

Comic strips for electrical and electronic engineering - a novel genre

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ABSTRACT: This article reports on the use of comic strips in engineering laboratory sessions. Engineering students tend to be visual learners, and resources that depict circuit behaviour in terms of a sequence of figures rather than just mathematics or verbal descriptions, could appeal more to the students. Therefore, they could provide another perspective with which students could understand circuit behaviour. The method of testing involved the researcher as *observer - participant* during two undergraduate engineering laboratory sessions at the University of Malta. The data were collected through the researcher's observations and interactions with students while participating in the laboratory sessions, and also through a short questionnaire, which was given to the students at the end of the session. Feedback from some electrical engineering lecturers about the nature of the resources was also sought. The results indicate that the learning aids were considered helpful for understanding the behaviour of the circuits in question. The students also commented that such qualitative resources make learning engineering more fun.

INTRODUCTION

The label *cartoon* or *comic* may be potentially deceptive towards these forms of art since people may strongly associate, or expect, cartoons and comics to be linked with humour. Figure 1 illustrates related and dissimilar features between cartoons, comic strips, comic books and graphic novels as defined by Tatalovic [1]. The relationship between these art forms is that they all combine text with images to convey information. A cartoon printed on a paper medium is understood as being non-sequential and comprised of a single panel displaying an image with text. A comic, once again if printed on a paper medium, is characterised by its sequential nature, apart from the image-text combination. The realm of comics can be further divided according to the variables of length and narrative complexity. Comic strips are shorter and simpler in their narratives with respect to comic books and graphic novels.

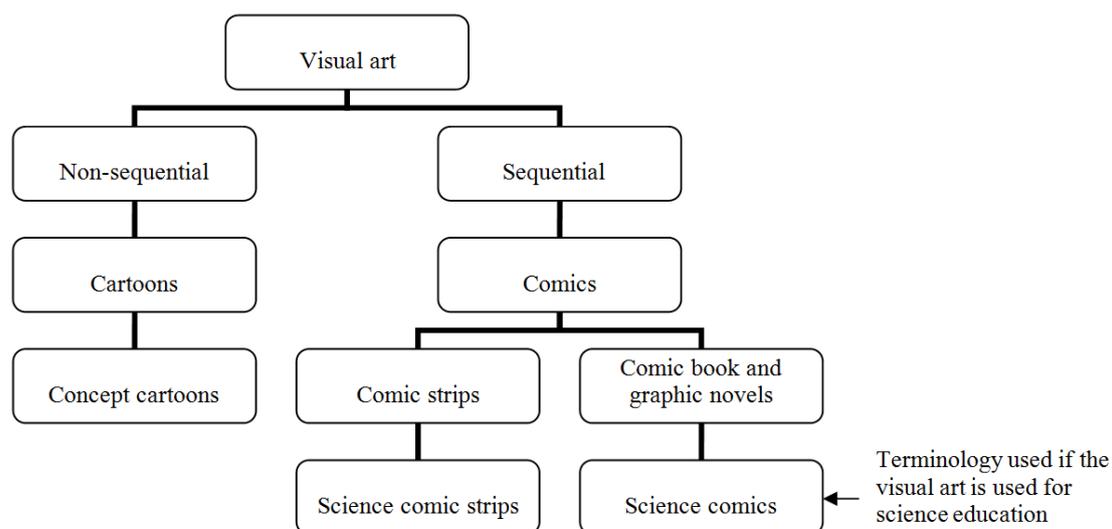


Figure 1: A simple classification of visual art featuring cartoons and comics.

In his book, McCloud gives a comprehensive analysis of comics and proposes this definition:

Comics: juxtaposed pictorial and other images in deliberate sequence, intended to convey information and/or to produce an aesthetic response in the viewer [2].

With such a definition, it is clear that the art of comics can be employed to describe sequential events, even if humour or satire is not intended.

