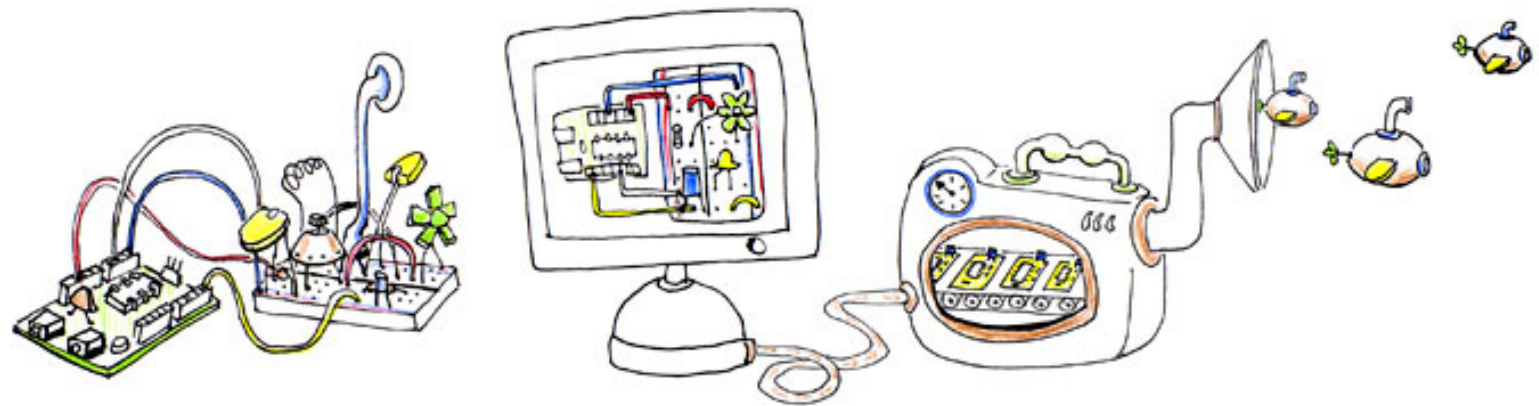


FRITZING

Open-source software for documenting prototypes,
learning interactive electronics and PCB production

www.fritzing.org



Supporting the tinkerer through all steps from breadboard prototype to a professional PCB production

Fritzing is developed by the Fritzing community and researchers of the Interaction Design Lab at the University of Applied Sciences, Potsdam with support from the Ministry of Science, Research and Culture in the state of Brandenburg, Germany

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1. Abstract:

What is Fritzing?

Fritzing...

- is a software that helps to document and share electronic prototype projects, teach electronics and manufacture professional Printed Circuit Boards (PCBs)
- represents electronic parts realistically and takes an intuitive approach to make complex technology usable by non-technologists (creating a low barrier to entry)
- supports so-called *makers* (designers, artists, students, Do-It-Yourself-practitioners) in taking the step from physical prototyping to an actual product
- is an ideal tool to use in a teaching environment to learn about electronics

There is a shift in the former expert-only dominated field of interactive electronics and physical computing: designers, artists, students and Do-It-Yourself-practitioners – so called makers – now have easy access to hardware and software and can fully participate.

Makers develop their own innovative ideas within this realm of “physical computing”. By manually wiring up circuits to a breadboard they build small prototype machines, which are able to react to their surroundings, or talk to other machines. Such circuits can range from simple (like making an LED blink) to highly complex (like interactive art installations).

Fritzing is a software tool which allows users to document these electronic prototype projects and share them with others. Due to its intuitive approach, it can help teach electronics to people without an engineering background.

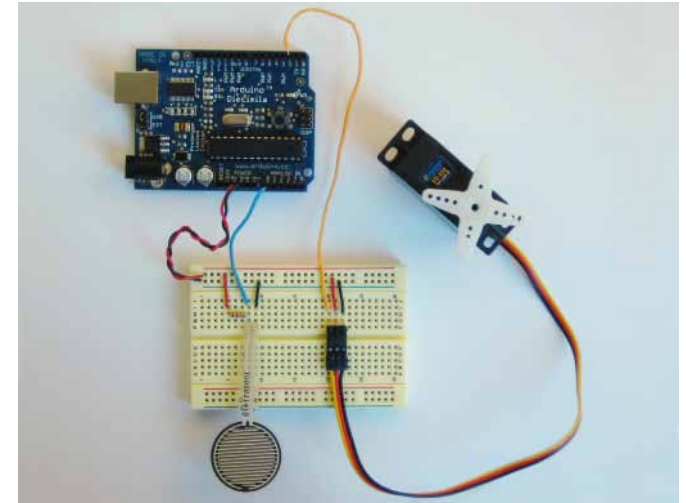
Until the development of Fritzing it was difficult to document or share these projects. Prototypes could only be photographed with their overlapping wires, which made them very difficult to “read”. Alternatively, users could look at schematic symbol diagrams, but these are very abstract and require some background in electronics to understand. Fritzing created a new standard for documenting: mimicking the realistic aspects of the electronic components used for tinkering (such as breadboard, sensors or cables) it enables an easy transfer between a hardware “sketch” and software representation.

This intuitive and visual approach has proven to be appealing to people who have had difficulty in starting with electronics in the past. In fact, Fritzing counts a large number of young people and females among its users.

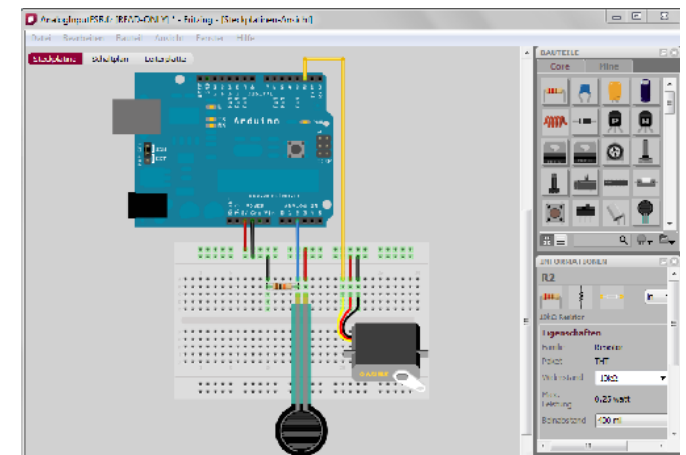
Another important aspect of Fritzing is that it helps users to create a Printed Circuit Board (PCB) based on their prototype. Hand-wired prototypes are easy to break and hard to make copies of. Since Fritzing can generate layouts for DIY production as well as the standard file format required by PCB manufacturers, users can see their projects “printed” to a stable form in as many copies as they like. This groundbreaking step opens up the possibilities for individual makers tremendously:

it grants access to a formerly closed, professional market.

Since its development in 2007 Fritzing has become the Open-source software platform to support its users in taking the step from physical prototyping to an actual product.



1.0.1 A breadboard-based prototype consisting of an Arduino microcontroller, a sensor and a servo motor



1.0.2 Fritzing's representation of the prototype in the “breadboard view” of the software

1.1 Democratization of Technology

“Since scientific discoveries and engineering innovation bring broad benefits, improved tools that advance individual, group and social creativity are important contributions.”

Prof. Ben Shneiderman: “Creativity Support Tools: Accelerating Discovery and Innovation”, 2007

Historically one finds that there is an increase in the diversity of creative exploration within a given field, once its technology becomes accessible to non-experts. We have seen this pattern arise, for example, in the fields of photography, desktop publishing and the internet. Once these technologies had become usable by everyone, they truly revolutionized our world.

Now, a large number of so-called makers - ‘Do-It-Yourselfers’ - are exploring the bridge between computation, electronics, and the physical and tangible world. These makers are on the forefront of opening up this new area of technology, and the results are being widely disseminated through the power of internet communities.

Building electronic prototypes lies at the heart of all their technical explorations, but what was still missing until the development of Fritzing was a way to document this complex process: to be able to talk about a project, share the knowledge and use the power of the already existing maker community. Fritzing’s abstract, yet still clearly physi-

cally-based representation of a prototype, enables this sort of conversation. But beyond this, Fritzing makes it easy to move from the fragile hand-wired prototyping stage to a stable, professionally produced Printed Circuit Board (PCB). In other words, Fritzing smoothens the path for anyone to create their own electronics-based product.

