



# De Vonk

Periodical of  E.T.S.V. Scintilla

Year 33 | Edition 2 | March 2015

## Main Article

Electrical Engineering meets Chemistry

## Master Thesis

Cooperative adaptive cruise  
control with CLaSH

# WE TURN YOUR IDEAS INTO TOMORROW'S PRODUCTS



## APPLIED MICRO ELECTRONICS

AME is a fast growing organization developing and manufacturing high quality products with electronics. Our goal is to create innovative products for our customers that exceed market expectations by making use of state-of-the-art development facilities and a highly automated manufacturing environment. Driven by technology, we strive for the best solution combining the disciplines of applied physics, electrical, mechanical, software and industrial engineering.



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# Another year

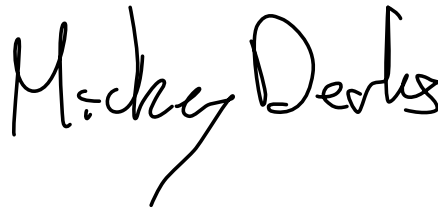
*Author: Mickey Derks*

Dear members, while I am writing this, I can look back to another year, with the busy December month at its end. We enjoyed the active member outing and, two days later, the Christmas dinner. It passed in a more structured way than I remember from previous years, with most active members still appearing to be somewhat tired. After SCALA had cleaned up, everyone could rest during two well-deserved holiday weeks.

Currently, those holiday weeks seem long ago, because of exams. When you are reading this Vonk, this will probably be the case as well. But, while you're studying, the end of the year already seems somewhat near. For the board, this means the last phase has started: recruiting a new board. In other words, one of the board members might want to talk with you about joining the board, and I would like to take this moment to reflect on everything Scintilla, with all its committees, does. Think of all the fun activities, like the recent Christmas dinner and all the other drinks and festivities, but also of the more serious activities, like the excursions, courses and lunch lectures, making sure you can buy your books and electronic components, maintaining the quality of the education, and last but not least, producing this Vonk. If you are as proud of this as I am and

would like to take a break from all the studying, have new experiences, but still spend your year in a useful way, please consider being a member of the 86th board next year. For now, good luck on your exams and enjoy reading this edition of the Vonk!

Dames en heren,  
Op de koningin, op Scintilla!



Mickey Derks  
President



## **Grolsch Excursion**

Thursday 09 April  
15:45, Grolschbrouwerij,

## **Hitchhiking weekend**

Saturday 18 April  
10:00h, Leuven, Belgium

## **43rd Batavierenrace**

Friday 24 April  
23:29, Nijmegen to Enschede

## **Scrapheap challenge**

Friday 08 May  
20:00, Educafé

# Masthead

## De Vonk

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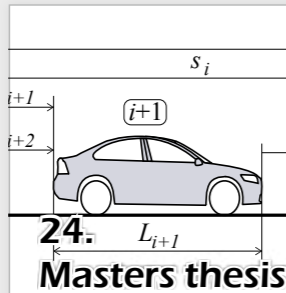
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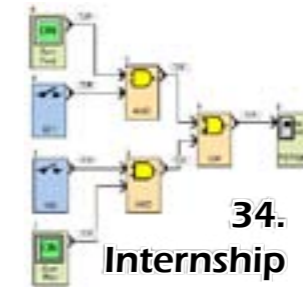
10. Main Article

The smaller a chemical lab would be, the more chemical labs there could be used, and the more efficient it would be. The lab-on-a-chip group from BIOS basically tries to make a complete working (bio)chemical lab on a smaller chip. The article will give more insight on the removing of ions using capacitive charging and the network analysis for microfluidic systems.



Hardware design is becoming more and more complex with the growing complexity of the hardware that has to be designed. The hardware description language VHDL is hard to learn, which does not make it easier. At the CAES group, they developed a hardware description language based on Haskell: CλaSH. In his master's thesis, Erwin used this language to describe a cooperative adaptive cruise control. In this article, you can read how.

Luuk Oudshoorn did an internship at Nedap at the retail market group. The retail market group develops many things, of which one is RFID solutions. This system is used for tagging individual products for shops and prevent theft. The response time of the tags unfortunately is too large, and therefore will not always work. At Nedap, research is done to make this response time shorter and therefore make theft prevention technology better.



For his bachelor assignment Tobias did research for the Integrated Circuit Design chair. His focus laid on the full-duplex radio communication where he did research on mixers within the integrated RF front-ends. Since it is in the frequency domain there is always distortion which must be taken into account. For his bachelor thesis Tobias compared three mixers and did calculations and simulations.



# Editorial

## Perks of re-doing

Editing de Vonk after a long day of following college or doing projects. That is how most of the lay-out evenings are. This one is different. Being a second-year student re-doing a first year module, there is time and space to enjoy the day. Not that studying is not enjoyable, but to be fair, time off instead of building a hovercraft has its perks. Not being tired after the day, and actually having time to clean instead of cleaning as a nice SOG-moment.

Having free-time, sadly does not result in concentration. Comparing myself whilst writing this editorial with the Vonkers around me headbanging to the music and changing the contrast of the calibrated screens, I am the most productive one at this time. Of course, concentration always can be seen as a sine. It has high moments and low moments. But that does not result in bad results per se. Writing an editorial is even with low concentration doable. It just feels like a writers block. But it is kind of fun to feel like a writer who fails at writing.

But now to the more important things; the progress of the Vonk after a relaxing day of playing games, reading and doing some committee work. For me it was not going that fast, I spell-checked some articles, and wrote this nicely done article. Next to me, there is a A4 long article being spellchecked for the last hour or so, and next to that the Puuzle is opened in 20-fold. Basically, the concentration is low, but the beer is open!

Guus Frijters

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# News for the electrical engineer

## Robots learn to cook

Robots are capable of many things, from building cars to driving cars, from dancing to grabbing a beer for you. Now robots are also capable of cooking. Robots that can cook already exist, but most of them use pre-programmed instructions. Telling a robot what to do and how to do it exactly is one of the most complicated things in designing robots.

Scientist from the University of Maryland changed the way in which the robot learned to cook. Instead of using pre-defined code they let the robot learn from a video. Visual processing is used so the robot can distinguish what the human in the video is doing, what objects it is using and how it is

performing the task. The final step is using the acquired information to replicate the actions as shown in the movie.

The university of Michigan used a dataset called YouCook to train their neural networks for recognition of the object used, and another one to classify and recognize the grasp that is used. The video database consists of 88 YouTube cooking videos where each frames has tags about the actions and objects used.

Recognizing the grasps is important because the robot may have different end effectors for different grasping purposes. Grasps were divided into six types: power grasps and precision grasps, each for small, large or spherical objects. The overall recognition ac-



Author: Maikel Huiskamp

curacy of the system was 83 percent, while the success rate for translating the grasp and object combinations into commands is 68 percent.

Source: <http://tinyurl.com/vonk3321>

## Nanoballs increase voltage capacity of power cables

Researchers from Chalmers University of Technology have demonstrated that adding carbon nanoballs (also known as C60 or Buckyballs) into the plastic insulation of high voltage cables enables the cables to handle up to 26 percent more voltage than the standard cable. This results holds promising results for alternative energy sources, such as wind turbines out at sea, where the energy has to travel a significant distance before it reaches the grid.

The researchers discovered that by adding the nanoballs to the plastic the breakdown voltage of the insulation increased. It was already known that using additives in the insulation plastic could lead to higher breakdown voltages, but until now it was unknown which materials and how much exactly should be added. By adding only a small amount of nanoballs to the plastic a maximum voltage capacity increase of 26 percent was observed. The nanoballs prevent breakdown by absorbing the free electrons that would otherwise destroy chemical bonds inside the plastic.

Source: <http://tinyurl.com/vonk3322>

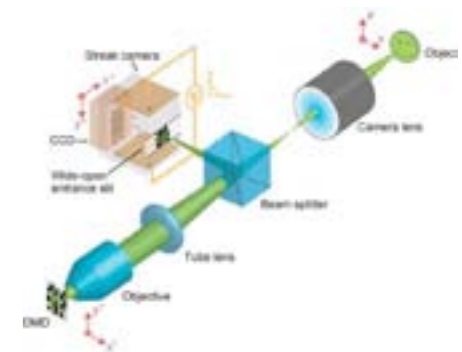
## 100 billion frames per second camera developed

At the Washington University in St. Louis a team of biomedical engineers developed the fastest 2-D camera in the world, which can capture up to 100 billion frames per second. This achieved FPS is magnitudes faster than any other currently available camera, which are mostly limited by on-chip storage and electronic readout speed.

The developed camera does not work like a normal camera. The photons from the object first have to travel through a lens where they are focused on a Digital Micromirror Device (DMD) which host a million mi-

cro mirrors, each one seven by seven microns squared. The DMD is used to encode the image, after which the photons are reflected back into a beam splitter. The beam splitter then sends the photons through the widened slit of a streak camera where an electric field is applied to change the height where the electrons fall on the CCD. This is done since a normal streak camera only has a one-dimensional view. By steering the light on the correct spots on the CCD a 2-D image can be created.

By using a technique called compressed ultrafast photography the scientists have made movies of the images they took with single laser shots of four physical phenomena: laser pulse reflection, refraction, faster than light propagation and photon racing in two media.



Immediate applications for the new camera can be found in biomedicine. By excitation with a green light pulse fluorescent green molecules can be converted to red. By tracking this fluorescence lifetime cellular environmental condition like pH or oxygen pressure can be measured.

Source: <http://tinyurl.com/vonk3323>

## Mysterious phase of matter competes against superconductivity

A mysterious phase of matter competes with high temperature superconductivity

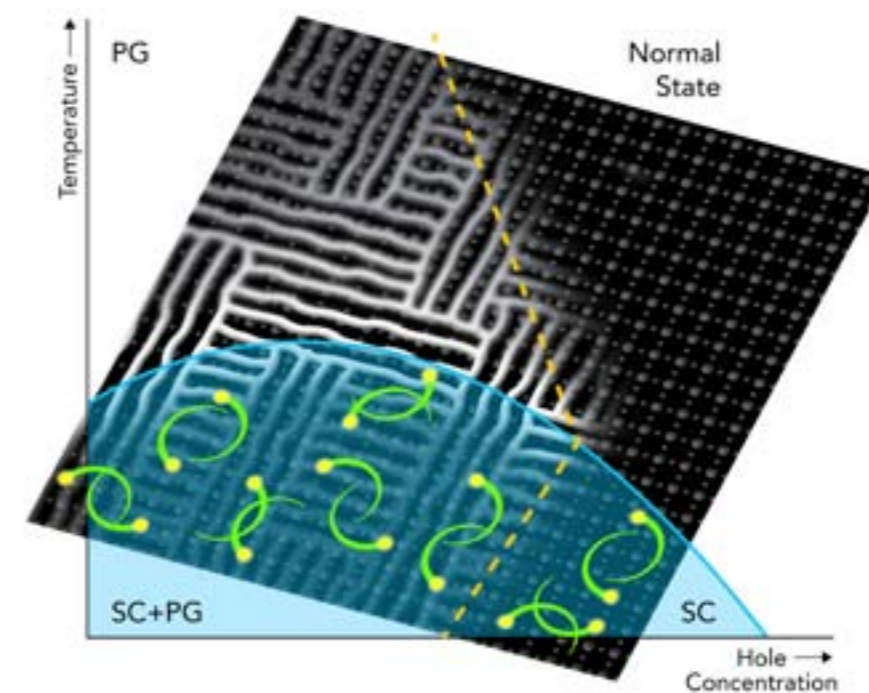
for the electrons that could otherwise form the Cooper pair needed for superconductivity. Research led by Stanford University for over 20 years was aimed at finding if the effect known as the "pseudogap" helps or hinders superconductivity. The results of this research clearly shows that the pseudogap is one of the things preventing us from getting superconductors to work at higher temperatures so they can be applied in sys-

tems for everyday use.

In the experiments a technique called angle-resolved photoemission spectroscopy, or for short ARPES, was used to characterize the behavior of the electrons inside the material. When using this technique electrons are knocked out of a copper oxide, which is superconducting at relatively high temperatures, and the energies and momenta of the ejected electrons tell the researchers how the electrons were behaving when they were still inside the material.

When an electron paired up with another electron to form the Cooper pair a characteristic gap was left inside the plots made by ARPES. However in the mid-90's a puzzling gap showed up in the plots at temperatures where super conductivity inside the tested copper oxide was not possible. Later it was discovered that this pseudogap and superconductivity are competing for the electrons. When temperatures are too high the pseudogap is winning the battle for the electrons, but when temperatures decrease the pseudogap spits the electrons back out so they are available for the super conduction process.

Source: <http://tinyurl.com/vonk3324>



# Ordering study-books

Author: Joep Zanen



I expect that the average Scintilla member assumes that ordering of books via Scintilla is a simple outsourced website which is effortless to maintain for the association. I, as Scintilla's commissioner of books, beg to differ. At the end of the previous study year I was introduced to the job of Scintilla's next top commissioner of books by my predecessor Laurie. What seemed like a straightforward task became a reality of continuously changing minds, late reactions and diplomacy between multiple parties with conflicting interests. I will skip the real hell that is the bulk delivery to the STORES in the first quartile and tell you the short version of what a commissioner of books does.