Cognitive Impact and the Use of Comics in Education

Jee argues that comics impact learning in many ways [3]. He explains how comics can make concepts more concrete and how they capitalise on the benefits of spatially contiguous text and images, while invoking schemas that may influence comprehension and metacognitive judgements about understanding. In order to target an educational purpose, the medium of comics has been used within myriad domains. Keogh and Naylor provide details of reported research projects which have employed comics to: a) improve reading comprehension; b) enhance vocabulary; c) solve problems; d) develop thinking skills; e) enhance motivation; f) elicit tacit scientific knowledge; and g) make ideas more accessible [4]. Tatalovic [1][5], and Jee [3] review the use of comics for the specific purpose of science education in the classroom or for public engagement. They both provide broad lists of the use of comics within scientific domains as diverse as a) general science; b) biology, health and medicine; c) chemistry; d) physics, astronomy and space science; and e) scientific research careers. Abate analyses the use of comics for communicating mathematics [6], while Park and his colleagues show how comics have been used for the study of anatomy [7]. Within scientific education and related areas, the role of comics has been to develop innovative teaching and learning strategies or to access, appeal and motivate wider audiences. The agenda of some research projects like Edu Comics [8], Comic Strip creator [9], Bit Strips for Schools [10] and CosyLLab [11] has been to develop digital tools for the design of customised, learner (or teacher)-centred comics to complement other learning/teaching strategies.

Close inspection of science comics, such as a) Adventures in Electricity; b) Tesla; c) Radio Shack catalogues; and d) the Manga Guide to electricity, shows that the domains of electricity and electronics is approached either from a historical point of view or else from a physics perspective where the dominant outlook is that of the motion of charges. It is uncommon to find comics, which take an engineering or technological perspective of electricity and electronics, whereby the dominant outlook is that of circuit behaviour analysis or design. The aim of this article is to propose a new genre of comics the purpose of which is to make explicit and accessible the visualisation of dynamic behaviour of electrical and electronic circuits from the engineering or technological perspective. According to the definition given by McCloud, the medium of comics should lend itself well to describe the causal sequences of circuit behaviour [2]. Moreover, as argued by Bruner, possessing a powerful and economic repertoire of visualisations based on imagery may be an essential or useful step for a learner to embody the abstractions related with the study of domains, such as electricity and electronics [12][13].

Design Features and Target Audience

The novel genre of comics proposed in this article has different features from the science comics cited in an early section. These comics do not involve use of the human figure and no humour is intended. Unlike other science comics, they are not based on familiar events on which a student may encounter in his/her everyday life and are certainly not directed towards the general public. Distinctly from concept cartoons as described in Keogh and Naylor [4], these comics do not present alternative interpretations of the phenomenon described. The novel genre of comics proposed in this work, simply make phenomena more visual so as to provide a qualitative understanding of circuit behaviour and, thereby, support in the development of a repository of visual imagery for each of the states the circuit may take. The comics are based on the familiar electrical circuit schematic symbols that are normally used to draw circuits. The inspiration for such design was taken from the work of Doering [14], del Rio and Rodriguez [15], del Rio and Valdes [16], Sullivan [17][18] and Gueuning [19].

METHODOLOGY

Participants

Fifty-five undergraduate second and third year engineering students from the Faculty of Engineering at the University of Malta, were selected as participants for this study. This cohort was selected because the foundation knowledge required to understand the laboratory session, indicated in another section, had been covered within their course in previous years, and they had had ample opportunity to practice and apply their knowledge in several engineering domains both theoretically and practically. The cohort was representative of the second and third year of the Maltese Engineering course at the University of Malta. Two engineering lecturers were invited to express their comments on the learning aids used.

Context, Experimental Design and Procedure

One of the topics for investigation was to analyse the astable multivibrator designed with transistors, as shown in Figure 2. It was hypothesised that if students lacked a thorough grasp of resistor-capacitor network behaviour, it was very likely that they would find difficulty in understanding the astable multivibrator circuit design shown in Figure 2. Therefore, the comic strip in Appendix B was given as a learning aid, while the participants conducted their laboratory session on the astable multivibrator. The participants were invited to refer to the comic strip freely and to ask about its

interpretation should they feel the need. At the end of the laboratory session, participants were asked to fill in an evaluation sheet for analysing the use of the learning aid.