2. What is Fritzing for?

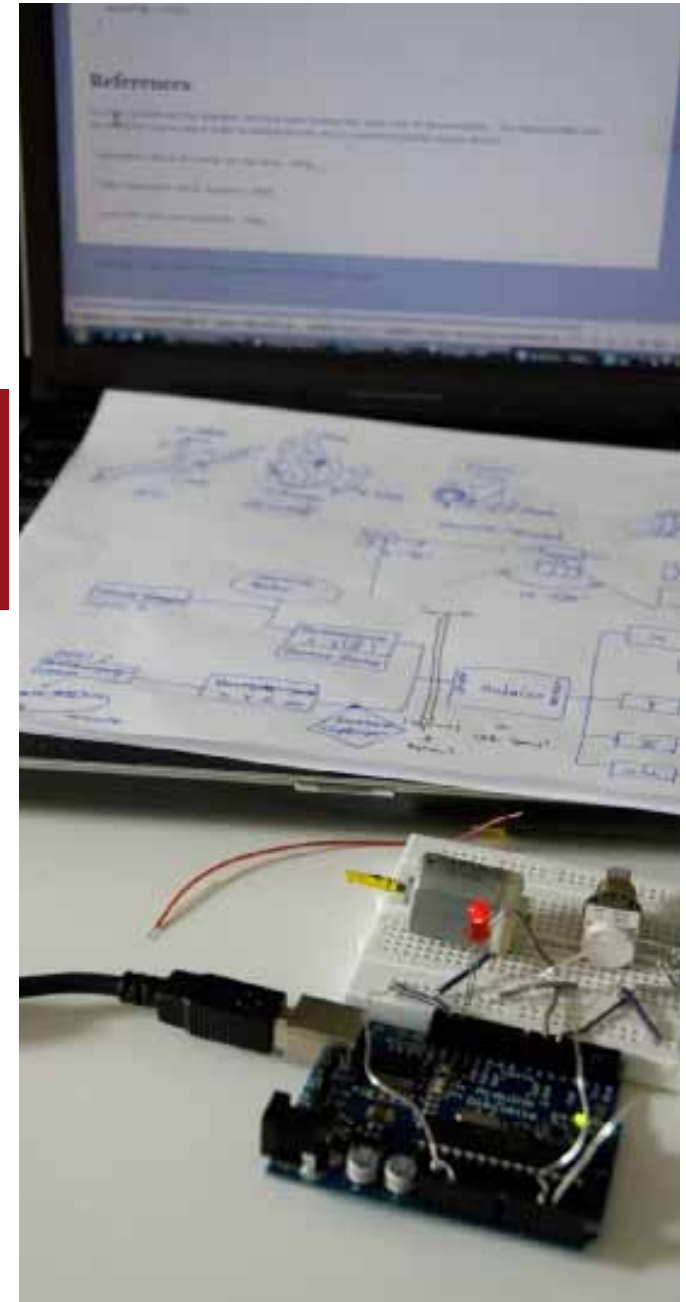
Fritzing is for...

- documenting projects
- sharing ideas and designs
- teaching and learning
- PCB manufacturing

2.1 Documenting

An important factor for a thriving learning community is an easy way to document existing projects and share them. Formerly in this Do-It-Yourself community, electronic circuits were documented by simply photographing them. However, these images were hard to read due to parts occluding other parts, and the difficulty of following wires that cross and entangle.

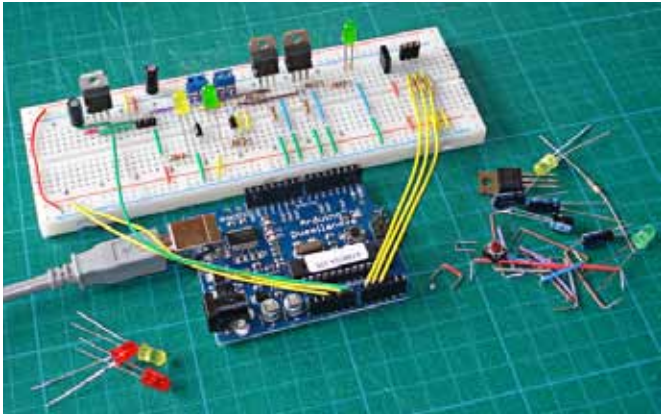
Fritzing provides a powerful means to document projects. The user simply recreates the circuit in software, and saves to a project file. The abstract yet reality-based representation is intuitive to read, can be discussed with colleagues and teachers, or published on a website for re-use and inspection by other users.



2.1.0 Basic experimenting with a fragile breadboard and a microcontroller- documenting and sharing knowledge was a difficult and unprecise task before Fritzing

2.1.1 From breadboard experiments to a professional file format

Whereas electrical engineers usually work with CAD software and from there transfer directly to PCBs (printed circuit boards), designers, artists and Do-It-Yourself-practitioners take a more hands-on approach. In conjunction with microcontrollers such as Arduino and other electronic prototyping



2.1.1 A typical electronic prototype including a breadboard, Arduino microcontroller (connecting to the PC), wires and parts

kits, they often use a breadboard and wire up their circuits manually.

This proves to be compatible with a self-taught trial-and-error approach, where the design is explored iteratively: modification followed by testing, followed by further modification... The breadboard is therefore an essential aspect of the design process.

However, the reliability and endurance of breadboard-based prototypes is a big problem: they are too fragile to be presented outside of labs or studios, they can only be replicated by hand, and there are limitations in miniaturization. Once a prototype is documented in Fritzing, the original breadboard becomes obsolete, as it can now be recreated from the documentation at any time. Combining this documentation with the source code that runs on the microcontroller, the complete blueprint for a

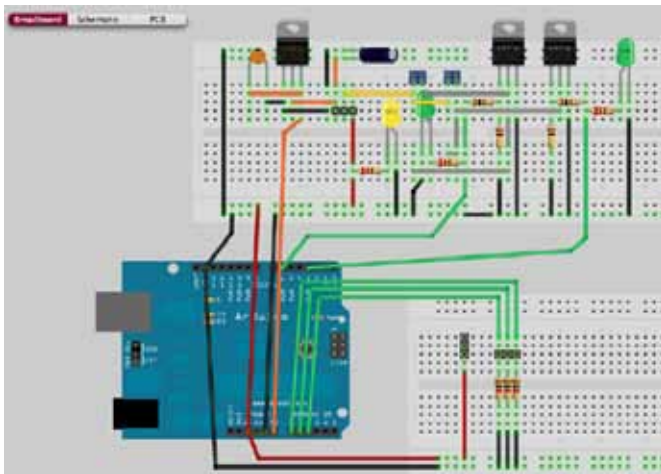
design becomes sharable.

“Fritzing is designed to help non-engineers take breadboard Arduino prototypes and quickly create schematics and PCB files. It’s just in an alpha version now, but the potential of this software is tremendous.”

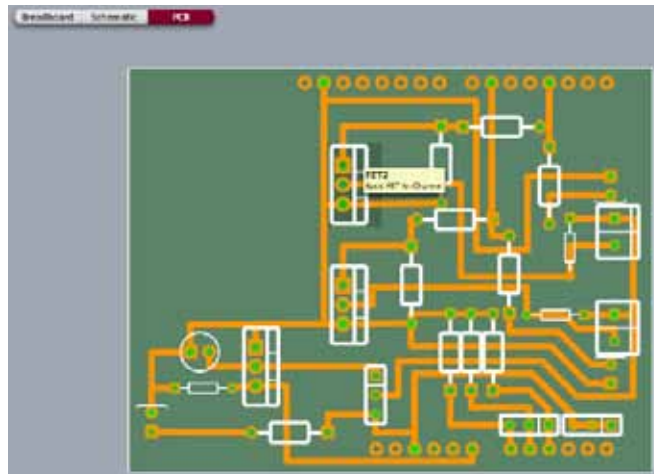
Chris Anderson, 2008, WIRED Editor in chief

Documenting in Fritzing has become a professional standard in:

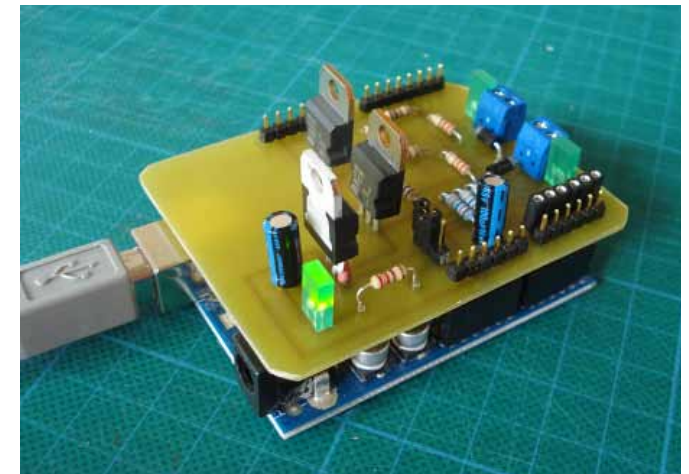
- academic use (teaching, self-learning, and archiving for future reference)
- industrial production (collaborating with experts)
- exchanging knowledge with peers (Arduino, the most popular microcontroller, has recently documented every example in their learning section with a Fritzing drawing and its schematic view.)