First the why. The reason Scintilla supports in study books is twofold: these are the study needs of our members, and Scintilla, as an association, can order books for a lower price than you can as a regular consumer. Dutch politicians decided, for a reason unknown to me, that is a good idea to have a minimum price for books and so they implemented this by law. The official reason states that this stimulates a more pluriform supply of books, but I cannot see how limiting the market is beneficial for the market. However, this law can partially be circumvented if books are bought by an association. The means that the books bought via Scintilla should always be a better bargain than other Dutch book shops. If they are not, please notify me and I will get you a better deal.

Let's start at the very beginning. At the start there are contracts. The contract with our current supplier has been signed two years ago. This was not an easy task for the board at that time because all possible suppliers did have some factors which made them less

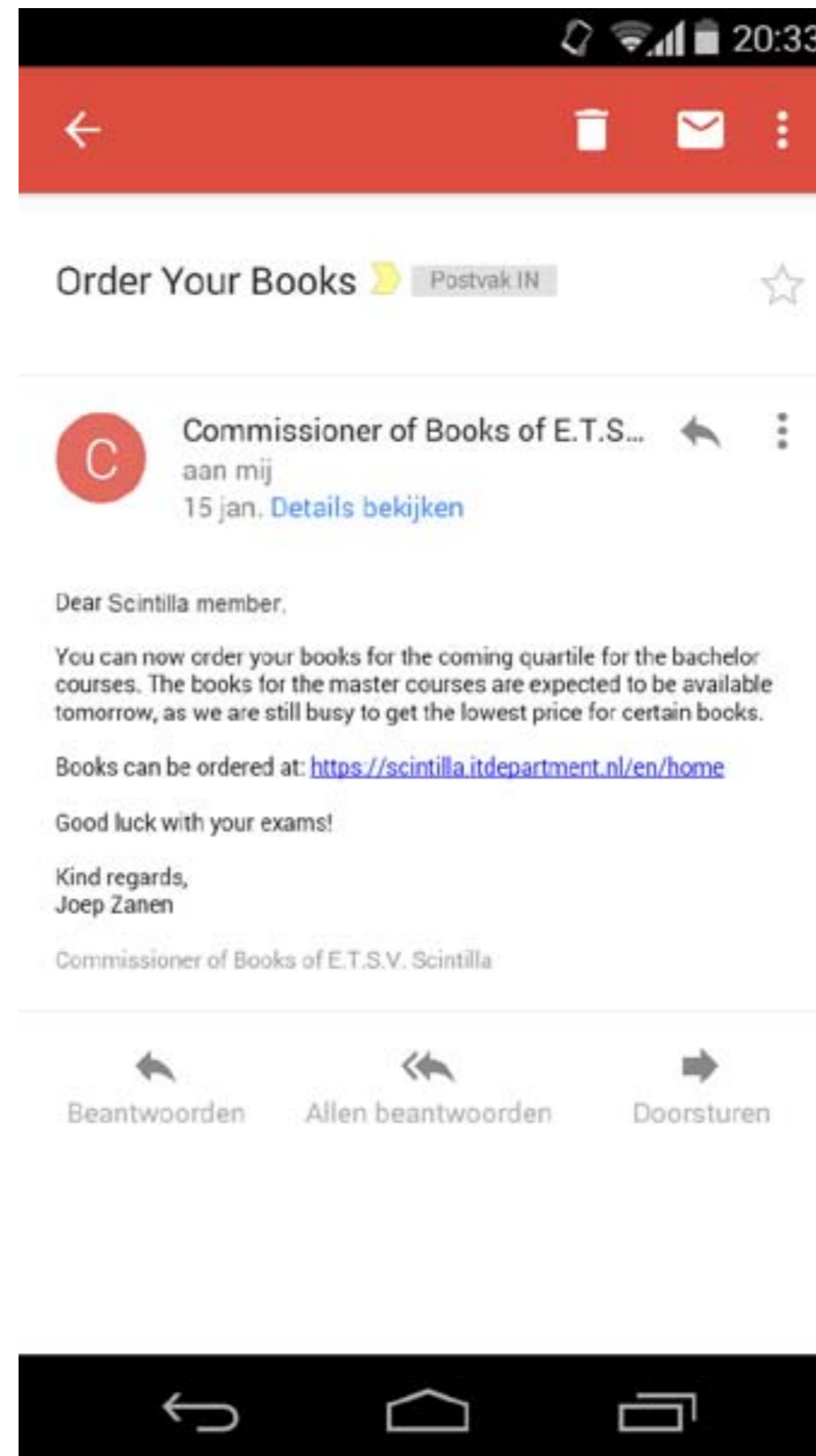
suitable, but at the end of the day a choice had to be made and Scintilla chose to sign with the supplier Studieboekencentrale. This contract is not signed by Scintilla solely, but by the OS: an association of all the study associations at the University of Twente.

"So if there is a contract, the books will be available in the web shop, right? Not even close."

By signing with all the study associations of the university together, the book orders would be very large, and thus a maximum discount could be bargained. This year yet another contract has been signed for the book website, which is yet another party in the process.

So if there is a contract, the books will be available in the web shop, right? Not even close. This is where the task of the commissioner of books normally starts. About two months before the beginning of the next quartile the actual process starts for me. Around this time I am asked by our supplier what the books for next period will be. This may seem early, but there's still a lot of steps ahead of us. At this moment I will look up which courses will be taught, what the literature is and who is the responsible professor. Commonly these are about twenty subjects per quartile and one or two will follow later because the details of these subjects are not available yet. I will then send an email to these professors to verify the information I found. After this email and multiple reminders, all lecturers, will have verified their details, after which I can tell the supplier which books we want to order.

In the next step, Studieboekencentrale will check with the publishers if they can buy the books I asked for. Often only another version is available and after checking if



these version are still fine with the lecturers, I, the commissioner of books, can order the books. This is where the hardest part starts. The supplier asks me for a prognosis of how many copies we are going to sell of each book. If I take the amount of students who are going to take the course, the price of the book and the selling rate of last year into account I should be able to make a decent estimation for this. However, none of these data are known to me. Once I have made an educated guess and have made extensive use of my diplomatic skills to actually get the amount I asked for, as the estimation of our supplier is always lower and we have to reach an agreement, most work for me is done. For now I wait.

In the meantime, there are always professors who come to me last minute to ask me if I can still order the book for their course. Sometimes this is because they forgot to answer my emails, but most commonly this is because the course is new or changed and the information was not made available to me yet. This means that I have to stop everything I was doing at that moment to see if I can still fix this book. This is a stressful situation and it happens at least once every quartile.

After about two weeks Studieboekencentrale notifies me that the web shop is open and then, at last, I send our members an email to remind them to buy their books for the upcoming quartile. You log in at the seemingly effortless web shop and I take a break and drink my next cup of coffee. I breathe out and feel relaxed, until I remember that the complete cycle will restart again in three weeks.

# Electrical Engineering meets Chemistry

Authors: Floris van den Brink, Stefan Dekker, Susan Roelofs & Mathieu Odijk

Lab-on-chips are micro fabricated devices, that aim at miniaturizing a small (bio)chemical reaction to reduce time, safety issues or waste products while increasing the reaction efficiency, improve detection of chemicals or open up new possibilities that simply would not be possible at larger scales. An example of such a Lab-on-chip is shown in figure 1. Typically, it contains fluidic channels in the order of the size of a human hair or smaller (~60 micrometer or less).

The field of Lab-on-Chip has expanded rapidly starting from the early 90's. One of the main driving forces was the challenge to map the human genome. In 2001, the cost to map the genome of a person was \$100 million US dollar, while in 2012 the cost has already dropped below \$10 thousand US dollar. In the same time the amount of kilobases per day that could be analyzed by a single machine went from 10 for manual

operation in the 1980's to 100 million in 2009 [1]. A decrease in cost and time per base pair which would only have been possible by developments in the field of Lab-on-Chip. BIOS the Lab-on-a-Chip group is embedded within the EEMCS faculty and is part of the Electrical Engineering program. Many of the developments taking place in this relatively new and exciting field would not be possible without Electrical Engineers. In the remainder of this article we show where the Electrical Engineering meets (bio)chemistry.



In the case of laminar flow (see inset), a linear relation exists between the pressure across the channel and the average volume flow through it, similar to Ohm's law.

“The knowledge about electrical circuits, that an electrical engineer possesses, can be used to gain insight into the mechanical properties of a fluid in a microfluidic device.”

Ohm's law tells there is a linear relationship between the voltage over a resistor and a current flowing through it. By introducing a hydraulic resistance the result for the fluidic domain can be written in the following formula:

$$\Delta P = R_h Q$$

Where the pressure difference ( $\Delta P$ ) is the fluidic equivalent of the voltage ( $V$ ) in an electrical system and the volume flow ( $Q$ ) can be regarded as the equivalent of the current ( $I$ ). With this new hydraulic resistor ( $R_h$ ), complex fluidic systems can be described as electrical circuits. These so-called

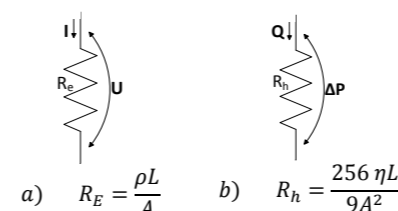


Figure 4, a) electrical resistance ( $R_E$ ) and b) hydraulic resistance ( $R_h$ ) for a square channel [3].

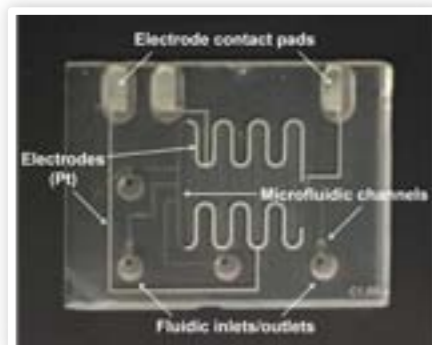


Figure 1, example of microfluidic chip for drug screening.

## Control of fluids in microchips

The knowledge about electrical circuits, that an electrical engineer possesses, can be used to gain insight into the mechanical properties of a fluid in a microfluidic device.

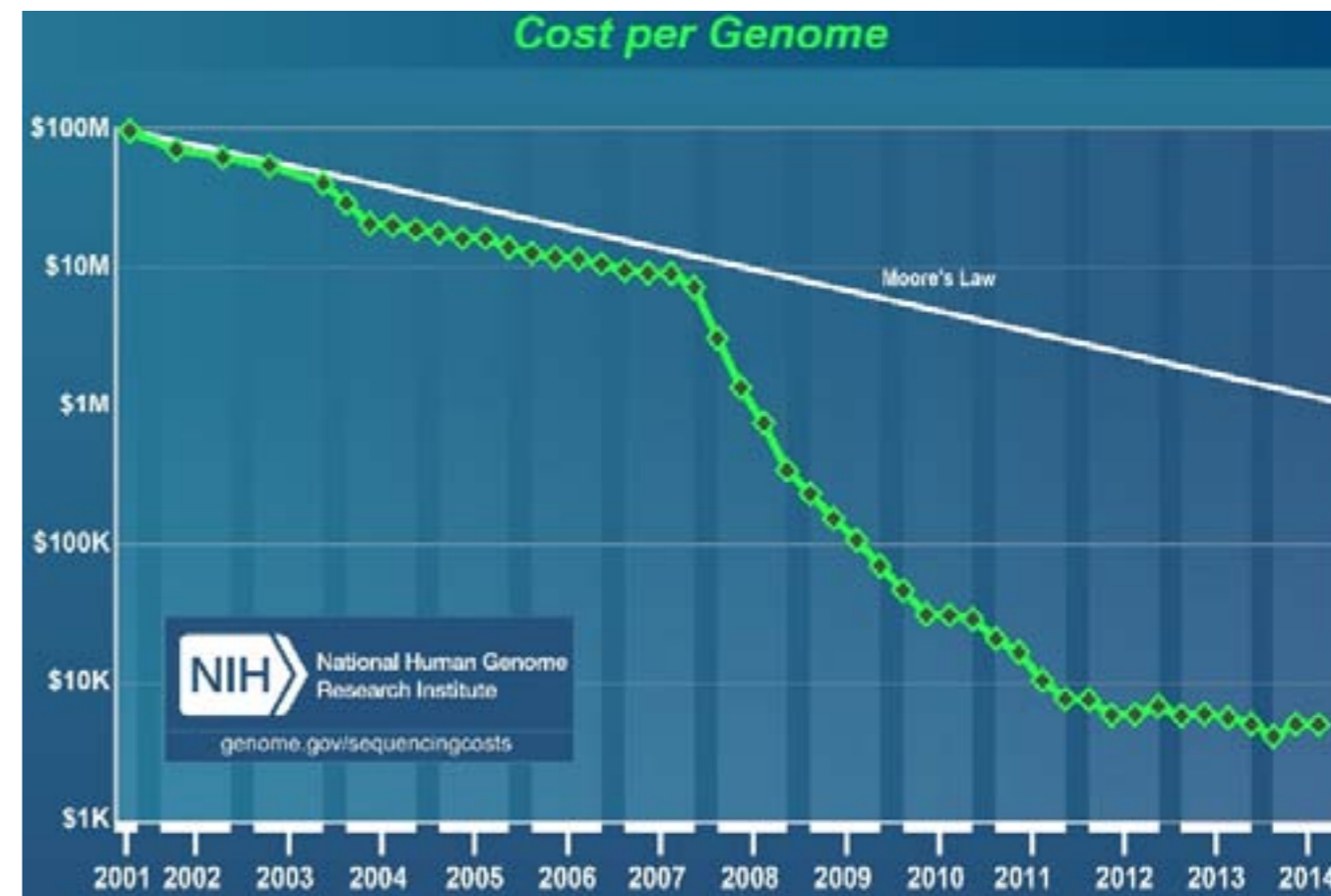


Figure 2, cost per genome. (Source: <http://www.genome.gov/sequencingcosts/>)

## Laminar flow

In 1883, Osborne Reynolds published a paper describing the behavior of fluid at various flow rates [2]. The so-called Reynolds number describes the ratio between the inertial forces over the

viscous forces:  
 $Re = \rho v d / \eta$   
 It accounts for characteristics of the fluid density ( $\rho$ ), velocity ( $v$ ) and the dynamic viscosity ( $\eta$ ) and the characteristic dimension ( $d$ ) of the flow channel. If the Reynolds number is below ~2300, the flow behaves laminar (as shown in figure 3, a), above ~4000 it behaves turbulent (figure 3 b & c). Since the characteristic dimension of microfluidic channels is so small, fluid always behaves laminar in Lab-on-Chips.