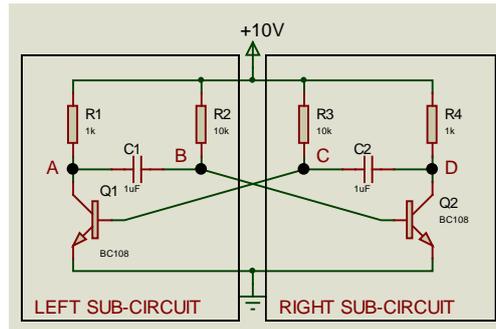


Figure 2: The astable multivibrator designed with transistors.

FINDINGS

Quantitative and qualitative analysis of the evaluation sheets gave rise to the outcomes in Figures A.1 to A.5 and Table A.1 in Appendix A. The comments at the foot of each bar chart, and those presented in Table A.1, are verbatim extracts from the qualitative data collected. The qualitative analysis of students' comments revealed the following points for reflection and possible debate:

1. A dominant theme, which emerged from students' comments was how the comic strip presented the information *step-by-step*. The deliberate explication of sequence was important to students and it seems that, they perceived this better from the comic strip rather than from their class notes or other learning media. This may be due to affordances present in the comic strip as defined by McCloud [2], but absent in other forms of formatting information.
2. Some students seem to be aware of diverse learning styles and may have innately discovered that they learn better through images rather than by verbal means.
3. Some students seem to be able to discriminate: a) foundation material from higher level material; b) qualitative ways of learning or describing phenomena and quantitative ways by which this can be done; and c) where they would locate qualitative forms of describing phenomena within their engineering educational experience.
4. Students used the comic strip resource in different ways, a) for reference; b) for revision; c) as the main source for understanding; d) as a complimentary source for understanding; and e) for reassurance about their own performance.
5. While the accuracy of the resource was seldom questioned, students had different opinions about the suitability of the resource for use within a formal engineering course: a) some found it helped them considerably; b) others just a little; c) some found it confusing, while d) others rejected it altogether, sometimes on the basis of seeming *too childish*. Opinions were also expressed on the length of the narrative where, some students found it concise and precise, while for others it lacked detail. Similarly, there were varying comments about the aesthetics of the resource, whereby some students found it appealing and organised, while others found it too cluttered.

The two engineering lecturers commented on the comic strip resource, as listed in Table 1.

Table 1: Engineering lecturers' comments on the comic strip.

Lecturer 1	I think it is a great way to stimulate students' minds. The aesthetics are appealing and the inclusion of the components on the waveforms is a very good way to visualise which device is causing which part of the curve.
Lecturer 2	I find that it matches my intuitive understanding of the circuit and the animated waveforms certainly help to assist the student with forming his/her own (correct) intuitive understanding. However, I feel that it still does not replace a good classroom explanation of the underlying processes... The animated comic strips serve well to remind students of the correct way of visualising (and building a mechanical analogy) of the processes. I find the notation of the comics refreshingly intuitive. Using diodes with hooks to indicate a unidirectional voltage clamp, and using springs to denote the effects of resistors on nodes. I also like the idea of moving components (and nodes) around in relation to the potential they are at. Of course, you need to point out the fact that these mechanical analogies have limitations and that there might be exceptions. At the same time, it is important that you convince the students at the outset that it is legitimate to think of circuits in terms of mechanical analogies by highlighting that the mechanical counterparts share the same differential equations and behaviours. You will find students who will resist assimilating such analogies by associating them with the <i>poor man's understanding</i> of electronics. This often works out against them, serving only to slow down the process of understanding in terms of a mental model.

