures 17, 18 and 15.

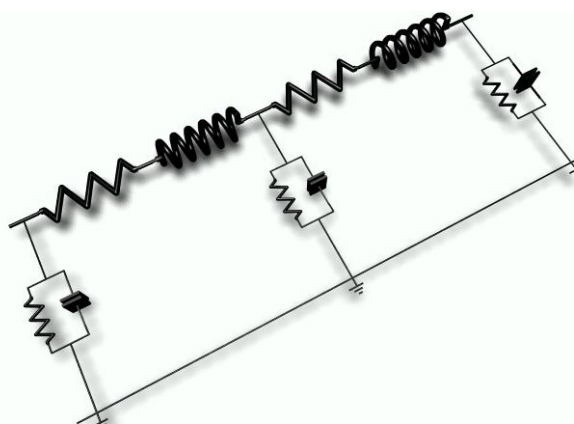


Figure 16. One of the first 3D circuit models with square shaped 3D icons for capacitances . These capacitances do not look like a 2D drawing of a capacitance when viewed using parallel projection.

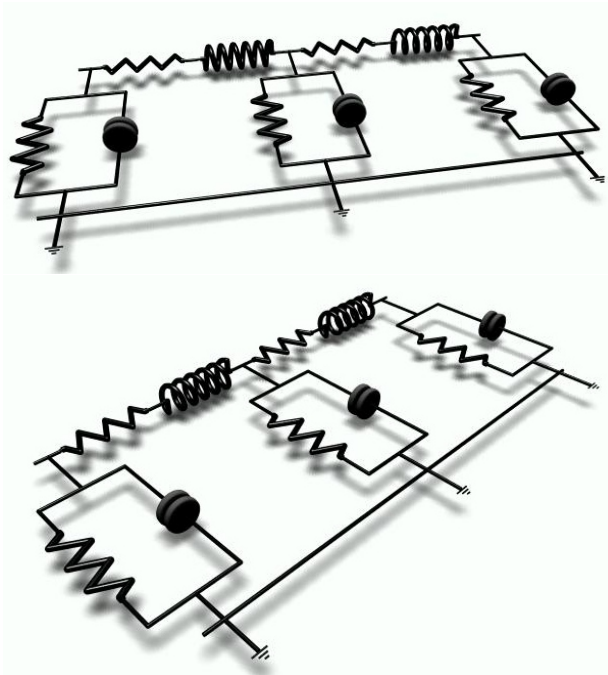


Figure 17. The same circuit with improved icons for capacitances. The new icons make capacitances clearly visible in any perspective view.

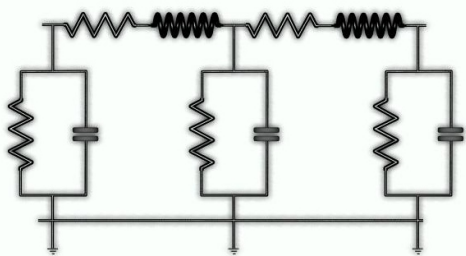


Figure 18. Parallel projection of the circuit looks a lot like a 2D circuit drawing.

4 Conclusion and Future Work

We have introduced new 3D icons for electrical circuit elements and provided a simple mechanism to render the circuits for high quality interactive viewing on web. Our approach improves the quality of visual representation of circuit drawings without changing the nature of 2D icons. Our parallel projections can look exactly like a 2D circuit drawing. Moreover, our 3D representations are faithful the classical 2D representations. Both novice users and classically trained electrical engineers easily adopt to our representations. Moreover, it is straightforward to create similar high quality 3D depictions by using existing modeling and animation tools. For electrical engineers it can be useful to develop an interactive 3D circuit drawing plug-in for one of the existing circuit analysis systems such as MatLab or Pspice.

5 Acknowledgments

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References

- [1] The webpage: www-viz.tamu.edu/faculty/ergun/ee
- [2] Reprints from *Annales Industrielles*, Cinquième Année, Octobre 1873, *The Electrician: A Weekly Journal of Theoretical and Applied Electricity & Chemical Physics*, Vol.1, 12 October 1873, (Pg. 470, Figure 2 - Resistance).
- [3] Reprints from *Annales Industrielles*, Cinquième Année, Octobre 1873, *The Electrician: A Weekly Journal of Theoretical and Applied Electricity & Chemical Physics*, Vol.1, 12 October 1873, (Pg. 475, Figure 7 - Capacitance and resistance).
- [4] Notes on Mr. Willoughby Smith's Paper Upon "The Working of Long Submarine Cables." *The Electrician: A Weekly Journal of Theoretical and Applied Electricity & Chemical Physics*, Vol. 3, 11 October 1879, (Pg. 244, Figures 7 and 8 - Induction plates, induction coil).
- [5] Notes on Mr. Willoughby Smith's Paper Upon "The Working of Long Submarine Cables." *The Electrician: A Weekly Journal of Theoretical and Applied Electricity & Chemical Physics*, Vol. 3, 11 October 1879, (Pg. 243, Figures 4, 5 and 6 - Induction plates and resistance coils).
- [6] V. A. Gravier, "Über den Einfluss der Menge des Eisens im Gramme'shen Ring auf die Wirkungsweise

des Ringes als Induktor" *Electrotechnische Zeitschrift*,
March 1885, (Pg. 93 Figure 1 - Resistance)

- [7] *National Electric Light Association Proceedings*, Vol. 3, 1887-1888, "The Energy of Alternating Currents", (Pg. 500, Figure 4 - Resistance).
- [8] *American Electrician*, Vol. 11, No.1, January 1898 (Figure: Return Coil Feed Water Feeder - Actual resistance), Pg. 48
- [9] H.E. Raymond, "Types of American Lighting Arresters" *American Electrician*, Vol. 11, No. 2, February 1899, (Pg. 66, Figure 4,6 - Reactance Coil).
- [10] C. T. Child and G. T. Hanchett, "The Wehnelt Interrupter", *American Electrician*, Vol. 11, No.4, April 1899, (Pg. 166, Figure 2 -Capacitance).
- [11] *American Electrician*, Vol. 11, No.6, June 1899, (Pg. 256, Figure 17 - Transformer).
- [12] H.S. Webb, "Simultaneous Telegraphy & Telephony and the Construction of Apparatus Therefor" *American Electrician*, Vol. 11, No.9, Sep. 1899, (Pg. 422, Figure 11 - Capacitance).
- [13] *The Electric Journal*, Vol. 26, No.4, (Pg. 190, Figure 11 - Capacitance: Representation of Dielectric).
- [14] www.maxmon.com/1883ad.htm
- [15] www.maxmon.com/1926ad.htm
- [16] www.mathworks.com
- [17] www.powersimtech.com/
- [18] www.pspice.com/
- [19] www.emtp.org/