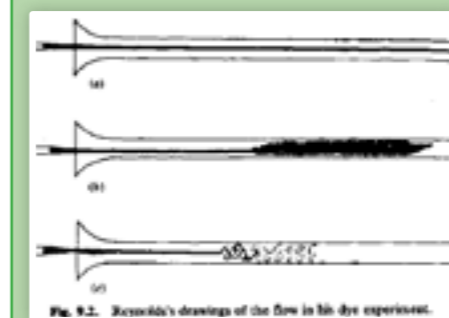


Figure 3, Reynolds's drawings of the flow in various regimes [2].

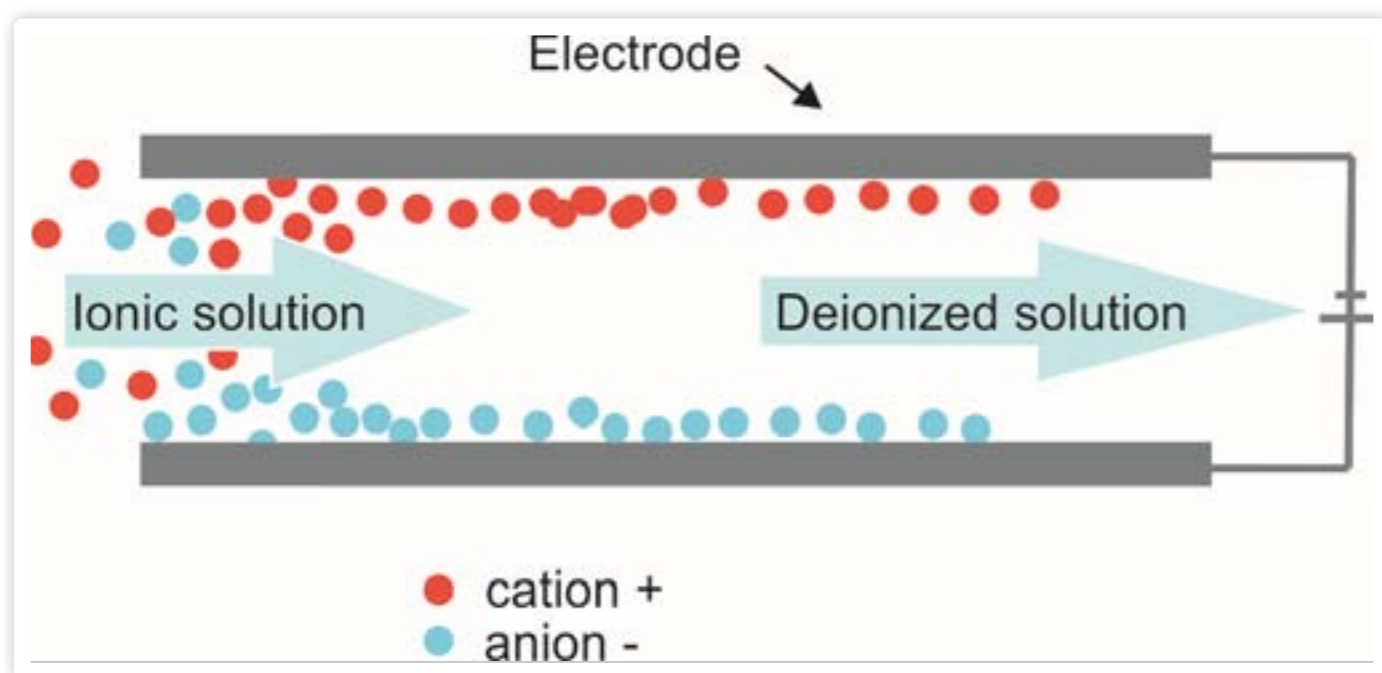


Figure 5, Geometry of a capacitive deionization cell. Two electrodes are facing each other. An electrolyte is flowing in between. Upon the application of a potential of approximately 1 V the ions in the solutions migrate to the oppositely charged electrode.

“The main driving forces was the challenge to map the human genome.”

equivalent electrical circuits can be used to calculate pressure and flow throughout the fluidic system. As such, these circuits are useful design tools as they include the parameters needed for a physical implementation.

Figure 4 indicates the similarities and differences for fluidic and electrical resistors. In the case of an electrical resistance its value is defined by the specific electrical resistance ( $\rho$ ), length of the conductor ( $L$ ) and the cross-sectional area of the conductor ( $A$ ). The hydraulic resistance (of a square channel) holds information about the viscosity of the fluid flowing in the channel ( $\eta$ ), the length of the channel ( $L$ ) and the cross-sectional area ( $A$ ). Note however, that the resistance of fluidic resistors scale with the power of the area. As such, the resistance increases more rapidly for smaller channels. If one wants to know the flowrate in a microfluidic system this analogy with an electrical resistor can also be used. In electronics

a shunt resistor is often used to measure current. In a microfluidic device a hydraulic resistor could be used as a flow sensor. The pressure drop over the hydraulic resistor is a measure for the flow through it. This pressure can be measured with a commercially available pressure sensor. By correctly dimensioning the channel, the flow rate range

of interest will be transduced to the output voltage of the pressure sensor. Further processing and application of the sensor signal are typical electrical engineering tasks and could for example be used to control the pump of the system.

## Electrical double layer

An electrical double layer occurs upon the insertion of an electrode into water (fig. 6) [8]. Two layers can be distinguished, the Stern layer and the diffuse layer. The Stern layer consists of the first layer of ions closest to the electrode surface. In this layer the potential is linearly related to the distance from the electrode. The diffuse layer, first described by Gouy and Chapman [8], consist of ions further away from the surface. In this layer the potential changes exponentially away from the surface. CDI uses this phenomena to temporarily store salt ions extracted from the solution.

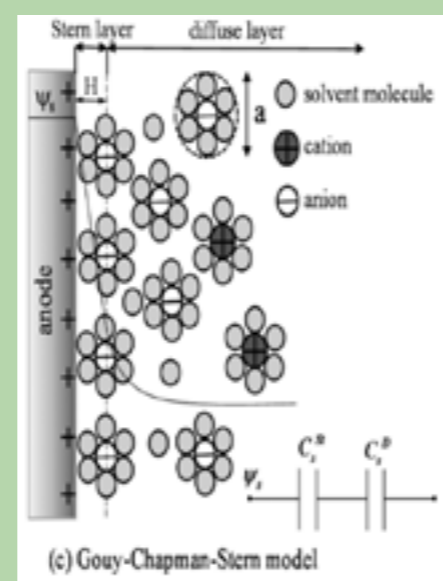


Figure 6. The electrical double layer. Adapted with permission from [9] with permission from The Royal Society of Chemistry.

## Capacitive Deionization

Desalination of water is typically applied on the macro-scale for drinking water production from seawater or brackish water. Brackish water has a salinity of 1 g/L [4], whereas, the salinity of seawater is 35 g/L on average (source: <http://www.nodc.noaa.gov/>). According to the World Health Organization, the amount of people living in countries suffering from a fresh water shortage is expected to increase from one-third of the world's population (2004) to two-thirds in 2025 [5,6]. The urge for energy efficient methods to unlock the salt water sources for drinking water supply is reflected in the growth of the amount of desalination plants throughout the world in the past decade [6,7]. These plants operate mostly on the basis of reverse osmosis or distillation based techniques.

## CDI

Capacitive deionization (CDI) is an emerging desalination technique which is potentially energy efficient for desalination of brackish water and waste-water streams from industry. In contrast to reverse osmosis or distillation, CDI does not require high temperatures or high pressures. A typical CDI cell consists of two electrodes facing each other with an electrolyte flowing in between. A schematic overview of a CDI cell is shown in figure 5.

To remove ions from the electrolyte solution, a potential of approximately 1 V is applied across two porous electrodes. The ions move to the oppositely charged electrodes and are stored in close proximity to the electrodes in the so-called electrical double layer (see inset). The storage capacity of the system is proportional to the effective

surface area of the electrodes and the potential applied across the electrodes. After the saturation of the electrodes, the system is regenerated and a concentrated stream exits the system. Ideally, there are no actual electrochemical reactions taking place at the electrode surface. In CDI, no chemical reactions are taking place at the electrodes. In the next application, we aim for the exact

“The amount of people living in countries suffering from a fresh water shortage is expected to increase from one-third of the world's population (2004) to two-thirds in 2025”

## Cytochrome P450

CYP450 enzymes are so-called haemoproteins, which mean that they have a haem group tightly bound to the protein. An example of such a haem group within a CYP450 protein is shown in figure 7. A haem group consists of an iron atom contained within a large heterocyclic organic ring called a porphyrin. The best

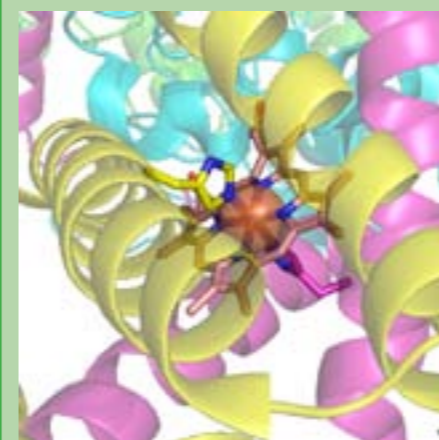
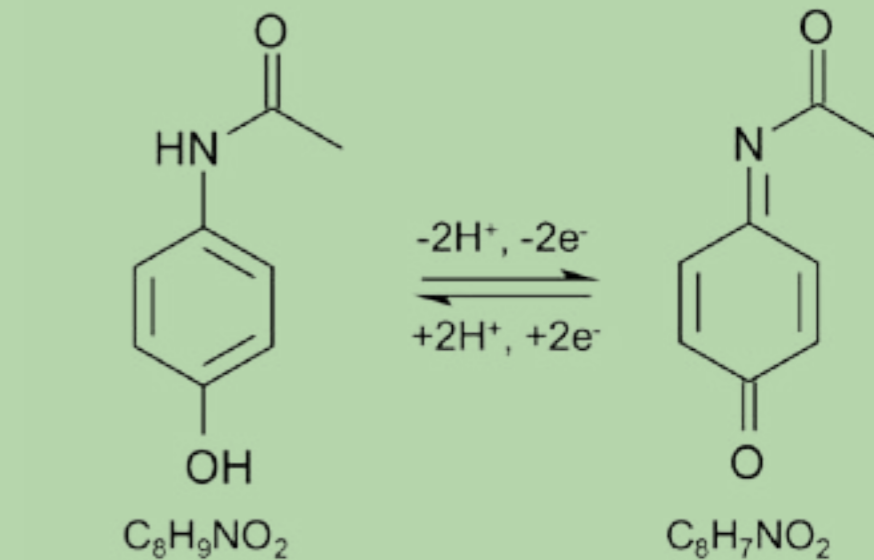


Figure 7, 3D picture of haem group within a CYP450 enzyme (Source: Wikipedia).



known example of a haemoprotein is hemoglobin, which is responsible for the oxygen transport in red blood cells. CYP450 enzymes are mainly present in membranes of liver cells, but they are also found in e.g. the lung or the intestine [10,11].

CYP450 enzymes catalyze the oxidation of all kinds of mol-

ecules in the body. As an example reaction, paracetamol (left) is converted into its reactive metabolite N-acetyl-p-benzoquinone imine (right) by CYP450. You can see that there are two electrons removed from paracetamol, indicating an oxidation reaction [12].