CONCLUSIONS

As with any other learning medium, the novel genre of comic strip proposed in this article for electrical engineering and technology education carries with it disadvantages together with advantages. Even though engineering phenomena can usually be explained through analogies and are usually causal, some complex phenomena might simply not lend themselves easily to qualitative analogical modelling of the type presented in this article. The risks of having an overdone analogy may include the inclusion of further misconceptions than if the domain was taught with all its raw and unaltered complexities. Nevertheless, considering that research about diverse learning styles abounds, and it informs about how different individuals learn in diverse ways, the novel genre of comic strip proposed in this article may provide yet another method for the transfer of engineering and technological knowledge.

ACKNOWLEDGEMENTS

Acknowledgements to the Head, academic and non-academic members of staff of the Department of Electronic Systems Engineering, and Dr Liberato Camilleri at the University of Malta. This article develops a minor concept, which originally featured in the doctoral research presented by the author at Loughborough University, UK, under the guidance of Dr John McCardle.

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APPENDIX A: OUTCOMES OF STUDENTS' EVALUATION AND STUDENTS' VERBATIM RESPONSES

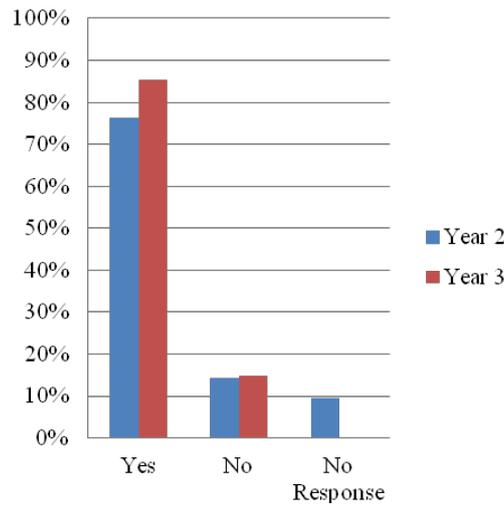


Figure A.1: Do you think that the comic strip frames 1 to 6 convey a clear message of how this circuit behaves?

1. The marked nodes A and B together with the word explanation conveyed a very clear message, especially, for the waveforms of the capacitors, which may be a bit difficult to visualise. It shows clearly how the waveforms correspond to each other.
2. The comic strips gave us the concept of how to expect the circuit works. The animation of components helps to understand the changes in the system.
3. The comic strip alone was not enough to understand, the description at the back was very important. The mechanical analogy is overdone, and one would need to think mechanically. I think it is better for younger minds.

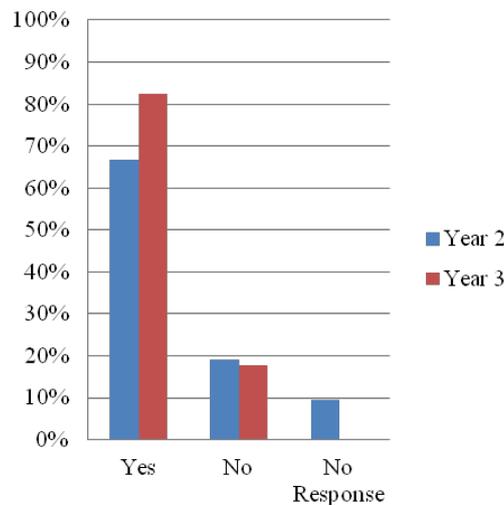


Figure A.2: Have you referred to the comic strip frames or the waveforms during your practical session?

1. Often. They were very helpful.
2. We started the session by looking at the comic strip to refresh concepts before starting. To get the background before the experiment was started.
3. Not a lot, just reference. Mostly at the waveforms.
4. I did not refer to the comic strip frames that much since I prefer to try and figure things out on my own first. I had already drawn some drawing for myself to understand the circuit.

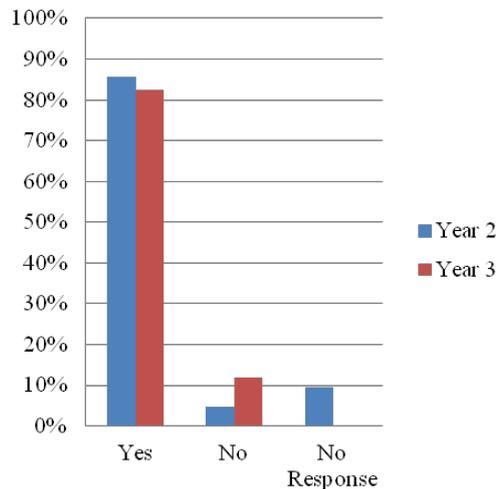


Figure A.3: Do you feel that the comic strip has helped you visualise better what to expect on the oscilloscope while doing your laboratory (at least half of the astable multivibrator)?