2.1.3 The prototype and its parts displayed in Fritzing’s breadboard view



2.1.4 This is the same project in the PCB view - ready to be produced by one’s lab or sent to a manufacturer



2.1.5 The resulting PCB functions as a solid “shield” for the Arduino. Additional parts can be added safely to this smaller and compact format, without the risk of wires detaching.



2.2 Sharing ideas and design

“The sharing of electronics-based interaction designs is one of the key benefits of Fritzing. This has not been easily possible before and Fritzing makes this efficient and complete for the first time.”

Reto Wettach, Professor at University of Applied Sciences, Potsdam, Germany

Easy ability to share is mainly made possible through a carefully designed file format.

Sharing a Fritzing file enables you to...

- talk to peers and learn from one another
- ask for help if you have technical problems
- collaborate much more easily with engineers
- feed your example straight back to Fritzing and therefore improve Fritzing

Besides openly sharing designs documented in Fritzing, the web site provides a platform for members to exchange their general knowledge in using electronics. Some of this knowledge is then fed back into the tool itself. This interactive transfer strongly involves the users. They care about the quality and future development of Fritzing, because de facto they are an active part of this project and their opinion may feed straight back into the improvement of Fritzing.

2.1.6 With this board, designed in Fritzing, you are able to control a portable heart pressure meter--an inexpensive, off-the-shelf part--using it as a pump. This was a student's first project.

2.2.3 The community

Fritzing relies on its community and cannot blossom without it. Essential to the development of Fritzing is the community's feedback: bug reports, lively discussions in the forum, publishing and sharing new parts or helping with translations of Fritzing into various languages. Also, the community helps to spread the word about Fritzing and supports Fritzing financially with donations.

2.2.4 The Fritzing.org Website

A tight integration with the website further enhances sharing, since it is possible to upload a design with only one click from within the tool, and to instantly become part of an online gallery of fully documented projects. The newly submitted shared files enable other users to interactively inspect circuits by moving elements around and switching between views.

A community website is an essential element in fostering creativity across the field.

“As a geek I always wanted to hack hardware like this, but at the same time I was intimidated by my little knowledge of electronics. So it's truly amazing how much can be done with such simple tools, and how much I learned in past half a year since my good friend introduced me to Arduino. For me it's just the essence of the Arduino phenomena - a perfect combination of open-source hardware, software and the community.”

Szymon Kobalczyk about Fritzing, geekswithblogs.net

Fritzing's Website contains....

- projects, examples and tutorials
- pragmatic information about electronic parts
- links to relevant resources



2.2.1 The Fritzing community discusses relevant topics in their website's forum - or at workshops and research sessions

2.3 Teaching

Fritzing can be used...

- to enhance teaching practical electronics in the classroom
- for presentations, homework assignments and project troubleshooting
- as an easy self-paced learning tool for electronics through its tutorials and examples provided online.

2.3.1 Why learning electronics is important

Since digital technologies have become a large part of every day life, it is of great value for everyone to understand the basic structure of electronics. However, most people find it difficult to overcome their inhibitions and fears in approaching technol-

ogy - everything seems too complex, obscure and unintuitive. Fritzing is an ideal tool for granting access to this field, since it breaks down complex technology to an essential, straightforward representation.

"This is going to be THE KILLER TEACHING TOOL for hardware-focused media tools; I'm going to dive into this whole-heartedly, because it radiated 'The Future'."

Darwin Grosse, Director of Engineering, Cycling74 [Max/MSP]

2.3.2 The Power of Making

The basis of tools such as Fritzing, is the power of "making". Empowering people to "make something" in the physical world is a very liberating and effective action, since they learn intuitively, quickly and deeply through a tangible, visual and hands-on approach. Wiring up parts, making an LED blink and directly experiencing how a piece of code affects real electronic parts has proven to be more stimulating - and encouraging - than a dry theoretical lecture with no tangible example in the real world. Besides that - *making* in itself is a lot of fun and invites one to keep trying, experimenting and studying! Fritzing is the tool to guide and support these physical experiments, to talk to others about them, find mistakes, and share the information.

2.3.3 Teaching at schools

Schools are an ideal space and time to start learning about electronics. Understanding electronics



2.3.1 Touching parts, wiring up circuits - losing one's inhibitions about technology by touching and experimenting



2.3.2 Teaching basic electronics to a group of students using Fritzing for documentation and troubleshooting

at such an early stage empowers students and gives them confidence, showing them the endless possibilities of what they can actively achieve with technology.

Today, there is still a lot of scepticism when it comes to technology, but this is often caused by a lack of knowledge. Once people understand the rules behind it and see how things function, it is

much easier to see the opportunities and possibilities. Teaching electronics enables understanding, overcomes the initial fear and opens up to creative invention.



2.3.3 Due to Fritzing's realistic mimicry of real electronic parts, Fritzing lends itself to teaching: project a student's design file, zoom in, and explain electronics starting with a visual breadboard representation of circuits

2.3.4 Women in the forefront

Science, physics, electronics - it seems at first that these subjects are not for everyone. Women in particular are not seen as "engineers" as the low percentage of women in the industry indicates. However, especially in "creative" and "artistic" contexts, Fritzing has shown that expertise in electronics is not gender-specific: a lack of tangibility when dealing with electronics is a big factor. Due to Fritzing's highly visual and physically-

based approach when duplicating the prototype in software, the user experience is very intuitive. By being able to touch circuits in the tangible world and using Fritzing to support these experiments in documenting and learning, Fritzing allows physical, hands-on interaction combined with the security of a digital backup. This tangible, visual and creative way of working seems to drastically lower the entry-barrier - especially for the more intuitive approach of our female users. This is probably what explains the high participation of women at our workshops.

A tangible, physical approach in teaching is ideal, since we can involve all of our senses to learn and remember.



2.3.5 The Fritzing Starter Kit: our experience in teaching the basics of electronics have led to developing a comprehensive, compact all-you-need-to-get-going kit

2.3.5 The Fritzing Starter Kit

Prof. Reto Wettach, initiator of Fritzing, has been teaching "Physical Interaction Design" at the University of Applied Sciences, Potsdam since 2002. The basic groundwork for his lectures is to enable his students to deeply understand, apply and "think electronics" within a very short period of time. Using the Fritzing software for his lectures, he and his team created an accompanying "Starter Kit" containing the essential components of what is necessary to teach the basics of electronics for making students master this discipline. The "Fritzing Starter Kit" has proven to be highly practical in both teaching and learning. It has been purchased by individuals or in bulk for classes at various schools throughout Europe.



2.3.6 User taking his first steps in electronic prototyping using the Fritzing Starter Kit components

2.3.6 How Fritzing overcomes classical teaching difficulties

Teaching “practical” electronics to a group of non-engineering students is not an easy task. One difficulty is how to visually represent circuits. Second, in consulting with students it proved to be difficult to “read” their breadboard-based prototypes, as they were not built with clarity of presentation in mind. Finally, it is a cumbersome task to find bugs on a breadboard, as there are many reasons for errors. If any of these multiple sources of errors can be eliminated, debugging becomes easier.

In the classroom, Fritzing helps to teach electronics to a larger group of students by displaying it on a big screen, where the high-resolution graphics allow you to point out detailed aspects. Switching from the breadboard view in Fritzing to schematics was specifically introduced with teachers in mind. This way, students can gradually be exposed to the standard electronics notation system and access resources that are based on it.

Consultation with students is also enhanced by the ability to exchange Fritzing files. A student who is in need of help simply sends the current state of his design to the teacher who can review it and return it along with suggestions for improvement.

Further, we are planning to open up a new category on our website for sharing teaching materials, experiences of students from our workshops, teachers’ opinions on working with Fritzing and a greater collection of tutorials and relevant links.