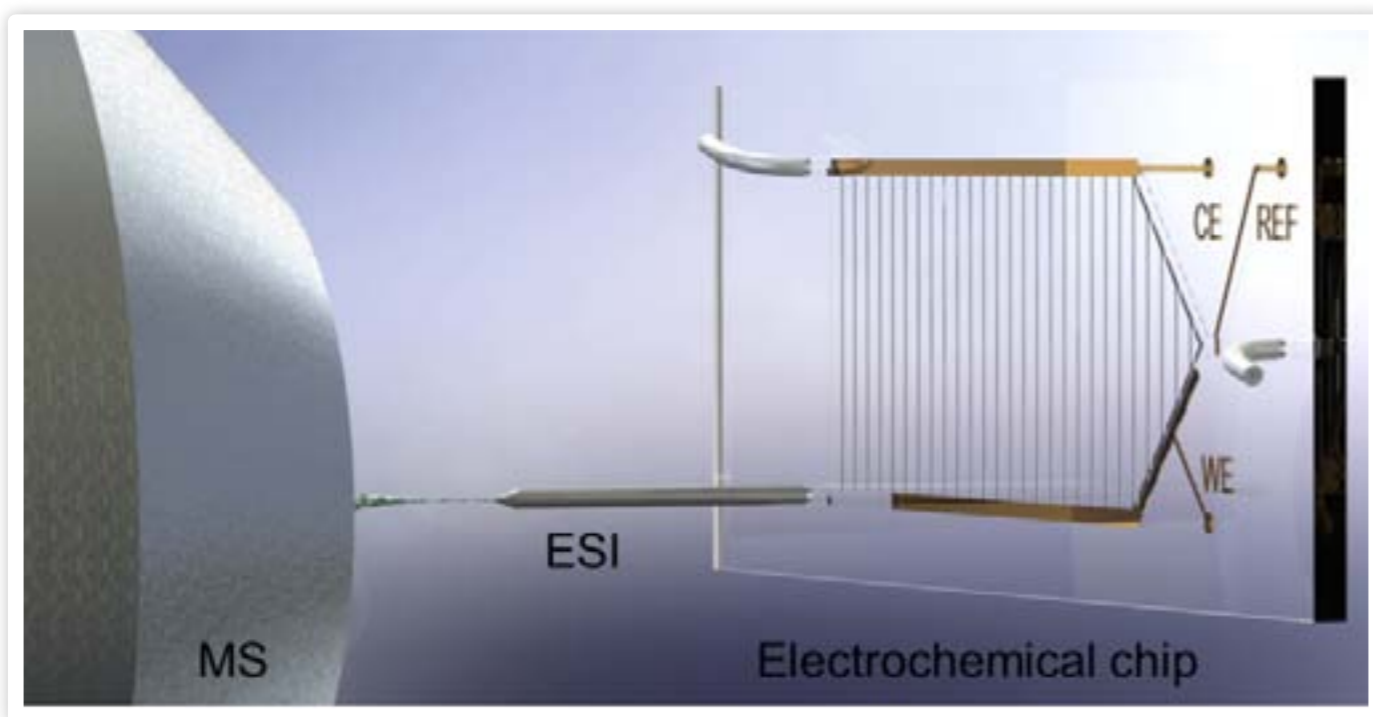


Fig. 8: Electrochemical chip with an electrospray ionization needle coupled to a mass spectrometer [12].

opposite by using different electrode geometries and electrode materials, potentials and different molecules in the solution.

## Electrochemical micro reactors

In today's pharmaceutical industry there is a need for fast and cost-effective screening of candidate drugs in the early stages of the drug development process, because large financial losses are incurred upon failure of compounds during the clinical trial phases. Among the pre-clinical tests are those related to drug metabolism, which concerns a series of reactions that either activate the drug or detoxify it, and from which also potentially toxic reaction products can emerge. The majority of drugs currently available are oxidized by enzymes from the cytochrome P450 family [13] (see inset), and therefore oxidative metabolism reactions have become of interest for in vitro drug development tests. Several complementary analytical techniques are developed in attempts to mimic cytochrome P450 activity, including the preparation of liver extracts, several chemical methods, and an entirely instrumental approach in which the com-

pounds are electrochemically oxidized at an electrode surface. Advantages of direct electrochemical oxidation include the extensive control over reaction conditions (potentials, electrode materials), the possibility for easy retrieval and rapid online analysis of metabolites (which is especially important in the presence of short-lived reaction products), and the possibility for miniaturization of the electrochemical reactor to minimize the amount of sample required/waste

**"In today's pharmaceutical industry there is a need for fast and cost-effective screening of candidate drugs in the early stages of the drug development process, because large financial losses are incurred upon failure of compounds during the clinical trial phases."**

produced.

## Design aspects and fabrication of electrochemical micro reactors

Generally speaking, electrochemical cells consist of at least two electrodes in a reaction volume (e.g., a battery or a fuel cell), but for more precise control over the WE potential typically three electrodes are used: a working electrode (WE) at which the reaction of interest takes place (in this case oxidation), a counter electrode (CE) which provides the necessary current (and at which the opposite reaction takes place) and a reference electrode (RE) which maintains a stable potential, relative to which the WE potential is controlled (think of the electrical ground in an electronic circuit). To integrate such a system in a microfluidic chip, both the fluidic and the electrical properties of the microchannels have to be considered. The small dimensions provide the advantage of high surface-to-volume ratios, enabling rapid electrochemical conversion due to short diffusion distances ( $l$ ), which is for 1-dimensional diffusion related to the

diffusion time ( $\tau$ ) as follows:  
 $l = \sqrt{2Dt}$

With  $D$  the diffusion coefficient of the species of interest. This means, that by locating the electrode at the bottom of a shallow channel of a few micrometers in height, rapid diffusive mass transport of molecules toward the electrode can be established. A schematic of the electrochemical cell is shown in figure 8.

Two separate channels are accommodating the WE and CE, to avoid mixing of the oxidation and reduction products. The RE is positioned in close proximity to the WE. This is essential to minimize the ohmic drop, which is induced by the solution resistance ( $R$ ) between the RE and WE when an ionic current ( $i$ ) flows between the WE and CE. If the WE potential is regulated to be  $E$  with respect to the RE:  $E_{WE} = E - ERE$ , due to the ohmic drop the actual potential is  $E_{WE} = E - ERE - iR$ , which is a deviation that has to be minimized. However, the shallow channels have a high electrical resistance, making the problem of the ohmic drop highly relevant in microfluidic cells. To reduce the current density flowing between the WE and RE a 'frit channel' system connecting the WE and CE has been integrated, consisting of a series of narrow channels which form a parallel resistance network. This frit channel system effectively reduces the ohmic drop, and also promotes a uniform current density over the entire WE as an added bonus.

Using microfabrication techniques, various

**"These selected examples show the tip of the iceberg of electrical engineering expertise used in the field of Lab-on-Chip."**

types of electrochemical chips can be fabricated. They can be equipped with metal electrodes (Pt, Au), but currently we are interested in boron-doped diamond because of its superior electrochemical properties.

The chips are often made from glass by etching techniques, but also plastics such as cyclo-olefin polymers are promising alternatives to enable disposable chips, to reduce costs and to avoid problems associated with cross-contamination between experiments. In the measurement setup for drug metabolism studies, this electrochemical chip is interfaced with a mass spectrometer using electrospray ionization (EC/ESI-MS). See figure 8 for an overview of such an arrangement. Special attention has to be paid to the combination of the electrospray high voltage (typically 3 – 4 kV) with the sensitive electrochemical equipment ( $\sim 1$  V/1  $\mu$ A). After combining these elements, this setup has been used to successfully detect short-living and reactive metabolites of a variety of drugs [12].

## Summary

These selected examples show the tip of the iceberg of electrical engineering expertise used in the field of Lab-on-Chip. In this article we have shown network analysis for microfluidic systems, how to remove ions using capacitive charging and the application of electrodes to drive electrochemical reactions for drug development. Many other, exciting examples can be given including the development of sensors, the inclusion of optical waveguides or the control and integration of heating elements to name a few. However, for in-depth knowledge the collaboration with other disciplines from chemistry, biology, physics and medicine is essential to reach the best results. It is for that reason that research in the Lab-on-Chip field is carried out in a very multidisciplinary environment. Feel free to contact the BIOS Lab-on-a-Chip group (m.odijk@utwente.nl) if you are interested in broadening your scope, and joining this multi-disciplinary environment during your bachelor or master assignment. The group has a long track-record of bachelor and master students being co-author on journal articles, due to their participation in cutting-edge research.

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# Over-engineering a horn

Author: Jan Lenssen



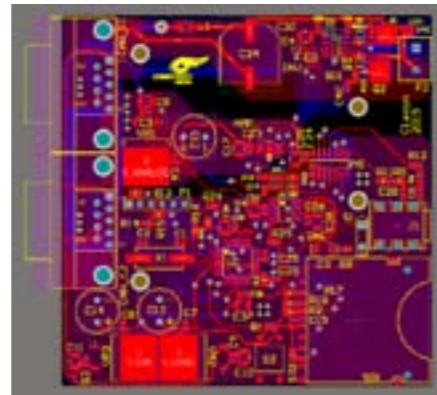
The horn of the H2ZERO is a component that might be a bit over-engineered. With the famous saying “Better safe than sorry” we started designing our noise source so that there would be no chance for the other modules to panic and fail due to excessive voltage drops. The old horn was off-the-shelf and required a large amount of power to produce the required sound level. This year the design is based on a standard speaker with a class D audio amplifier, meaning that the horn will become much more efficient, but also a lot more complex in the electronics that generate the sound.

With the use of a class D amplifier, the microcontroller has to generate the data of the required horn sound. While this is possible in theory, an easier solution would be to store the required sounds on an external memory. Adding an SD card opens up the way to an even fancier horn. During the race it will be possible to play all the sounds we like. While the standard horn sounds will be used during the laps, we can intimidate our competition by playing everything else we have available during breaks. To complete our horn/jukebox, we added the ability to play music directly from a line input.

The technical challenges in this module are mostly based around the amplifier. Getting the right signal to noise ratio and making sure the gate driver works correctly are part of the circuit design problems. The other big challenge is making sure everything works together in the software on the microcontroller. The used NXP microcontroller has limited memory and has to process many different tasks, like reading and writing from and to the SD card, communicating via SPI to the DAC, processing the sound files and checking different inputs.

The first prototype of the horn showed that the length of the traces from the gate driver to the gates of the MOSFETs were too long. A lot of electromagnetic interference was present and the communication with the digital devices was severely interrupted when the input voltage was according to the design. It was capable of creating the desired noise however, but only with a lower voltage on the input of the voltage regulators. The revision of the PCB contained shortened gate lengths, together with many other improvements. More thought was put in the design of ground planes as well.

While the horn may seem overkill and a bit like a joke, it does have to pass the technical inspection with a minimum sound level at a certain distance. The added functionality makes it possible to use music and sound as part of the PR, which is worth the effort. Things like this make the Green Team Twente even more fun.



## Want to join Greenteam?

### Who are we?

The Green Team Twente is a student initiative that began at the University of Twente whose goal is to build an ultra efficient car that runs on hydrogen. Every year a team of 20 students join this challenge either taking on part-time or full-time roles. The team encompasses disciplines spanning the educational system at the University of Twente and the Saxion. This includes Electrical Engineers, Mechanical Engineers, Industrial Designers, Chemical Engineers, and International Business Administration. The end goal is the Shell Eco Marathon, a unique race where the winners are determined by efficiency rather than speed or time. Over 200 teams from Europe and Africa join the European edition of this race. The race is currently held Mid-May in Rotterdam, however from 2016 will be moved to London.

### What would you do?

Members of the Green Team Twente partake in various and diverse tasks either on the construction of the vehicle itself or important peripherals. As electrical engineers your expertise in the field will be valuable. It is also a great opportunity to develop your skills and apply what you have learnt into a real world scenario. On top of this you have the chance of widening your capabilities especially in the fields of mechanical engineering, chemical technologies, public relations, fundraising, and day-to-day business operations. Examples of current roles in the car include designing and building a functional car body, motor controller, and fuel cell. Members of the Green Team Twente also have the possibility of doing their minor at the team, as many members have done in the past.

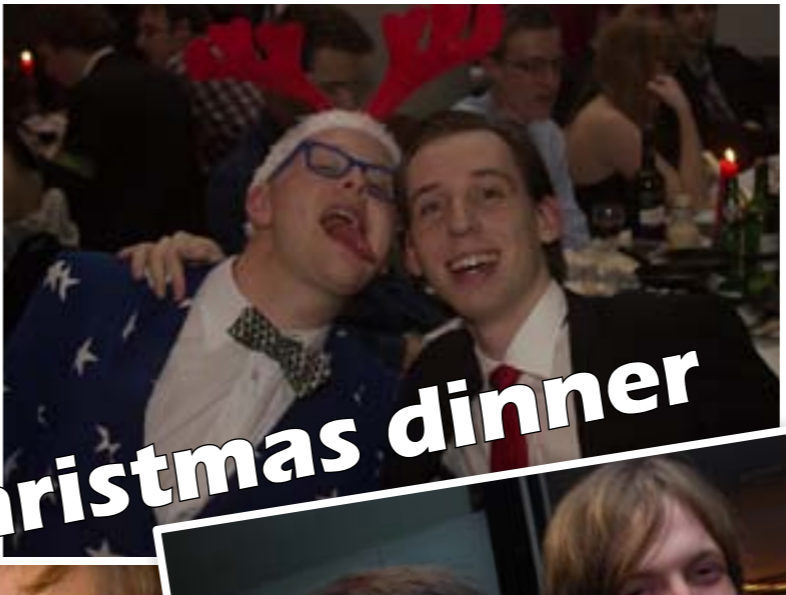
### What we expect?

We are looking for enthusiastic students who enjoy electrical engineering and are willing to sacrifice their time and knowledge for their own personal development. This can either be in full time positions taking a year off your academic studies, or part time positions.