1. Yes, especially, when we had the frequency too high.
2. The superposition of components on the waveform helps understand the oscilloscope data better. They were cool. They provided an understanding that the diode became reverse biased.
3. I do not find visual explanations very helpful.
4. By getting the output on the oscilloscope like that in the strip makes you more confident when explaining the response. Since I could understand half of the circuit, then I could extrapolate for the whole circuit.

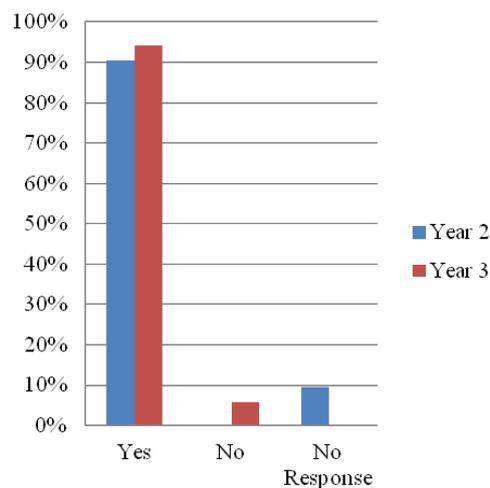


Figure A.4: Do you feel that such qualitative explanations of how circuits work would help engineering students study electronics more efficiently?

1. A lot more! Pictures are very helpful. Since electronics is sometimes abstract, it is better to have step-by-step clear explanations of components/circuit behaviour.
2. Yes, especially, students having learning styles based on images/visual. Yes, definitely, since these gave me a pictorial vision of exactly what was happening.
3. Definitely. If at the beginning of the first year we were given these visual tools, I have no doubt that we would have had better grasp and application of the subject. If these explanations were given to us in the first year of our study I believe that we would all be better engineering students today.
4. By using qualitative explanations one can understand better. Yes, engineering students will take more interest in the subject and understand what is happening, not just for examinations. Qualitative explanations combined with figures are better than mathematical explanations. If the concept is learned well, it would be easier to understand any other circuit of similar concept.
5. Some quantitative explanations along to the figure will give a complete picture as to how the circuit works. Those comments in Figures 1 through to 6 do the trick. Knowledge of mathematical perspective is required for being a *full* engineer.
6. It should start from first year, in third year students already think differently. It is good for the early stages of education starting from post-secondary or foundation courses pre-university. Not for engineering, more for A-level. We need to learn to think electrically not mechanically.

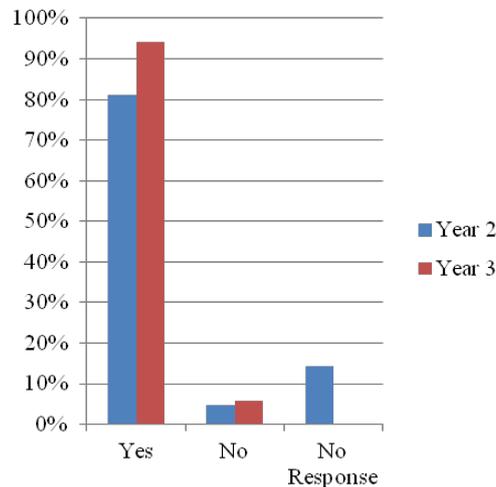


Figure A.5: Was the design of this resource different to what you are used to as notes or textbook? In what way?