2.4 Manufacturing

“Before Fritzing it was a nightmare to prepare for an exhibition and the wires never lasted”

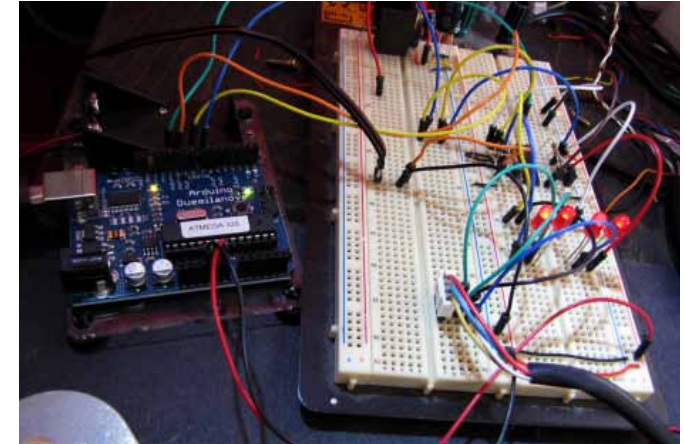
Kinga Kielczynska, Artist

The original motivation for Fritzing was to move designers, artists or Do-It-Yourself-practitioners closer to a position of a producer, i.e., to enable them to create higher-fidelity artefacts. Therefore it is necessary to move beyond the breadboard, since those original prototypes are simply too fragile to transport and very difficult to reproduce.

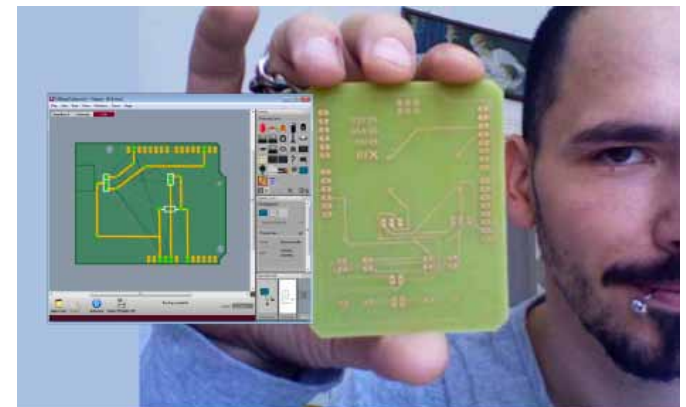
Therefore the software makes available a second representation of the design, as a Printed Circuit Board (PCB), and enables the user to quickly and easily switch between representations. It is the PCB representation that is used to manufacture a more robust version of the original prototype.

Fritzing enables manufacturing because:

- it guides designers of electronic artefacts through the necessary stages
- it semi-automatically generates the data necessary to produce PCBs - by hand or by a board house
- it soon offers its own fabrication service, that lets designers produce small numbers of PCBs inexpensively



2.4.1 The downside of a breadboard based prototype: too big, too fragile, difficult to spot mistakes, hard to transport, extremely difficult to reproduce



2.4.2 A compact, robust and industrially reproducible PCB (right), manufactured from a Fritzing file (left)

2.4.1 How to produce with Fritzing

Instead of starting with schematics, as most tools for engineers would do, we decided to allow the user to document the breadboard-based prototype with a visual metaphor that mimics the user’s real world situation - our so called ‘breadboard-view’. Once this is accomplished, the software allows the user to switch between

a schematics view or a PCB view, where the initial breadboard circuit gets previewed as a PCB and exported for professional PCB production service or self-manufacturing.

Fritzing lies at the border between interactive design and electrical engineering (Electronic Design Automation). As such, the microcontroller Arduino provided an ideal opportunity to build on. Arduino is a mature platform that is respected and well-established among physical interaction designers. Also, it is easy to learn and by its design lends itself well to an integration with Fritzing. Though Arduino is the most widely used starting point for beginners using Fritzing, other microcontrollers are equally well supported.



2.4.3 Fritzing files are intuitive to read, easy to share and provide a standardized format for communication with professionals

3. Who uses Fritzing how

Fritzing is currently used in a wide array of fields. We would like to introduce some of our ‘ambassadors’ from the most important sectors.

3.1 Teachers

3.1.1 Academic

Leah Buechley directs the MIT Media Lab's High-Low Tech research group, which investigates the integration of high and low technology from cultural, material, and practical perspectives, with the goal of engaging diverse groups of people in developing their own technologies. Leah Buechley uses Fritzing for her academic research and in teaching.



3.1.1 Assistant Professor Leah Buechley uses Fritzing for teaching at MIT

3.1.2 School

The Fritzing software and the Fritzing Starter Kits are used for various technology focussed classes at the Rosenstein High School in Heubach, Germany. Their Junior-Engineer-Academy is a project sponsored by metal company Südwestmetall to raise interest in the engineering profession. Here students experiment with LED displays and building various counters. Advanced students can join a seminar in natural science and technology with themes such as “Medical Science and Microcontrollers”. After some basics about medical science, programming and microcontrollers, the students are asked to develop their own medical device or copy an existing device in which a microcontroller is predominantly used.



3.1.2 9th grade students use the Fritzing Starter Kit and Fritzing software for technology classes. Teacher: Dirk Wegner



3.1.3 Stefan Hermann teaching the basics of electronics with Fritzing in Liepaja, Latvia

3.1.3 Workshop

There is a long list of workshops, which use Fritzing for teaching since it naturally lends itself to learning, documenting and final product production. It is used to teach the basics of electronics - often combined with Arduino beginner courses. The picture above shows a five day workshop in Liepaja, Latvia for 'New Media Art' University students.

3.2 Manufacturers

3.2.1 Board Manufacturer

The GoGo board is a Stanford University project. It is a programmable device designed for building sensor-based and controlling projects such as robots, data loggers, or devices for human-computer interaction. Their main goal is to offer low-cost boards for purchase and allow people to build a GoGo board out of parts which are cheap and



3.2.1 Sleeping tracker project using a GoGo board. Five switches hidden underneath the pillow detect when your head moves.

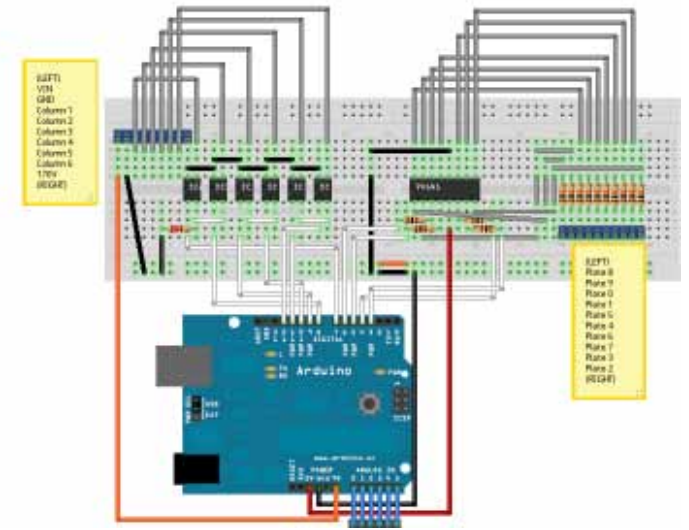
available in every country. With the GoGo board available in Fritzing, users can easily create new modules and shields. GoGo board also donated to Fritzing to support development in order to secure free access to everyone for our essential open-source software.

3.2.2 Producer

Arduino, the most popular microcontroller, makes wide use of Fritzing to document and explain their own technology. They include a Fritzing sketch in breadboard- and schematics view for all examples in their online tutorials.

3.2.3 Retailer

Spark Fun is an online retail store that sells a wide variety of electronics parts and components. They have converted a large selection of parts into representations suitable for use in Fritzing.