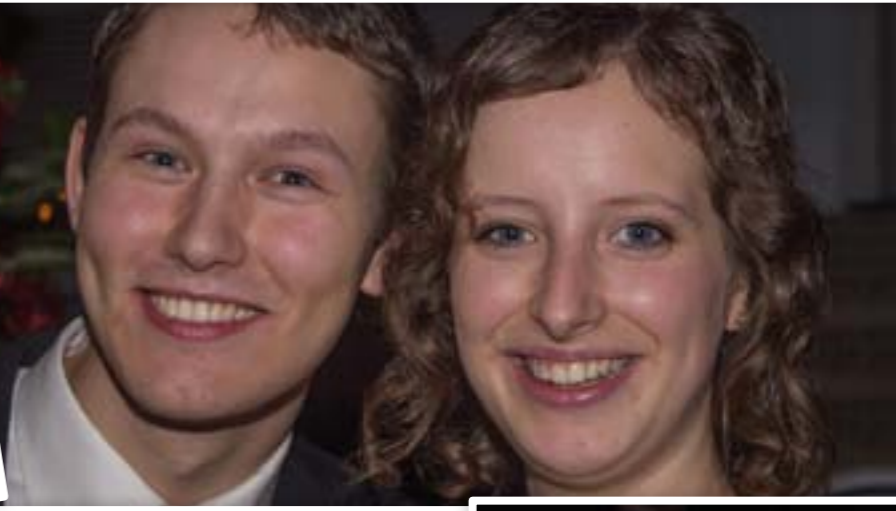
Are you willing to take your expertise to the next level? Contact us at [info@greenteam-twente.nl](mailto:info@greenteam-twente.nl) or talk to one of our current members. You can also come by our place, of course, next to the “Windpark” on the campus. High chance someone will be there.







**Christmas dinner**



**Poker and Klaverjas tournament**



# NXP excursion

Author: Jippe Rossen

It was 10:45AM on a rainy Thursday morning. The first members who signed up for the trip to the NXP factory started coming into the SK with a slightly confused expression on their faces, as our beloved LEX member (Lunch lecture and excursion committee) Robert was still out to fix our means of transport. After a quick count at 11:07 we were ready to head southwards. In two black Renault Meganas and a Volkswagen bus we were on the road with 19 attendees.

As Robert's navigator I was in charge of taking care of the route, which was quite challenging as I wanted to listen to some music on the radio in the mean time. After a rainy trip over the freeway ( we had to drive 50 km/h due to the sight radius being reduced to the windscreen of the car due to heavy rainfall), we arrived at our destination. Surprisingly, we ended up directly behind each other as we approached the terrain of NXP.

After a fifteen minute delay of passport

checking, we were allowed inside and were led to the director's room for the welcome presentation. We passed through several long, curved, white corridors which were decorated with one single painting and multiple escape plans. After this short walk we were given some cookies and coffee and sat down for the presentation.

As is often the case, the presentation started with a general talk about the history of electronics, in which, of course, the expla-



nation of Moore's law and the invention of the transistor could not be skipped. Even though every electrical engineer has heard of these events dozens of times this still brought some new insights. For example, I did not know that the transistor was originally invented for hearing aids. For most uses tubes were sufficient and because of their availability preferred. Only for hearing aids the transistor was useful as it required to be small, light and energy efficient.

"What is the least expensive material: 1cm<sup>2</sup> Silicium wafer, 10m<sup>2</sup> toilet paper or 1cm<sup>2</sup> of gold foil?"

The presentation then shifted its focus to the role of NXP in the development of electronics. Our host started of by asking how many of us were using NXP devices right now. Most of us considered this (correctly) as a trick question. NXP produces over 70 billion products each year. With some rules of thumb and some calculations he eventually calculated that any of us in the room had to have at least 100 NXP products in their possession at any given time! Among these 70 billion products there are small components such as diodes, but it still is



an impressive amount. They also included a nice quiz into the presentation with some trivia about electronics, such as: "What is the least expensive material: 1cm<sup>2</sup> Silicium wafer, 10m<sup>2</sup> toilet paper or 1cm<sup>2</sup> of gold foil?" (If you want to know the answer you can always come to me).

After the presentations the actual tour began and we were divided into 2 groups. Together with the rest of my group I first visited ITEC, the industrial technology and engineering center. This has been operational since 1991, which was before the company was separated from Philips. Here we were received by two researchers which cumulatively had more than 40 years of working experience at NXP. Here, we started of with a five minute video on how their products were tested.

They explained that they would much rather show us the actual process, but unfortunately this was impossible. In the past the demands on electronics were much lower than nowadays. 10 years ago the machinery was still open to be viewed from the outside. Today's demands on the process makes it impossible to work with open systems. All their sophisticated processes are now being done in closed, large, white cabinets that make a lot of noise. The video was still impressive though. Nowadays it takes NXP about 50ms to put a diode die into its package. Sadly for NXP the cost of the most electronic components is only 25% of the

total value, the package in which the component is placed, is 75% of the total price.

"One of NXP's best practices are their testing capabilities."

One of NXP's best practices are their testing capabilities. They found that it was crucial that their components had to have the highest possible standards. In the world of small components, the market is saturated with competitors. If a product is faulty, the customer will simply switch to another supplier and is lost forever. Therefore every component that leaves their factory is tested twice by separate hardware. This to ensure that it is truly their product that is being tested and that they are not subject to the hardware characteristics of the testing equipment. The minimum and maximum values that are listed in their data sheets are tested within a staggering 25ms! If a batch of the product fails to meet these requirements, a different label is printed on them and the batch is sold as a lower grade product, optimizing their profits. The total testing time of each chip is less than 100ms! After this presentation we were lead through one of their design labs to see their work in progress projects.

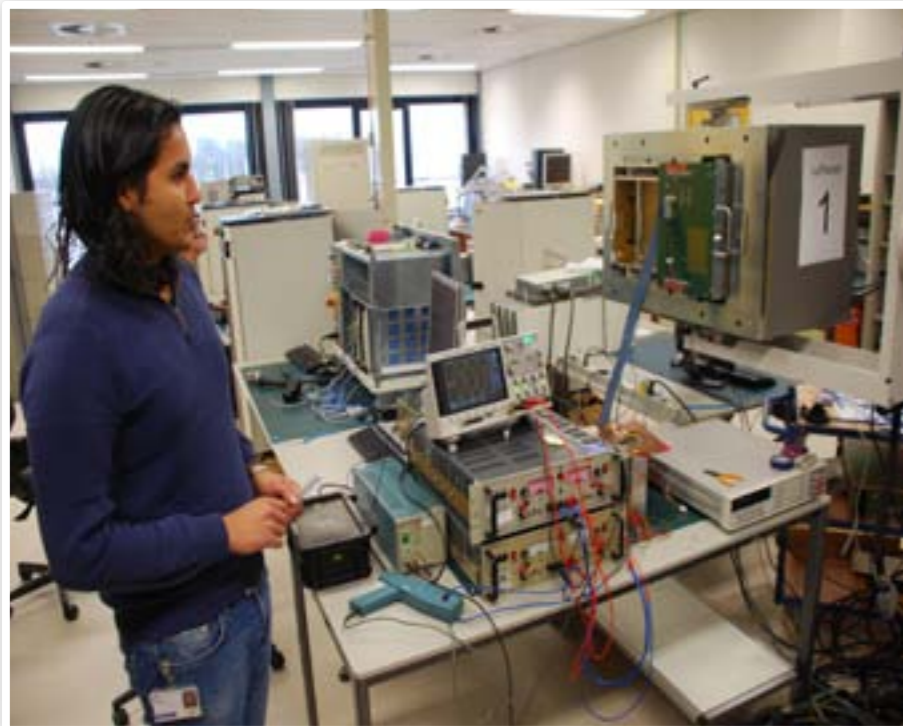
The second part of the visit was a quick

look inside their failure analysis department. NXP produces a wide range of new product ranging from power convertors in Smartphones to RF-transistors. In the design process of these product often problems arise. The product designers will then need to call in the help of the failure analysis department. The department is composed of 40 employees who have over 500 years of analyzing experience combined.

If a new product is faulty the product is analyzed by means of laser scanning. A laser excites certain parts of the circuitry and simultaneously checks whether the response of the circuit is as expected. If a section is faulty the laser beam is set to a narrow beam and the faulty section is scanned again, isolating the problem. The chip is then further analyzed in that section to determine what the cause of the failure was. Sometimes this includes in literally scraping off layers of a die to lay the problem bare.

The failure analysis department is a very demanding (you may also call it challenging) environment to be employed in. The progress in the working field is massive and research is constantly trying to find more efficient ways to pack more transistors on the same amount of space on a chip. Way back a chip consisted of only two copper layers which made testing relatively easy. Nowadays a common chip can have over ten copper layers. Failure analysis therefore has to invest a staggering 2 million USD each year to keep their testing techniques applicable to the current technology.

After a small tour at this site, through several rooms with high-tech equipment, both groups rejoined. At 4:15pm and after handing in our visitors passes we went back to our vehicles. After a short discussion of who went into which car and which cars would drive by the McDonalds, we went home with some great experiences. We have seen how two of the divisions of NXP operate, what the challenges were of both the engineering aspects and the organizational aspects and gained a lot of information about developing and testing electronics. Altogether, we had a great trip and went home with our engineering curiosity satisfied!



# Cooperative adaptive cruise control with CλaSH

Author: Erwin Bronkhorst

In the last decades, technological improvements in hardware are invented every day. This makes hardware better and better, but also harder to use. Especially the parallelism that is introduced is a great challenge for software engineers. The traditional programming languages like C or Java are often seen on general purpose processors, but exploiting parallelism is very hard in these languages. For hardware design, for example in FPGAs, a hardware description language like VHDL is often used. Due to the nature of hardware, parallelism in this kind of languages is quite intuitive, but programming in this language often results in long development times. To describe hardware on an intuitive way while preserving a high abstraction level, the CAES group at the University of Twente developed the language 'CλaSH'.

With this language, one can use a subset of the functional programming language Haskell to describe hardware. For the people who don't know what Haskell or a functional programming language is, I recommend reading [1]. In short, a functional programming language consists of (mathe-

tical) function application which maps inputs to outputs. Due to the fact that the behaviour of physical systems can (often) be described with purely mathematical expressions, a functional programming language is well suited for physical applications.

Going back to CλaSH: this is a language that can be used to describe hardware in. At the CAES group, a compiler (also called CλaSH) is developed which compiles a functional hardware description into fully synthesisable VHDL code which can be programmed into an FPGA, for example.

## CAES Computer Architecture for Embedded Systems

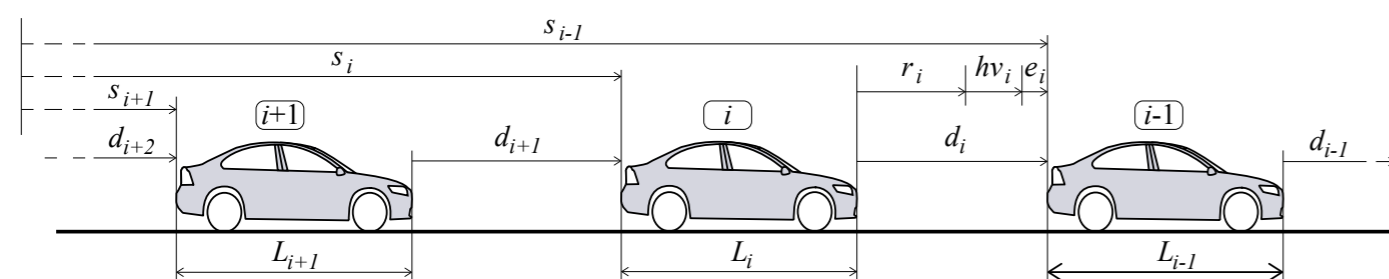


Figure 1: Schematic overview of a string of vehicles

The goal of my master's thesis was to implement a use case for CλaSH, which implements a cyber physical system. The description of these systems into mathematical expressions is quite straightforward and therefore a perfect use case for CλaSH.

The cyber physical system that was chosen for this thesis, is a vehicle string controlled by a cooperative adaptive cruise control system. Most people will know a cruise control, which is able to let a car drive at a constant speed. An expansion to cruise control is adaptive cruise control. This system also makes sure that the distance to a preceding vehicle will not become too small by lowering the speed while approaching a preceding vehicle. Unfortunately, the minimal distance between cars must be set to a relatively high value to make sure no accidents happen when the preceding vehicle suddenly breaks. Cooperative adaptive cruise control (CACC) extends adaptive cruise control by adding inter vehicle communication to the system. A vehicle communicates its actual acceleration (or deceleration) to the vehicle behind it, so the following vehicle can react faster. This can decrease the minimal following distance while increasing the safety performance without degrading the comfort for driver.

The first step for implementing the system (a vehicle string controlled by CACC) was to construct the mathematical description of the behaviour. The chosen description represents a following policy where the desired distance  $d_{ri}$  between vehicle  $i$  and its predecessor  $i-1$  is the sum of a constant distance  $r_i$  and a speed dependent distance  $hv_i$ , which is the product of a constant factor  $h$  (called time headway) and the speed  $v_i$  of vehicle  $i$ . The control error  $e_i$  is then the actual distance  $d_i$  minus the desired distance  $d_{ri}$ , which can be calculated as follows:

$$d_i = d_{ri} - r_i - hv_i$$

This is schematically shown in Figure 1.

The next step was to add a controller to this model, which is able to control the vehicle string with a minimal time headway. This results in small following distances and therefore a better traffic throughput. When controlling a vehicle string, the so called

string stability is very important. A vehicle is string stable if fluctuations in the speed of a vehicle are not amplified upstream. In other words, if a vehicle brakes and the vehicle platoon is string stable, the next car should brake a bit less without crashing into its predecessor. A string stable vehicle string is required to prevent the occurrence of so called phantom traffic jams. These traffic jams are caused by cars that are braking harder than their predecessors, leading to cars that have to stand still eventually. I won't lead you through the design of this controller, but it is important to know that there are three gain factors ( $k_p$ ,  $k_d$  and  $k_{dd}$ ) chosen in the controller in such way that the vehicle string is stable.