1. In most textbooks, designs are of a more *serious* nature. I like the aspect that in engineering, it can be fun to learn how capacitors work with these methods. Unfortunately, most of the explanations given in class are textbook, which takes out most of the fun of learning.
2. Although by the look of them they look like the ones used in secondary school physics classes, they indeed were helpful. Every step is illustrated in a way that helps you visualise. Visualising electronics in this way makes it clearer in my mind.
3. The textbook does not provide us with the screenshots, but only the theory. Like this, we understand more how the system is operating.
4. Story mode. Story helps keep things interesting and exciting. It is less formal. It is more fun.
5. Textbooks usually give a mathematical explanation, which is not very helpful in understanding basic principles. Normally, we use a much more formal approach consisting mainly of formulae and datasheets.
6. Textbooks are designed on a more theoretical and analytical approach. This comic helps you understand through visualisations of the concept. Notes and textbooks do not provide the mechanical analogies the comic strip resource provides. Textbooks do not show circuits with graphs.
7. It concentrated on the basics and did not use many equations. The reasons for a result are given. It is a clever way of understanding how the system works.
8. It shows you the different values at different points by re-drawing the circuit. More organised than notes and somewhat easier to understand. Everything is explained clearly.
9. I could not understand the behaviour of the circuit beforehand but managed to do so with the visual's help.
10. I never found a comic that explained engineering principles. Never imagined mechanical models to represent electronic circuits. We never considered the forward bias or reverse bias of a diode in this manner. It detailed what was happening step-by-step. Very positive.

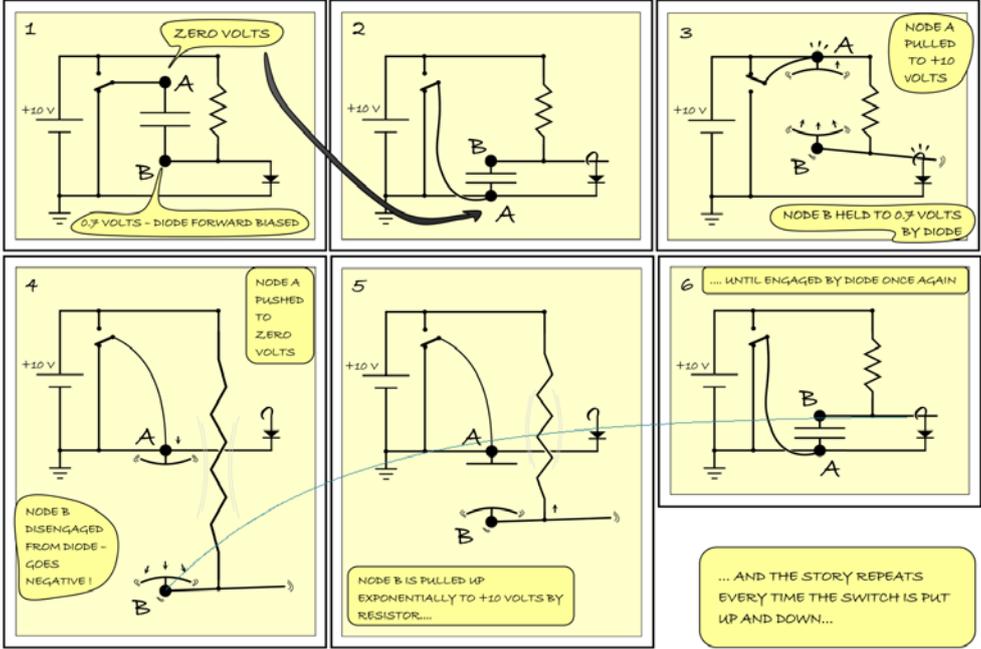
Table A.1: Students' general comments about comic strip resource and its suitability for engineering education.