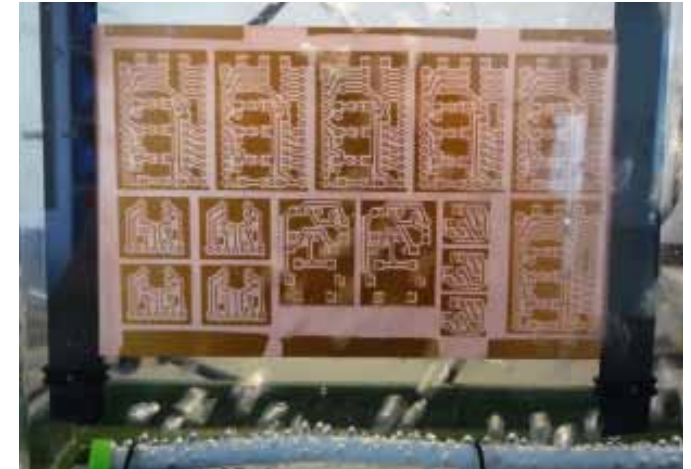
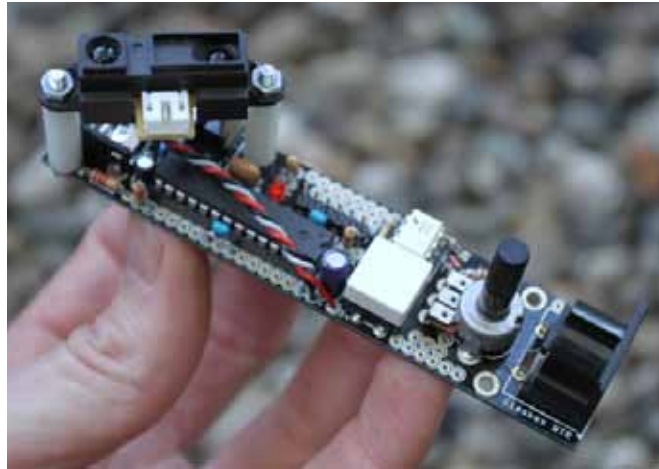


3.3.1 Hobby practitioner *arms22* using Fritzing, a microcontroller and extra bits to find a contemporary way of using old Nixie Tubes. Top to bottom: 1. Fritzing breadboard view, 2. microcontroller, Fritzing generated custom PCB and Nixie Tubes in self made box 3. Nixie Tubes displaying numbers

3.3 Makers

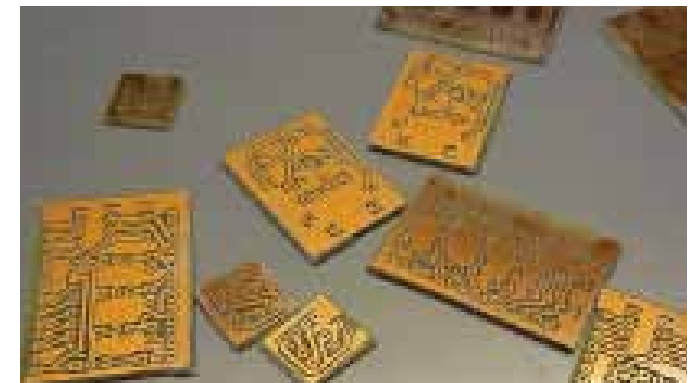
3.3.1 Hobby Electronics

Hobby practitioners using Fritzing range from engineers tinkering (along with their kids), to beginners in electronics and experimental geniuses finding new ways to combine technologies. The example on the previous page shows an advanced Nixi Tube controller made by Japanese hobbyist arms22. His blog displays projects and offers products for purchase, exploring the border between hobby tinkering and physical computing.



3.3.2 Artists / Designers

Fritzing was originally designed to lower the entry barrier for using electronics - particularly with artists and designers in mind. Since people from these backgrounds often thrive on a visual and tangible understanding of things, Fritzing presents itself as intuitive and hands-on as possible. We are happy to see that a wide range of people from all disciplines use Fritzing for documenting, sharing and production. Experimental electronic musician and sound designer Gijs Gieskes builds and sells small sound making machines and uses Fritzing files for his PCB production.



3.3.3 Researchers

The Interaction Research Studio of London's Goldsmiths College is currently exploring a home sensor network. All prototypes and boards used are made with Fritzing. André Knörig is a member of the research team creating the boards.

3.3.2 Gijs Gieskes' Wave Table Radar is an experimental contemporary re-creation of a theremin. Picture on top without, above with case. For purchase.

3.3.3 Fritzing used in production: All above images show the process of making custom PCBs for Goldsmiths University's home sensor network research project.



3.4.1 Fritzing in the press: four new books use Fritzing to document and teach

3.4 Publishers

3.4.1 Books

Four new books make extensive use of circuit layouts created with Fritzing: “Arduino: Praxiseinstieg”, by Thomas Brühlmann (mltp, German), “Beginning Arduino”, by Michael McRoberts (Apress), “Building Wireless Sensor Networks”, by Rob Faludi (O’Reilly), “Praxisbuch Arduino”, by Ulli Sommer (Franzis, German).

They are using breadboard diagrams, schematics, and part graphics to illustrate examples and guide the learner throughout the book. Some even offer the related Fritzing .fz files for download from their website. We are very proud to see Fritzing becoming a de-facto standard for documentation and teaching!

3.4.2 Magazines

Fritzing has always been at home in many worlds. It’s a tool that is equally used by designers and art-

Make:
technology on your time

Blog

MAKE Magazine

Videos/Podcasts

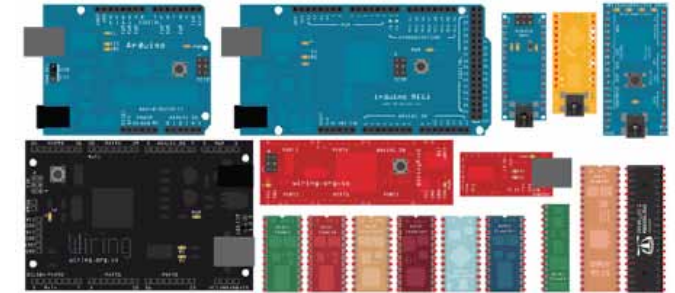
Projects

◀ Soft circuits workshops in SF

↶ Main

Junkbots per excellence ▶

Fritzing Adds Support For Propeller, Wiring, Basic Stamp, And More



Fritzing, the open source toolkit that “allows users to document their prototypes, share them with others, teach electronics in a classroom, and to create a pcb layout for professional manufacturing”, has added support for more

3.4.3 One of many posts about Fritzing on MakeZine’s blog

ists who are looking for a simple way to bring their concepts to life, as well as by Do-It-Yourself-practitioners and makers of all kinds who love to play with electronics. Two recent publications exemplify this diversity: The exclusive British design-trends magazine “Viewpoint” (issue 27) writes about Fritzing as an example of the implications that DIY has for business, and the French hobbyist magazine “Eletro-nique Pratique” (issue 356) has an 8-page feature introducing Fritzing in-depth.

3.4.3 Blogs

MakeZine is one of the first and most influential platforms for making - an essential guide about how to make almost anything. Their huge community and readership makes MakeZine’s position even more valuable. They are big fans of Fritzing and often post news about our software and services.

4. Fritzing: Development Model and Feature Set

“It [should be] easy for novices to get started (low floor) and possible for experts to work on increasingly sophisticated projects (high ceiling).”

Mitch Resnick, Professor at MIT Media Lab:
“Some Reflections on Designing Construction Kits for Kids”, 2005

4.1 Arduino, Processing and Fritzing

Arduino followed the model of the programming environment Processing, and Fritzing chose the same path, benefiting from the already existing community. Processing, Arduino and Fritzing run on all three major operating systems, heavily relying on the open-source idea. They all share an orientation towards designers and artists as users.

4.2 Why Open-source

Fritzing follows the ethics and principles of the open-source idea for many reasons. Offering complete transparency and involving the users in the process of making software (e.g. by valuing their opinion about software improvements) naturally creates what people need and builds stronger software. Using standard and open file formats means that users aren't “locked-in” to a particular set of tools. Combining this with being “no-cost”, Fritzing gives wide access to software which is designed to empower people and move them to the position of

independent producers.

4.3. Three views of Fritzing

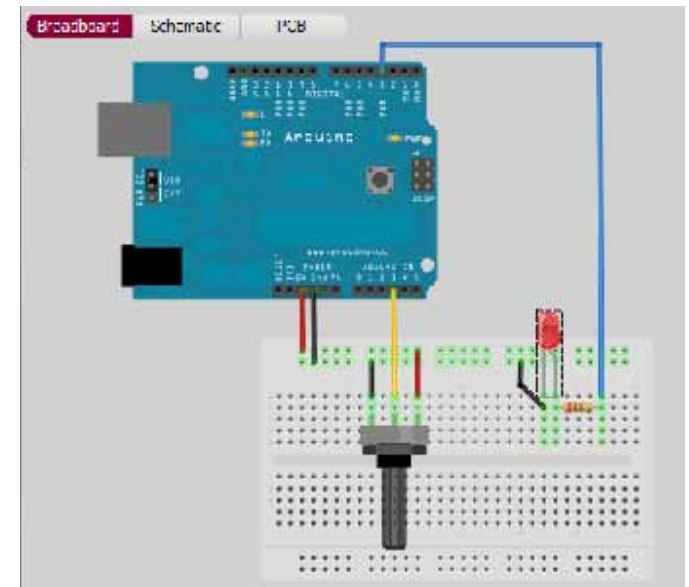
The main challenge of the tool is to make complex technology usable by non-technologists. Fritzing was therefore designed to integrate seamlessly with a user's current practice, and carry the user through the next steps of the process. It is a top priority that the tool can be used by anybody who knows how to make an LED blink with Arduino.