The used system model for a vehicle platoon can be described with a matrix representation of the state space equations:

$$\begin{pmatrix} \dot{e}_i \\ \dot{v}_i \\ \dot{a}_i \\ \dot{j}_i \end{pmatrix} = \begin{pmatrix} 0 & -1 & -h & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{k_p}{h\tau} & -\frac{k_d}{h\tau} & -\frac{1+k_d(h+k_{dd})}{h\tau} & -\frac{h+\tau+k_{dd}h}{h\tau} \end{pmatrix} \begin{pmatrix} e_i \\ v_i \\ a_i \\ j_i \end{pmatrix} + \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & \frac{k_d}{h\tau} & \frac{1+k_{dd}}{h\tau} & \frac{1}{h} \end{pmatrix} \begin{pmatrix} e_{i-1} \\ v_{i-1} \\ a_{i-1} \\ j_{i-1} \end{pmatrix}$$

In this matrix representation, you can find the state of vehicle  $i$  expressed in its absolute position  $e_i$ , its speed  $v_i$ , its acceleration  $a_i$  and its jerk  $J_i$ . With this matrix equation, you can calculate the state change of vehicle  $i$  by means of its current state and the state of the direct predecessor. In the equation you can find the time headway  $h$ , the gain factors  $k$  and a time constant  $\tau$ . This time constant represents the engine dynamics.

The core of the hardware description that is made in this thesis is this state space equation. This equation is modelled in Haskell

```
data CarType = Null |
  Car { carid :: Int,
        position :: Float,
        speed :: Float,
        carLength :: Float,
        state :: [Float]
      } deriving (Show, Eq)
```

Figure 3: Definition of a CarType in Haskell

using the forward Euler method, resulting in the code of Figure 2.

“A string stable vehicle string is required to prevent phantom traffic jams.”

In Haskell, you can define your own types consisting of properties that are useful for your specific case. Before I will guide you through the code of Figure 2, I will introduce a new datatype that is defined in Figure 3. In this datatype definition, you can see that an object of the type CarType can have two 'values': a Null value and a Car () value with several properties. The Null value is used in the model as a virtual first vehicle, the 'predecessor' of the first car. All real cars have different properties as you can see. The state-property is modelled as a list of Floats. In this case, the list will consist of four elements, corresponding with the state used in the state space equation. The Show and Eq keywords after 'deriving' indicate that the datatype can be visualized (printed) on screen and that you can compare them, but they are not relevant in this article. It is hard to explain the complete code snippet from Figure 2 if you have no knowledge of

```
drive :: CarType -> [Float] -> (CarType, [Float])
drive car predState = (car', state') where
  car' = car { position = pos',
               speed = speed',
               state = state' }
  Car { state = stateCar,
        position = posCar,
        speed = speedCar } = car

state' = zipWith (+) stateDiff stateCar where
  stateDiff = map (*dt) dstate
  dstate = zipWith (+) (mxv a0 stateCar) (mxv a1 predState)

(._v' :_) = state'
pos' = (speed'+speedCar)*0.5*dt + posCar
speed' = veq + v'
```

Figure 2: Calculation of the state change in Haskell using the forward Euler method.

Haskell, but I will try to explain the basics.

On the first line, you find an optional type declaration. In this case, the line says that the function 'drive' has a CarType and a list of Floats as inputs, and a tuple of a CarType and a list of Floats as output. In mathematical form, you would write something like  $g(x,z) = (n,\dot{g})$ .

The second line is the actual function definition. You can find again the function name 'drive', with both input variables car and predState. After the equals-sign, the output is defined as (car',state'). Please note that a quote symbol is a valid character in a variable name in Haskell and is often used to indicate 'the new' variable. On this line, the output variables have not yet a value, but the 'where' keyword indicates that this will be taken care of on the next lines.

The first thing that is worked out, is the output car' on line 3-5. You can see that it is built up a bit like the datatype definition of Figure 3. All properties in the Car value are filled in. To simplify the mode, the carid and carLength are not used. Unfortunately, the values that are used are still unknown, but because we are in the 'where' clause, we just read on. The line that starts with Car (note the capital) 'extracts' the CarType with the name 'car', that is used in the input, to its different properties. This enables the programmer to use the value of the position, speed and state of the input vehicle individually.

"A higher order function is a function of which an argument is a function by itself."

The line that starts with state' (line 10) is the implementation of the state space equation that is presented earlier in this article. This part requires some extra knowledge of a functional programming language, because it uses a higher order function. A higher order function is a function of which an argument is a function by itself. In this part of the code, the higher order function

'zipWith' is used. The first argument of this function is an addition (indicated by the + sign). The next two arguments are stateDiff and stateCar and these arguments are expressed in the two lines underneath it. The word 'where' here is optional, because we are still in the where-part of the function 'drive', but I have added it here to show that it is some kind of a subfunction or helper function.

As explained before, the zipWith function has a function as its first argument. The next two arguments are lists and the result of the zipWith function is a new list. The zipWith function creates pairs of each element in the lists that are given as arguments and applies the given function to it. So in this case, it adds the first element of each list to each other and that becomes the first element of the resulting list. Next, the second item of each list is added and the result is the second element in the resulting list. This continues until all elements are calculated. In this piece of code, the subfunction expresses the new state as a sum of two things: the state change and the current state. This is exactly what the forward Euler method is: each state variable is added by the state change of that variable to calculate the new state.

As you might know, the forward Euler method uses a time step for the state change. That is what is used in on line 11. Here, we see the higher order function 'map', which applies the function that is given as first argument to each element of the list in its second argument. This can be compared with the zipWith function, but the difference is that in the zipWith function, the function from the first argument requires two arguments (one element of each list) and the function in the map-function requires only one element. In this case, each element of the list 'dstate' is multiplied by a constant dt, which is defined somewhere else in the program.

On line 12, you might identify the state space equation that was discussed before: the change in state is the sum (using zipWith (+)) of two matrix vector multiplications. The matrix vector multiplications are done in the mxv function, which is defined somewhere else in the code. It is not shown

here, but is it briefly described on the last page of this article. You can identify the data that is used for this calculation: a0 and a1 are the constant matrices from the state space equation, stateCar is the state of the current vehicle and predState is the state of the preceding vehicle.

"It is very nice to see that the Haskell code looks very much like the mathematical description that you are used to."

The last three lines are used to calculate the new absolute position and speed of the vehicle, based on the calculated new state. First, the new speed  $v'$  is extracted from the state' and using the midpoint rule for integrating the speed, the new position is calculated. Strictly, the  $v$  in the state of the vehicle is not the absolute speed, but the speed difference with the desired speed  $v_{eq}$ . Therefore the desired speed is added to the speed in the state to calculate the absolute speed. After all these expressions, the 'values' for the outputs car' and state' are known and the function can return the required information.

The code from Figure 2 is only a very small part of all the Haskell code that is used to describe the full behaviour of a vehicle platoon, but it contains the core of the model: the state space equation. It is very nice to see that the Haskell code looks very much like the mathematical description that you are used to. If you have seen Haskell code for a while, it is very intuitive to read and interpret the description. Due to the fact that it looks a lot like the classical mathematical description, no difficult transformations must be done and the model can be translated to a behavioural description quite easily. The real power however comes with the CλaSH compiler which compiles the Haskell code to synthesisable VHDL code. Eventually, we want to convert the model to real hardware so this is an important step.

Before the written Haskell could be compiled using CλaSH, some small changes had to be made to the code. The most important change was that CλaSH does not support floating point numbers. This is because floating point calculations are very expensive in terms of hardware usage. It is a lot more efficient to make use of fixed point numbers. CλaSH provides a prelude for Haskell, which contains different usefull functions and data types. One of them is a fixed point data type. By using the data type that the CλaSH prelude provides, you can define the size of the integer part and the fractional part. In this assignment, I defined my own data type with predefined sizes for the integer and fractional part and called it FPnumber. With this data types defined, I could replace all occurrences of 'Float' in the code with 'FPnumber'. This was an important change but it took almost no effort to execute.

The second thing that had to be changed, was the use of lists. In Haskell, lists have no predefined length: they can grow and shrink during execution. Due to the fact that Haskell is a lazy language, they can even become infinite long. In hardware, however, this is almost impossible to implement. When you think about memory allocation, it is very hard to support lists with variable (or even infinite) length. Therefore, CλaSH does not support lists. The alternative is to make use of vectors, which have a fixed length. In the CλaSH prelude, there is a vector datatype defined and for this assignment I used this datatype to define my own ones. For example, the state of a vehicle was implemented as a list of four elements in Figure 2. I defined a vector 'StateVec' with four FPnumbers in it for the state and a 'PlatoonVec' with five Cars to describe a small vehicle platoon. At the time of my master's thesis, CλaSH had separate higher order functions for vectors. The name of these functions was the name of the equal function for lists, prepended with the letter v. So, instead of zipWith and map, you must use vzipWith and vmap. Fortunately, in the most recent version of CλaSH this is not required anymore and you can make use of the overloaded functions zipWith and map. The change from lists to vectors required some extra changes in the code, but again due to the fact that you can define your own

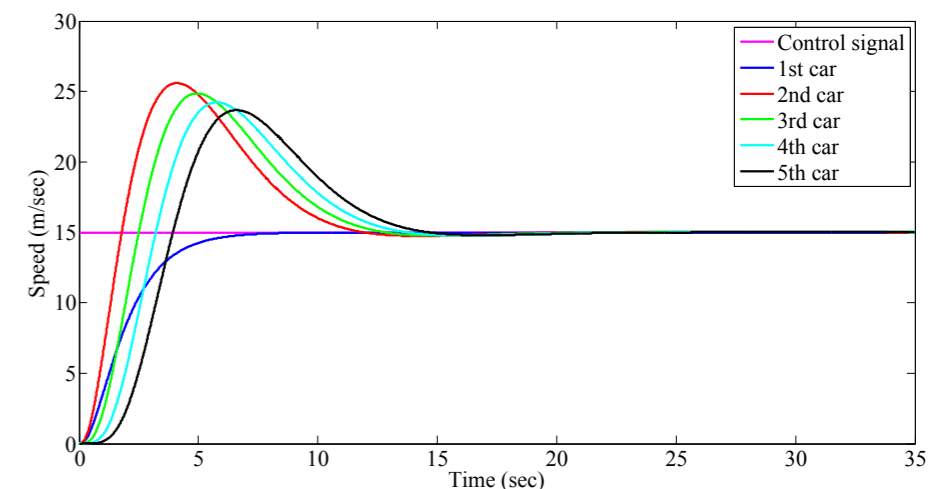


Figure 3: Simulation results of the Haskell code (vehicle speeds).

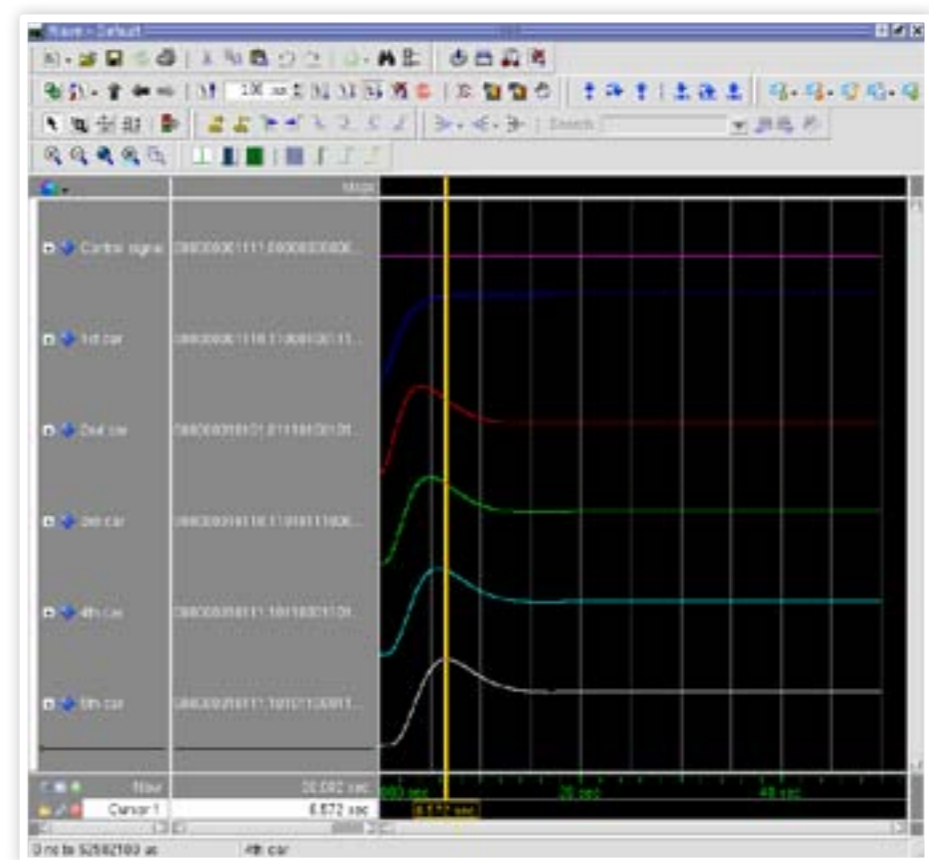


Figure 4: Simulation results of the VHDL code (vehicle speeds).

data types, this change was relatively easy to implement.