Aesthetics = 8/10, Visual appeal = 8/10, Simplistic = 4/10, Short = 8/10, Confusing = 2/10, Not enough explanation given = 0/10.
Well Done! I like this style of teaching. I wish we had had it from first year because at third year some things are still not very clear. In my opinion, it is very good to explain in this way what is happening. I really like the idea of figures 4, 5, and 6 (green curve) which shows by the aid of the three figures how the plate of the capacitor (plate B) is attracted back by means of the resistor.
These models gave me an idea of what mechanical models could be used to explain abstract electrical models. Keep it up. It would have been great to have all subjects presented in this way.
I appreciate that such things are/might be very helpful to students taking early electronics courses. It is also refreshing to see different ways of circuit analysis. I personally think that electronics courses incorporating resources, such as comic strips are important, however, only if used in conjunction with the classic theory.
They are clear and visually appealing, are not difficult to understand while paying attention to details. Simplistic and may seem babyish, however, a good aid.
I prefer points rather than paragraphs because when I see a paragraph I grow impatient of reading it.
Starting from basic and moving to more complex - so helps a lot in understanding. The fact that we had results before lab helped a lot the understanding.
The movements shown in the capacitor help get a feel of how the components react together and how the sequence flows.
Cool aesthetics and format. The format is appealing; especially, the comic strips in colour, encourage better understanding. The capacitor plates being bent was slightly confusing. Comic strip format may have too many arrows, maybe the capacitor should be drawn as straight lines.

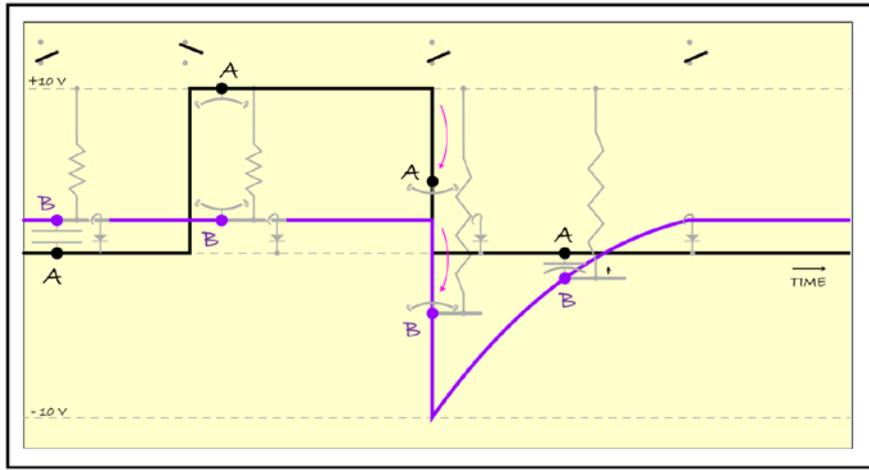
Probably not enough explanation given. Certain words cannot be replaced. It is too short to provide insight of circuit operation. It may be a good resource for younger (A-level) students.

APPENDIX B: COMIC STRIP RESOURCE

SINGLE SHOT STORY



WAVEFORMS FOR NODES A AND B



Description of Dynamics	
Frame 1	Frame 1 shows the salient nodes A and B indicated. The switch is initially connected to ground. Therefore, node A, which is directly connected with the switch is at zero volts. The diode is forward biased through the resistor and, therefore, Node B is at 0.7 Volts.
Frame 2	
Frame 3	The switch is now flipped on to connect to the +10 Volts power supply. Node A, also, the upper plate of the capacitor, is sharply pulled up to +10 Volts. Node B, the lower plate of the capacitor, momentarily feels the upward pull. It is nonetheless held at 0.7 Volts by the diode. A voltage is developed across the capacitor because its plates are held at different voltage potentials.
Frame 4	The switch is once again flipped over to connect to zero volts. Node A and the upper plate of the capacitor, are now pushed down to zero volts. The voltage across a capacitor cannot change very quickly, and so, Node B and the lower plate of the capacitor are forcefully pushed down as much as Node A. This causes Node B and the lower plate of the capacitor to take on a negative potential.
Frame 5	The only thing that can pull up node B is now the resistor. The resistor tries to pull up Node B exponentially to its upper anchor point, that is, +10 Volts.
Frame 6	Nevertheless, as soon as Node B engages the diode once again, the latter becomes forward biased and arrests the upward motion of Node B at 0.7 Volts. The circuit resumes its initial condition.