“I really think you're on to something here with a growing community getting into electronics from a new angle, i.e. from the art and design world. For me Fritzing works mainly as sketchbook and documentation. I really like the PCB side of it as well, but the immediate usage for me is testing and documenting my projects. Up until now I've been relying heavily on photo documentation of my projects, since I have no formal training and thinking in “Schematics” does not really work for me...”

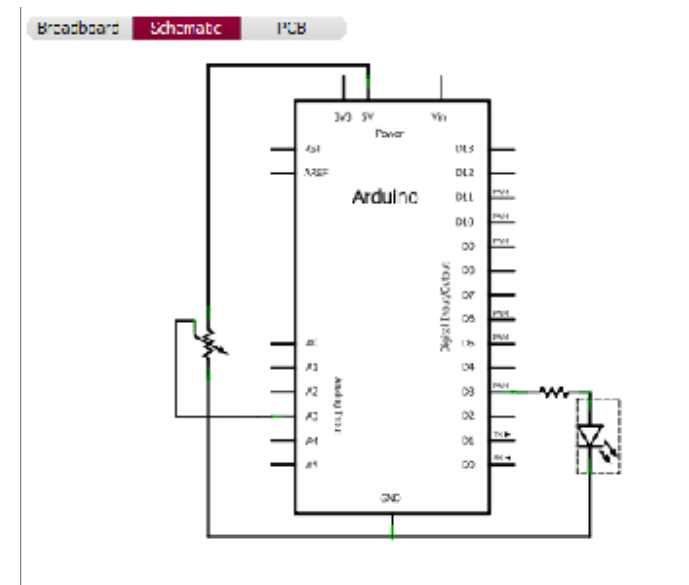
Fritzing forum post by Peter Boman

Fritzing offers three alternative views on the circuit: breadboard, schematics, and PCB view. Each view can contain additional information such as notes or part ordering numbers.

In the process of creating a sketch, a user assembles multiple parts by dragging them from a parts bin, and connecting them with graphical wires. This can be accomplished in any of the three views.



4.3.1 Fritzing's breadboard view: mimicking the actual physical parts. Low entry barrier. Intuitive usage.



4.3.2 Fritzing's schematics view: classical representation, engineering standard, helps in teaching electronics and communication to professionals

All the graphical components in the views--such as parts and wires--are based on the Scalable Vector Graphics (SVG) standard. From a technical standpoint, basing our system primarily around SVGs gave us very fast infinite zoom capabilities and enabled us to easily manipulate the graphics programmatically.

4.3.1 Breadboard view

This is a graphical editor that resembles the real world situation in look and feel. Parts that look like their real counterparts can be dragged from a simple parts palette onto a large sketch area. They can be rearranged and wires can be drawn among them, until the virtual sketch is identical with the physical one. This “breadboard view” does not exist in professional Electronic Design Automation packages, but it is very useful for the electronics amateur, providing a simple, safe, and playful environment.

4.3.2 Schematic view

Fritzing’s schematic view, a classical schematic diagram view, is valuable for teaching and also for dealing with more complicated circuits. It also serves as an entry point for users coming from a more traditional electronics background. In most cases, it offers the possibility for users to gradually get familiar with the professional notation system for circuits and paves the way to discuss one’s work with professional engineers.

4.3.3 PCB view

Our PCB view is a layered printed circuit board design model similar to that seen in CAD applications.

The PCB view allows the designer to turn the sketch into a professional circuit board. This does not require much work, as Fritzing takes care of most of the tasks. In this view, the user can make adjustments to the positioning of the parts and control the routing process.

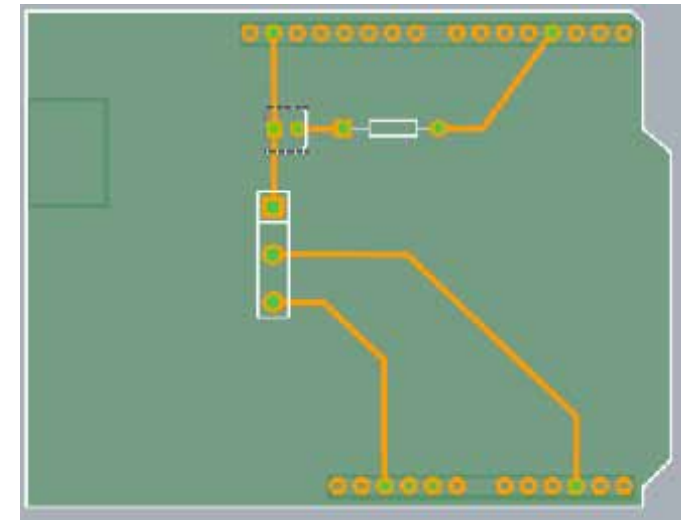
Although a typical user might start with our breadboard view and gradually migrate to the PCB view, we have found that different users have a different approach to circuit building and how they use the three views. Fritzing’s job is partly to educate users about these alternative options. Synchronization refers to the problem that all views need to maintain the same state - a semantic change in any one view must be directly reflected in the others. This ensures a simple mental model and is another feature oriented to the non-engineer’s unplanned style of working.

4.4 Parts editor

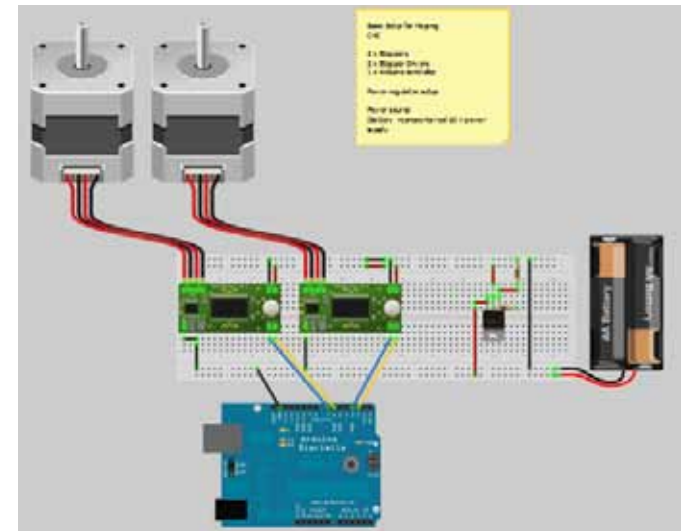
The part is the main user-manipulable unit in Fritzing, and it is SVG-based. The Parts editor provides users a means to create their own custom parts. Because part graphics are SVG-based, users can use familiar editing tools to create the images used in parts.

4.4.1 Personalizing Fritzing

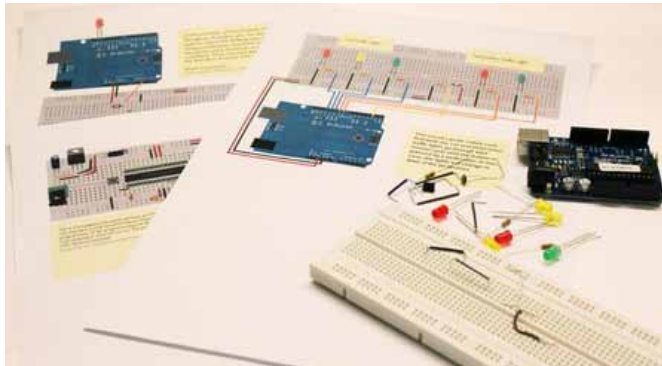
While we provide a set of common and useful core parts it is impossible and impractical to maintain a library that holds every part that any user could possibly want to use. Therefore, we encourage users to create their own parts providing a “Parts Editor” for that purpose. The parts editor allows



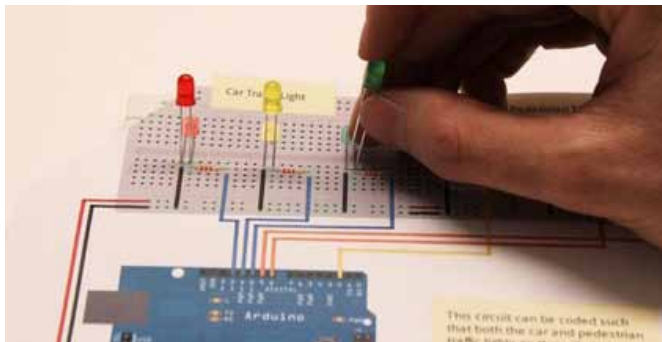
4.3.3 Fritzing’s PCB view: representing the circuits as a PCB layout as seen in CAD applications, allows professional PCB manufacturing



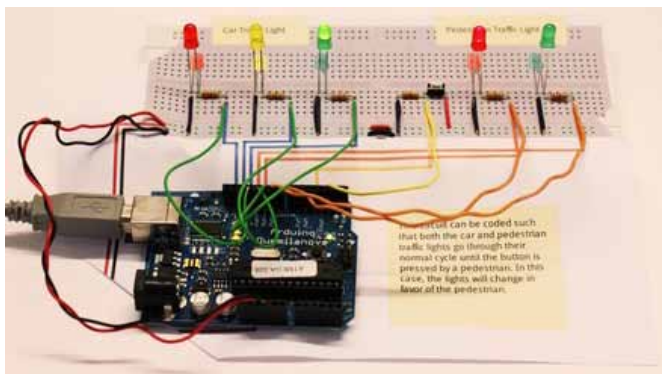
4.4.2 Notice the real size representation of parts in Fritzing’s Breadboard view. The most common and useful parts are ready-to-use in Fritzing’s parts editor. Additional parts can easily be downloaded from the Fritzing website or created new. Not only individuals, but e.g. companies distributing hardware create new parts for Fritzing.