After applying these changes to the Haskell code, the code was ready to be compiled by CλaSH, which resulted in VHDL code. The next step of the assignment was to compare the behaviour of the resulting hardware description with the behaviour of the

mathematical description. Therefore, I ran some simulations in QuestaSim. The results of this simulations were compared to the results of the simulations done in Haskell before the transformation to fixed point numbers and vectors. The results were pretty much equal, which is a nice result. One of the simulations that was done, was with a vehicle platoon of five cars. The first car was

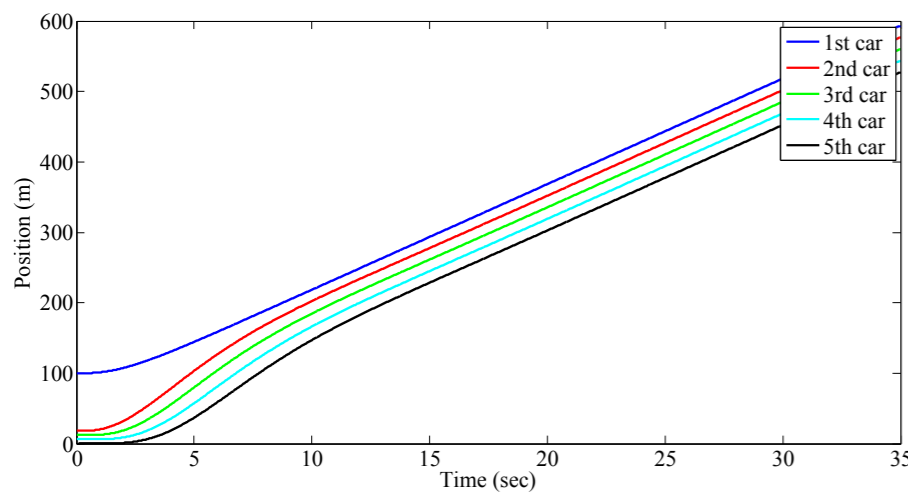


Figure 5: Simulation results of the Haskell code (absolute vehicle positions)

placed on an absolute position of 100 meter. The second car is placed on an absolute position of 18 meter and each following car 6 meters behind its predecessor. The length of each car was fixed on 4 meter and the standstill distance was set to 2 meter. The desired speed was set to 15 m/s. Finally, the time headway was set to 0.7 seconds. With these values, the cars will eventually all drive at a speed of 15 m/s at an equal distance of 16,5 meter (including the vehicle length). In Figure 3 you can find the vehicle speeds over time for the simulation of the Haskell code. In Figure 4, the same results for the VHDL simulation are shown. Looking to Figure 3, you can see that the front vehicle smoothly drives to a speed of 15 m/s. Each following vehicle first have to reduce the inter vehicle distance. For example: the distance between the first and second car is 82 meter, where the desired distance is 16,5 meter. Therefore, the vehicles will first accelerate to a higher speed, but eventually

string stability, in which the fluctuations in speed are attenuated upstream. If you compare the results of Figure 3 with the ones from Figure 4, you can see that the shapes of the lines match. For this research, I exported the exact values of the simulation results of the VHDL code to a text file and plotted them with MATLAB the same way I did for the Haskell simulations. I chose not to show this image, because on this paper size, the difference could not be seen. There are some very small differences due to the rounding errors in the fixed point number conversion, but the behaviour of the system is unchanged.

In Figure 5, the absolute position of the vehicles is plotted over time. You can see that the vehicles start too far from the leading vehicle and that they decrease the following distance at the start. After 10 seconds, the desired inter vehicle distance is reached and the distance is kept for the rest of the simulation.

The simulation results gave a good confidence in the correctness of the compilation from Haskell code to VHDL. Due to time limitations, I did not try to run the simulations on real hardware, but the VHDL code that was produced by the CλaSH compiler is fully synthesizable and therefore it can actually run on hardware. It is not expected that the results will differ from the results of the VHDL simulations.

I think one of the nicest things from my master's thesis is the great coupling between

a mathematical description in a format a mathematician is used to can quite easily be written in a functional programming language like Haskell. The biggest advantage of this straightforward conversion is that there is a smaller chance of errors, compared to a more complex conversion to an imperative language like C or Java. With the presence of the CλaSH compiler, the resulting description can be fully automatically converted to VHDL. This again drastically decreases the chance of adding errors in the system, compared to a design flow where you would directly rewrite your mathematical description to VHDL.

“With the CλaSH compiler, the resulting description can be fully automatically converted to VHDL.”

Another very nice thing to see, is te relation between the mathematical description and the actual implementation on hardware. When looking to the RTL (Register-transfer level) view of the generated VHDL code, you can exactly see where which calculation is performed. This is also illustrated on the next page, where I describe the full path from the mathematical description of a matrix vector multiplication to a hardware implementation of that calculation.

I think that with the growing complexity of hardware, we need a change in hardware design and using a functional programming language this can be achieved. The CλaSH compiler has a great potential in the world of hardware design. If you want to read more about CλaSH or if you want to try it yourself, take a look at the GitHub page [2], or contact someone of the CAES group.

- [1] <http://learnyouahaskell.com/introduction#so-whats-haskell>
- [2] <http://christiaanb.github.io/clash2/>

## A matrix vector multiplication in Haskell

To illustrate the strong relation between a mathematical description, a description in Haskell and an actual hardware implementation, a matrix vector multiplication is discussed.

We start with the mathematical explanation of a matrix vector multiplication. With a matrix vector multiplication, you calculate the dot product of each row with the vector and the result is a vector consisting of the result of all dot products. A dot product is the sum of all element-wise products between two vectors. For example:

$$\begin{bmatrix} 8 & 11 & 15 \\ 9 & 18 & 17 \\ 4 & 17 & 13 \end{bmatrix} \begin{bmatrix} 1 \\ 15 \\ 14 \end{bmatrix} = ?$$

So the first step is to split it up in three dot products, one for each row of the matrix. The resulting vector of the three dot products can be found by calculating:

$$\begin{aligned} 8*1 + 11*15 + 15*14 &= 4200 \\ 9*1 + 18*15 + 17*14 &= 5908 \\ 4*1 + 17*15 + 13*14 &= 4592 \end{aligned} \Rightarrow \begin{bmatrix} 4200 \\ 5908 \\ 4592 \end{bmatrix}$$

With this basic information, let's look into an implementation of the vector matrix multiplication in Haskell. It is shown in Figure 6. The function mxv takes two arguments: a list of lists of floats and a list of floats. The first argument, xss, represents the matrix. It is implemented as a list in which where each item is a row of the matrix. The second argument, ys, is the vector. The function mxv uses the map-fuction that is discussed in the article before. In this case,

it applies the function “(.\*.) ys” to each element (each row) of xss. The function (.\*.) is the dot product, which is defined underneath it. The result of the mxv function is a list consisting of all results of this dot products.

The dot product on its turn is defined as an infix function. Infix means that the function operator is placed in between its arguments. In the previous examples, the function name was always placed in front of the arguments. The function (.\*.) takes two arguments: both lists of floats. In the function, two higher order functions are used. The zipWith function was seen before: it applies an operator element-wise to its arguments. This corresponds with one part of the dot product: the first element of one vecor is multiplied by the first element of the other vector, and the second with the second and so on.

The foldl function takes three arguments: a function (in this case the addition), a starting value (in this case 0) and a list (in this case the result of the zipWith function). The list for the first dot product of the given example would be [8, 165, 210]. The foldl function takes its starting value and the first item of the list and applies the given function to it. The result is used as next 'starting value' and the given function is applied to the second element of the list. This continues until the list is empty. The result is in this case the sum of all elements in the list: 4200. Due to the map-function in the mxv function, this dot product is calculated for each row in the matrix and finally, the result is returned as a list.

```
mxv :: [[Float]] -> [Float] -> [Float]
mxv xss ys = map (.*.) ys xss

(.*.) :: [Float] -> [Float] -> Float
xs .* ys = foldl (+) 0 (zipWith (*) xs ys)
```

Figure 6: A matrix vector multiplication in Haskell

The given Haskell code can be compiled to VHDL with CλaSH. When this is done and the VHDL code is synthesized, you can create an RTL view of the resulting hardware. The RTL view of the dot product is shown in Figure 7.

In this view, you see the element-wise multiplications on the left. Each block has two inputs: one element of the matrix-row and one element of the vector (the zipWith function). In this image, the output of the second multiplier is lead to an adder, with the other input connected to 0. The output of that block goes to an adder with the other input connected to the output of the upper multiplier. This continues until the output of the last multiplier is added to the result of the previous additions. This is clearly the foldl-function from the Haskell code.

As you can see, the relation between the description in Haskell and the actual generated hardware is very strong. This indicates that a functional programming language has great a potential when it comes to hardware design. Due to the fact that the conversion from Haskell to hardware is fully automated with the CλaSH compiler, there is less chance of making errors in the design, which speeds up the process and therefore reducing costs!

“I chose not to show this image, because on this paper size, the difference could not be seen.”

slow down to the desired speed of 15 m/s. What also can be seen, is that each next car in the vehicle platoon has a lower maximum speed. This is an indication of the desired

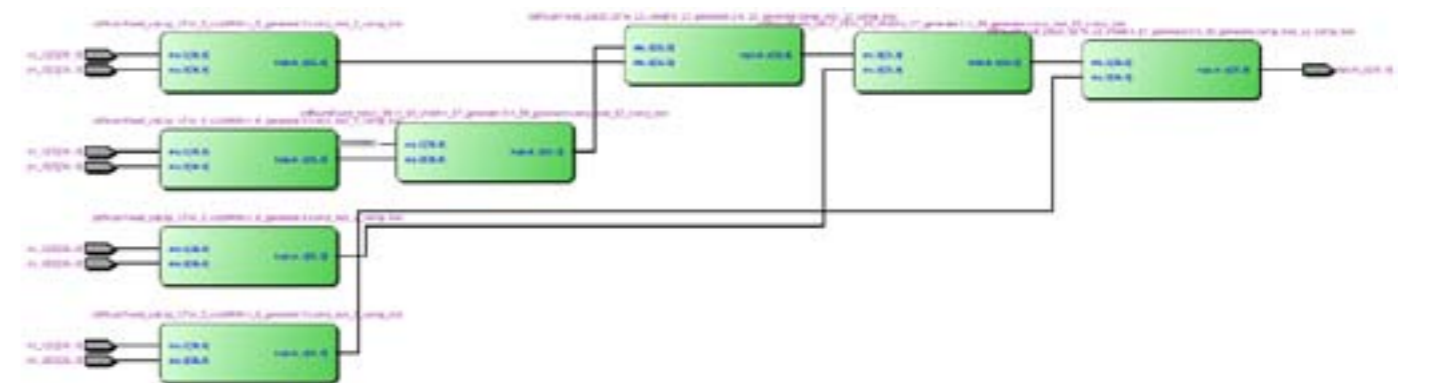


Figure 7: RTL view of a dot product



# Meet de Vonk

*Author: de Vonk*

**During this study year, a lot of the vonk Members have changed. A few people finished their study while some others started studying, both causing them to stop with the vonk. These members have been replaced by mostly second years. Turns out all current members have been raised by Annies.**



Hello, my name is Vera Nauta. I am a third year Electrical Engineering student and I am the editor-in-chief of the Vonk. Being the editor-in-chief, I make sure everybody does their job. Off course I also help layouting de Vonk and making sure authors deliver their articles on time.

When I'm not working on de Vonk, I spend my time on ballroom dancing, salsa dancing, one of my other six committees, and sometimes even on studying!

Hello reader,

I am Ewoud Vissers, and I am in my second bachelor year now. I joined de Vonk after the activate lunch in my first year.

I am now mostly busy with layouting articles for the Vonk, and together with Tim I am responsible for the final export of the Vonk. This means most of my layout-evenings are spent cursing at the general slowness of Scintilla thin clients. Next to this, I'm also responsible for the Green Team pieces this year, since I'm part of this team.

With the little bit of time I have left I'm also part of the Lustrumbook Committee, and a member of the Musilon Choir at the University.



My name is Jippe Rossen, in the previous edition I already introduced myself as a board member.

As the the commissioner of external affairs, I am responsible for all contacts outside the study association. For the vonk this means that I have to make sure all advertisements



are received in time. I also contact previous members to write articles for the afterlife section. The last task I have is to make sure that the Vonk is running smoothly and that the other editors have everything they need to create yet another wonderful Vonk!

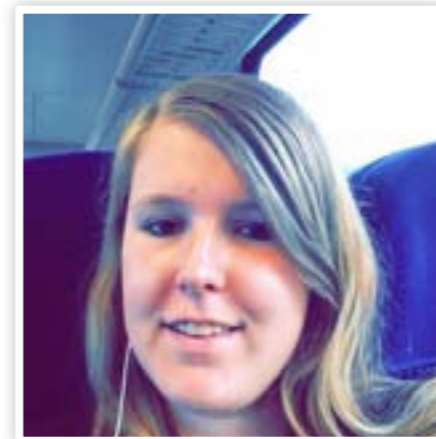


Hello all,

My name is Guus Frijters and I am a second year Electrical Engineering student. Since the beginning of this college year I am active in the Vonk. I started working with the Vonk at the end of last year, when Ewoud "needed help" with translating an article.