5.1.1 Due to being very strict about matching the scale of Fritzing to reality, you can actually reverse the process and print out your Fritzing designs as paper templates for breadboard prototypes



5.1.2 Align the printed breadboard with the physical one, stick the parts and wires through the paper in the printed represented holes accordingly.



5.1.3 Connect to a microcontroller (e.g. Arduino), load the associated code - done! What a great learning tool!

them to integrate these images into a part definition, define connectors for each view, and add meta data for the part and each individual connector. Even unusual parts, such as those found in hacking a toy can be added using the parts editor. By creating a library of custom parts, a user can give his creations a more “personal” feeling. Further, newly created parts can be shared in an online library.

4.4.2 Making parts simple

Classic software in this field forces users to choose from an endless list of technical acronyms, which creates a big barrier to learning. Instead, Fritzing offers a visual parts bin containing a set of ‘archetypical’ parts. One part in a given family can represent any of the others, so that the user simply picks ‘the’ resistor part, which can later be made more specific by changing its properties. While this looks like a simple interaction to the user, underneath this is a database-backed operation. This is unique to Fritzing. We intend to grow this mechanism to seamlessly search a web-based parts library in the future. Also, we are working on an RSS feed for new parts displayed inside of Fritzing.

5. Fritzing Quality

Appreciating quality is what makes our users choose Fritzing in the first place. Secondly, the wish for a constantly improving quality is why they get involved in the development of Fritzing. Here are couple of things which are unique to Fritzing:

5.1 Real size

Another big advantage of SVG for Fritzing is the ability to be able locate elements precisely, using measurements that translate accurately to real world units. Not only can you transfer your physical breadboard sketch easily into Fritzing, you can also do it the other way around, since we were very strict about matching the scale to reality. By loading a Fritzing sketch and printing it on a sheet of paper, users have a millimeter-perfect paper template which they can now fill in with the real parts. This again makes teaching and learning a lot easier.

5.2 Flexibility

Fritzing leaves flexibility to the user by making use of open standards like XML and SVG for the data it creates. Furthermore, it provides open interfaces for both import and export. Typical graphics formats can be imported and exported to ensure compatibility with the user’s toolset, and on a technical level Fritzing supports import of other tools’ part definition formats and is extending it to schematics and PCB descriptions.

5.3 Trustworthiness

Trustworthiness is given in part because Fritzing is publicly funded and open-source. Within the tool, it supports standard mechanisms like an infinite undo stack, quick saving, crash recovery, and a project folder that can be archived. A further aspect of trust is the community, which is actively



5.4 Workshops, ongoing research, teaching, development

participating in developing Fritzing.

5.4 Workshops and continuous research

In the past, Fritzing has held various workshops with a very diverse audience: experts in physical interaction design from and in various countries, university students, engineers, artists or undergraduate students from a physical computing class. Workshops are our opportunity to not only teach and bring Fritzing closer to people, but in return to learn first-hand from the users' experiences. Since Fritzing is developed by researchers of the University for Applied Sciences Potsdam, Germany, the environment of the university gives us an excellent opportunity for continuously testing the current state with students. Apart from ongoing workshops at various events, a new series

of teachers' workshops is planned for 2011.

6. Friends-of-Fritzing NPO

*"I've been trying to find the time to play with Fritzing for a long while. I have downloaded it and started to play with it today. I am *extremely* impressed. You've done some fantastic work. I would very much like to help Fritzing thrive, grow, and become much better."*

Nathan Seidle, Sparkfun CEO

Friends-of-Fritzing is our charitable non-profit organization (German: "Gemeinnütziger Verein") dedicated to the development of Fritzing. The goal of Friends of Fritzing is to ensure that Fritzing remains a constantly updated, free, open-source software and that there are resources

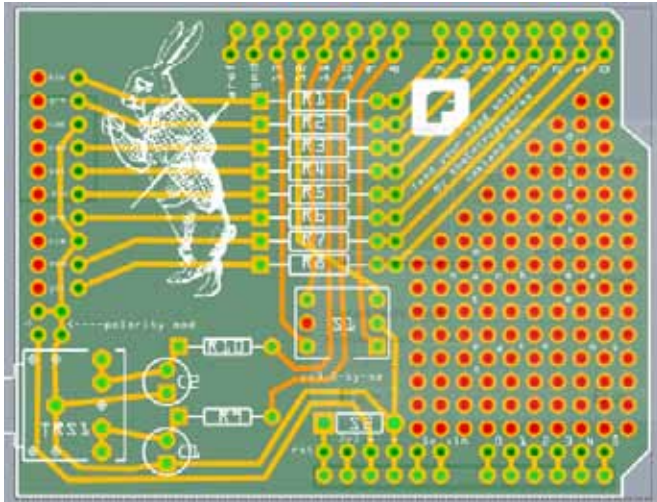
available to maintain and improve it. The NPO represents the essence of the open-source idea: it doesn't belong to anyone, you cannot buy it and it is not for profit, but for the community. Another part of FoF's project is to make the governance and progress of Fritzing transparent and accessible to anyone, and further, to encourage the community to get involved in moving Fritzing forward.

On a more mundane level, Friends of Fritzing acts as the voice of Fritzing for official announcements, press releases, and other forms of communications such as applying for proposals. The Friends of Fritzing NPO is also the legal body for receiving donations, to be able to continue the development work and hence secure the future of the free educational and open-source software.

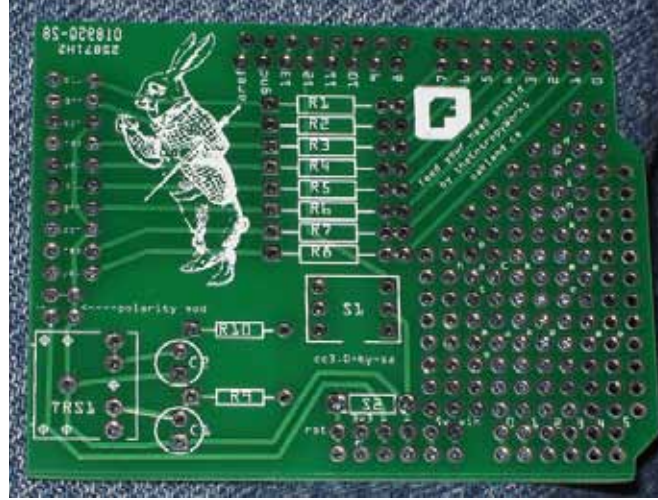
7. Fritzing Future Plans

In the years 2007 - 2010 the development of Fritzing has mainly been funded by the Ministry of Science, Research and Culture in the state of Brandenburg, Germany. From now on, Fritzing relies on its community of users and supporters to keep up the developing work necessary to support their growing community.

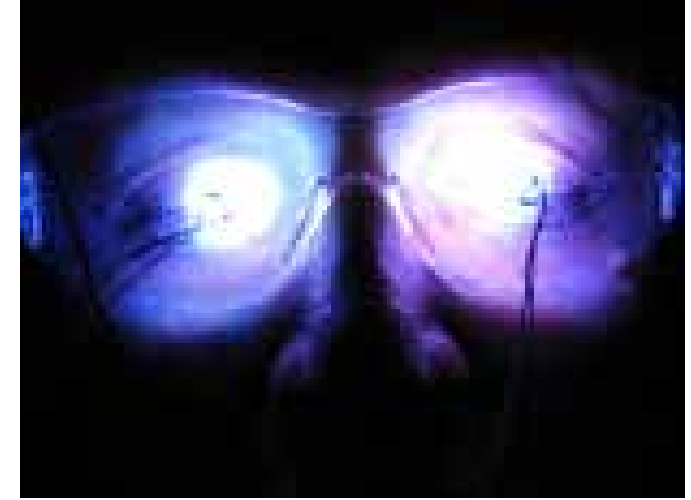
Since Fritzing has become more and more important in teaching electronics at various schools and universities throughout Germany, we would be very grateful to be able to continue the development work on Fritzing to support this urgent need for education. Fritzing strives to open technology



7.1.1 Fritzing's PCB view of an elaborate, personalized sound and light machine shield for Arduino by mtbf0



7.1.2 The custom designed and professionally produced PCB for mtbf0's "Feed Your Head Shield" project



7.1.2 mtbf0's "Feed Your Head Shield" project in action

to a community of creative, non-technical people. It is not about the new functionality – but rather the way that long-existing technology is made accessible, respecting the way a group of people work and embedding this in a lively community.

With the set-up of the Friends-of-Fritzing NPO we want to secure a powerful future for Fritzing and deepen our educational sectors with supplying additional teaching materials and teachers' workshops in 2011.

Also, the launch of our PCB production in 2011 should grant Fritzing more credibility as a professional tool. Not only can it be of great commercial value for some to be able to professionally manufacture their electronic artefacts, but being able to recognize a certain need for a product, coming up with a solution and then having the freedom and

opportunity to realize a certain product is a new and liberating step in history. It is not necessarily about developing a popular consumer product, but individually manufacturing a solid product taking care of personal needs. With the PCB production service Fritzing offers the possibility to create PCB in very small units, possibly a product that is of great practical and personal value for someone. There may not be a market for this particular product, but Fritzing takes care of this particular need.

"I am a beginner with electronics, controllers and never made a PCB but now with Fritzing I feel like I could give it a try! Thanks so much for all you guys do!" Fritzing forum post by merlin13

7.1 Roadmap

Technical improvements planned for Fritzing:
Auto router: We have recently replaced our original

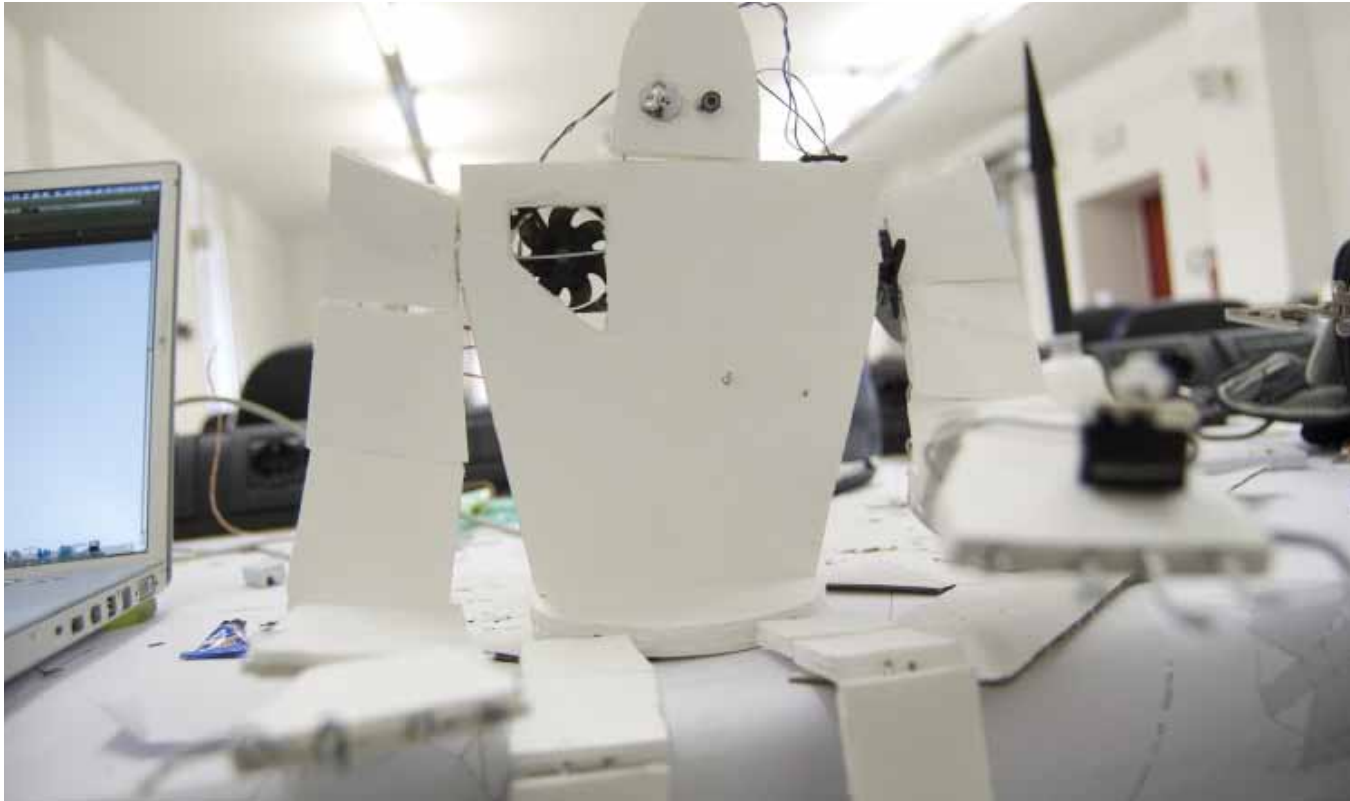
autorouter, but we would like to improve it and add auto-placement.

Electrical Rules Check: Providing live feedback about misconnected wires and short circuits
Website: For easier accessibility, new teaching materials and more frequent uploads, we are planning to rewrite our website.

New Parts Editor: By improving the UI, we would like to make it even easier to create new parts. The UI for dealing with connectors in PCB view needs to be reworked to make the task simpler.

8. Who is behind Fritzing?

Fritzing is being developed by researchers of the Interaction Design Lab at the University of Applied Sciences Potsdam, Germany. In the years 2007 - 2010 the development of Fritzing has mainly been funded by the Ministry of Science, Research and Culture in the state of Brandenburg, Germany.



8.1 A student project: self-made roboter electronically measuring creativity. Sensors, wires, cardboard, Fritzing all combined in this work taking a fun and light approach to physical computing.

8.1 Fritzing team members

Prof. Reto Wettach (supervision)

Reto is a professor at the University of Applied Sciences in Potsdam, where he teaches “Physical Interaction Design” and researches innovative, bodily-focused approaches to Human-computer interaction. He is the supervisor of Fritzing, likes to share his knowledge and thoughts at talks (Ideo Berlin 2010) and conferences and has found a solid research and testing base for Fritzing: his students. Reto has previously worked as an Asso-

ciate Professor with the Interaction Design Institute in Ivrea, and as a designer/researcher with Sony in Tokyo and Ideo in San Francisco. Reto is the founder and design director of IxDS and responsible for their overall design strategy.

André Knörig (project lead)

André is an interaction designer with a distinct interest in physical, embodied interactions. André holds degrees in computer science and design. His creative research has been published at conferences such as TEI and CHI, and been exhibited at Ars Electronica and NIME. Currently, André is

working as a researcher at the University of Applied Sciences Potsdam, where he is also project lead of Fritzing. He is managing the Berlin-based IxDS Interaction Design Studios, a design research firm that creates innovative interactive products and services.

Jonathan Cohen (chief software architect)

Jonathan is a silicon valley veteran with decades of experience in developing and prototyping software across all categories of devices. He has been a member of research labs at Xerox PARC, Interval Research, and Apple, where he has helped to invent the future of human computer interactions. Jonathan is also a researcher at the University of Applied Sciences Potsdam and developer at IxDS, Berlin.

Further core members are or have been:

Brendan Howell (electrical engineering), Mariano Crowe (software architect), Zach Eveland (electrical engineering), Dirk van Oosterbosch (ui design), Lionel Michel (illustration), Daniel Tzschentke (electrical engineering), Jenny Chowdhury (content, documentation, outreach), Travis Robertson (documentation), Myriel Milicevic (eco research & illustration), Kevin Haywood (ui design), Jannis Leidel (website), Johannes Landstorfer (ui design).

Big thanks to all contributors, workshop participants, and all the great people we have met through this project!