In the Vonk I am mainly responsible for the contact with the main article writers. This means that I get in contact with them and keep in contact with them. I also proof-read and layout articles. From now on I will also be a co-writer of the Junction.

Next to the Vonk I am active in the SKIC and in the Lustrumbookcommittee. When I am not studying or doing things for committees, I am active at NEST (the theatre-association).



Hello,

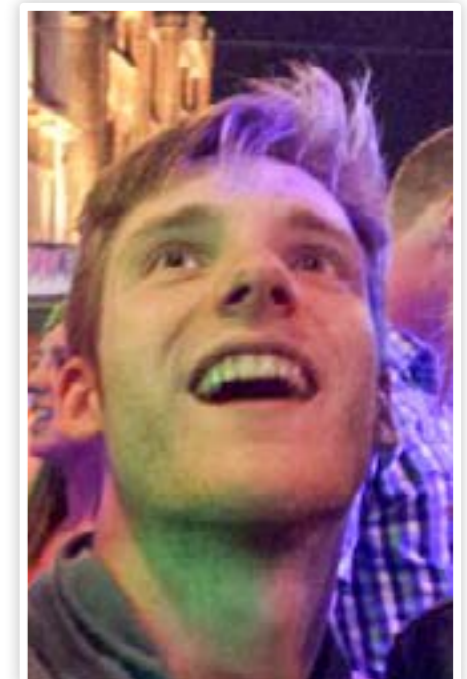
I am Lynn Bruins and I am a first year Electrical Engineering student. I am a famous Electrical Engineer-student by being a female at Scintilla. I joined the Vonk in the beginning of this year when my dogroupparents (Ewoud and Guus) convinced me to join a fun committee.

Within the Vonk I am responsible for the Junction, I make sure we have news in time and I am a productive lay-outer. The Junction, as you all know, is the article where we interview the less-known Scintilleans (or Electrical Engineering related people).

Next to the Vonk I am active in the Gala-committee (for the lustrum) where I am the location contact person. I also play handball at Cabezota.

Hey everyone,

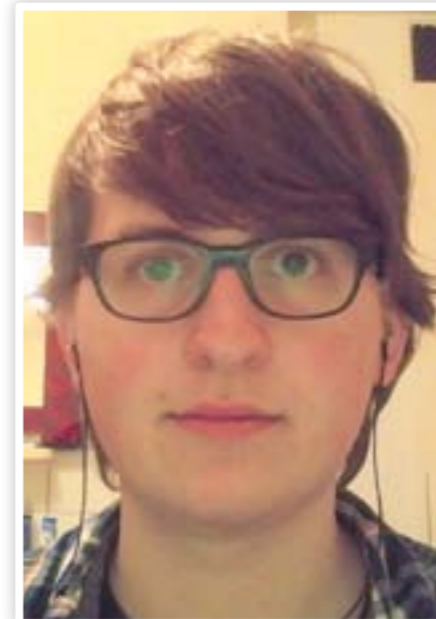
I am Bas Keet. I am now in my second year and I am also one of the awesome persons responsible for the Vonk. I joined this year and it is pretty fun to help Scintilla this way. I basically just do whatever the editor-in-chief tells me to. From chasing people to write articles, to lay-outing them. Other than that I'm also in SCALA and the SKIC. And if that is not enough, I also do survival run and theater, with which come another 3 commissions and a function as candidate board.



Good day!

My name is Pepijn Ekelmans and I am currently in my second Bachelor year. I am relatively new to Vonk, as I joined last September. After being part of last year's Parent's day commission I wanted to do something else, and in the end I decided to join Vonk. I help doing the layout and I make the Puuzles, so if there are any problems with it (again), you can come to me.

As Vonk doesn't take over my whole life, I have to fill up those empty gaps with things such as hobbies. I like watching movies, wasting time on the internet and playing the occasional game. I am slightly addicted to tea and YouTube videos.



# Junction

## Niels Leijen

Niels Leijen is in the middle of his second year as an EE student. With the hovercraft module well under way, we decided to ask him about himself, opinions on the current module, what he does at Scintilla and ways this electrical engineer in training spends relaxing.

You are in the second year of your study, how is it going so far, especially compared to last year?

Up until last quarter, it was going quite well. The parts I enjoyed most were the various projects, especially those last year, like the amplifier and antenna project. Even this quarter's hovercraft project was quite enjoyable, although this module is not going quite as smoothly, as the material was not only quite hard, but often time it wasn't made clear what the professors wanted, or their study materials explained.

Do you feel that is mostly due to the module being difficult, or being presented poorly?

While this module is quite difficult, I feel like the way this module was approached as far as teaching and lectures could have been handled considerably better, as most of the assistance from the professors seemed to be more along the lines of "look it up in the book", rather than an actual thorough explanation of the topic.

What are some positive/negative aspects of the Twente Educational Model?

The best tom module was the 1st module, because the lecture notes were very concise while remaining thorough, while the ones

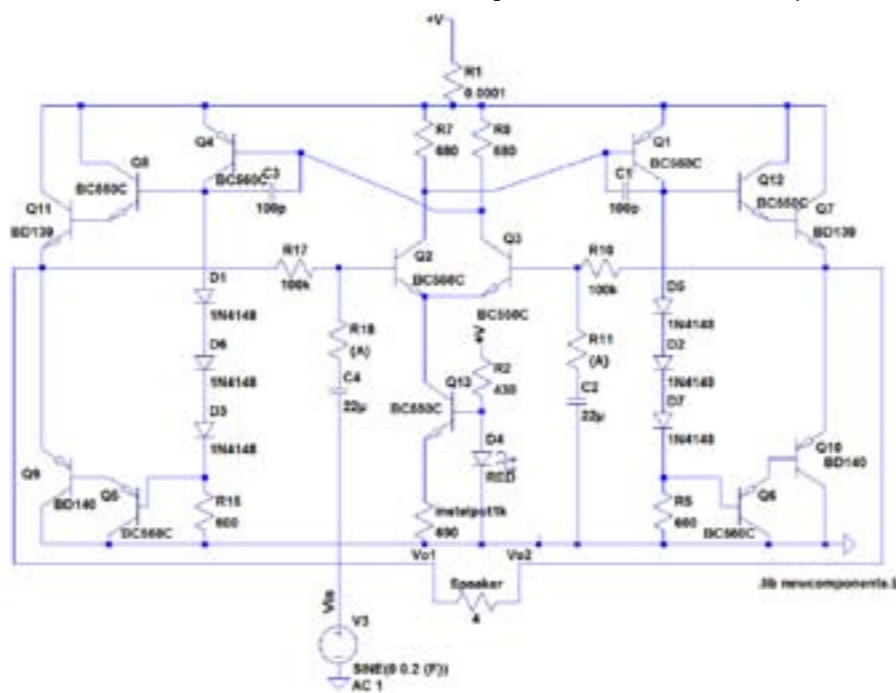
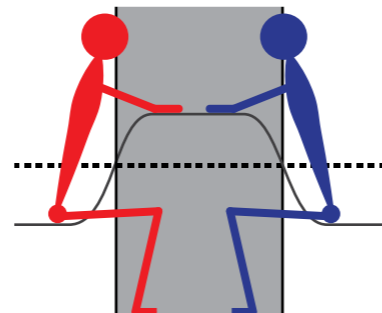
provided for this module seem unnecessarily expanded to a degree where reading them becomes impractical.

Some bad things, is that when you are failing only 1 part of the course, and are sure of your failure, the motivation to study any of the other subjects is totally gone. As a result, however, it forces you to know everything about the module, and keep up with what is being taught.

What do you think of the 4th module last year, with its very TOM-like structure of multiple PBL (problem based learning) sessions every week?

Having the PBL's everyday was similar to having a test, except without the pressure to know all the answers, since you got to do a lot of compact research, and anything you couldn't find, you learned from your peers or professor at the end of the day, the ran-

Author: Maksym Aleksandrovych



## Niels Leijen

Age

19

Study year

Second

Birth place

Den Helder

Favorite Color

No cares given

Favorite Drink

BaCo (Bacardi Cola)

dom element for choosing the presenter also ensuring that you couldn't fall too far behind. You had to learn to teach yourself things, without much student assistant help, so you really learned to figure things out individually, which helps when being a researcher in the future. But if you are stuck at a point in the assignment, you tend to get nothing accomplished until the end of the day.

Overall, what do you do at scintilla?

I'm currently organizing the SKIC. After being a dogroup parent, I thought it would be fun to organize the faculty kick in myself, with some classmates, while also creating fun activities for the new generation of kiddos.

In addition to that, I spend plenty of time drinking tea and coffee, as well as generally supplying my life earnings to scintilla via means of buying a lot of food there.

Is there anything that the study has allowed you to do in your spare time?

Having recently come across some old speakers, I tried using them, only to find out, to my dismay, that the amplifier was not only old, but output a very muddy signal. As a result, I decided to use the knowledge gained in the past year to fix that.

So now I'm currently creating an (differential) amplifier for my speakers, but decided to make it more fun by using only discreet components.

Could you give us a brief overview of the amplifier?

It uses a differential pair with a current source. To amplify the signal, feedback loops are used. For the initial amplification of the input signal, the differential pair is used. Moreover, it assures a high input impedance, which is important in an amplifier of this nature. Afterwards, it gets amplified by a transistor. And finally, a Darlington push-pull pair is used at the output, amplifying the current.

In the end, I ended up combining the knowledge learned during the 3rd module with general experimentation and trial and error within LtSpice, the simulation program used for the circuit.

Outside of EE hobby projects, what do you generally do in your free time?

As a TSAC member, I spend an evening a week climbing. Outside of sports, I tend to fill my time at home with some internet browsing (primarily consisting of Funny Junk and 4chan), as well as videogames, such as League of Legends and Hearthstone.

And most importantly, drinking at scintilla, as it is vital to a fuller EE student experience.



# Exit Night, Enter Light

Author: Tim Broenink

Some of you might be familiar with this story. It is early in the morning and you have to get up for some sort of lecture or another, so with an alarm blaring every few minutes and other measures to get you out of bed, you have to get up. One of the better ways to wake up, or so i have heard, is with a wake up light. I have heard about some projects using high power led bulbs and other powerful sources of light, but i have decided to make my own fusion-powered wake up light.

As it is very unpractical to build and maintain a fusion reactor, especially next to your bed, I decided to use a conveniently available one, the sun. My room had pretty big curtains, and if I would be able to open them when its time to rise, my room would be pretty bright. So I decided to build a system to open my curtains when needed.

The specifications for this system have become a bit extensive, partially due to the fact that the KiCad course at Scintilla allowed me to design a PCB for the system which resulted in a bit of a feature creep. The system was designed to include:

- A system for moving the curtains.
- A connection for a computer.
- A receiver for an optical remote.
- A wireless receiver for a wireless remote.
- A real time clock to keep track of sunrise and sunset.
- A lightsensor and endstops for automation.

With all of this hardware the system should of course be capable of a lot of things. According to my plans the system should of course function as an alarm clock. But in

my opinion it should be configurable via both remotes and have the capability to be extensively configured trough the computer interface. It also should be able to use relative light levels and the time of day to open

“The KiCad course at Scintilla allowed me to design a PCB for the system.”

and close the curtains when the situation requires it. For example, it should open the curtains after the alarm and when the sun is up, and close them when the sun goes down.

In the rest of this article I will detail some of the problems I experienced with the building and designing of this system, which were, in order, The actual actuation of my curtains, a very flexible motor axis, the Julian solar sunset and the large problem of designing a small print to control everything.

For actuating my curtains I decided to use a single motor to control both of my cur-

tains at once. This is done by using a rope and pulley system. This pulls both of the curtains in opposite directions when they move. To suspend this system next to the curtains I used the holes in which the curtain rail was suspended. I places 4 corner strips on these screws which allowed me to place a strip of wood of 5 cm wide and 2 meter 70 long behind the rail. On this wooden rail, the pulleys could be attached with a system to tighten the rope, and a motor with another wheel on the other side. The rope is then attached to the last carriage of both of the curtains and the curtains were tested for movement.



For the motor wheel I tried to use a small dc motor with gearbox like you can get in the stores. These motors have a large yellow wheel with a rubber tire attached to it. This looked ideal for conduction of the rope with sufficient friction. There was a small problem with these motors however. The wheel was attached with a small plastic pin, so when I tightened the pulley and the rope the wheel axle would bend. This did not only result in a lot of extra friction on the wheel, which prevented it from turning, it also resulted in the rope slowly sliding off the wheel. So I had to find a better solution.

Luckily for me I had a heavy nema-17 motor, which I could attach to the wood strip (picture, nema-motor). This motor had a metal axle. This could be easily attached to the wheel by drilling out the wheel a bit. By drilling this hole with a small enough drill the wheel fit very snugly on the axle. With this robust axle the wheel did not bend, and the whole system moved smoothly.

So with the Mechanical and Electromechanical part out of the way, the only problem left was to control this system according to my specifications. For this I designed a circuit board at the Kicad course (see figure below). This board is however not finished at the time of writing, so sadly I am not able to tell about my problems with getting it to work. I have however done some research on how to determine the time of the sunrise, which was, contrary to my expectations, a difficult problem. It might be due to the fact that our system of measurement was not designed for this kind of problems and that our calander is actually pretty impractical, or maybe it was the fact that there are four standards for sunrise.<sup>1</sup>

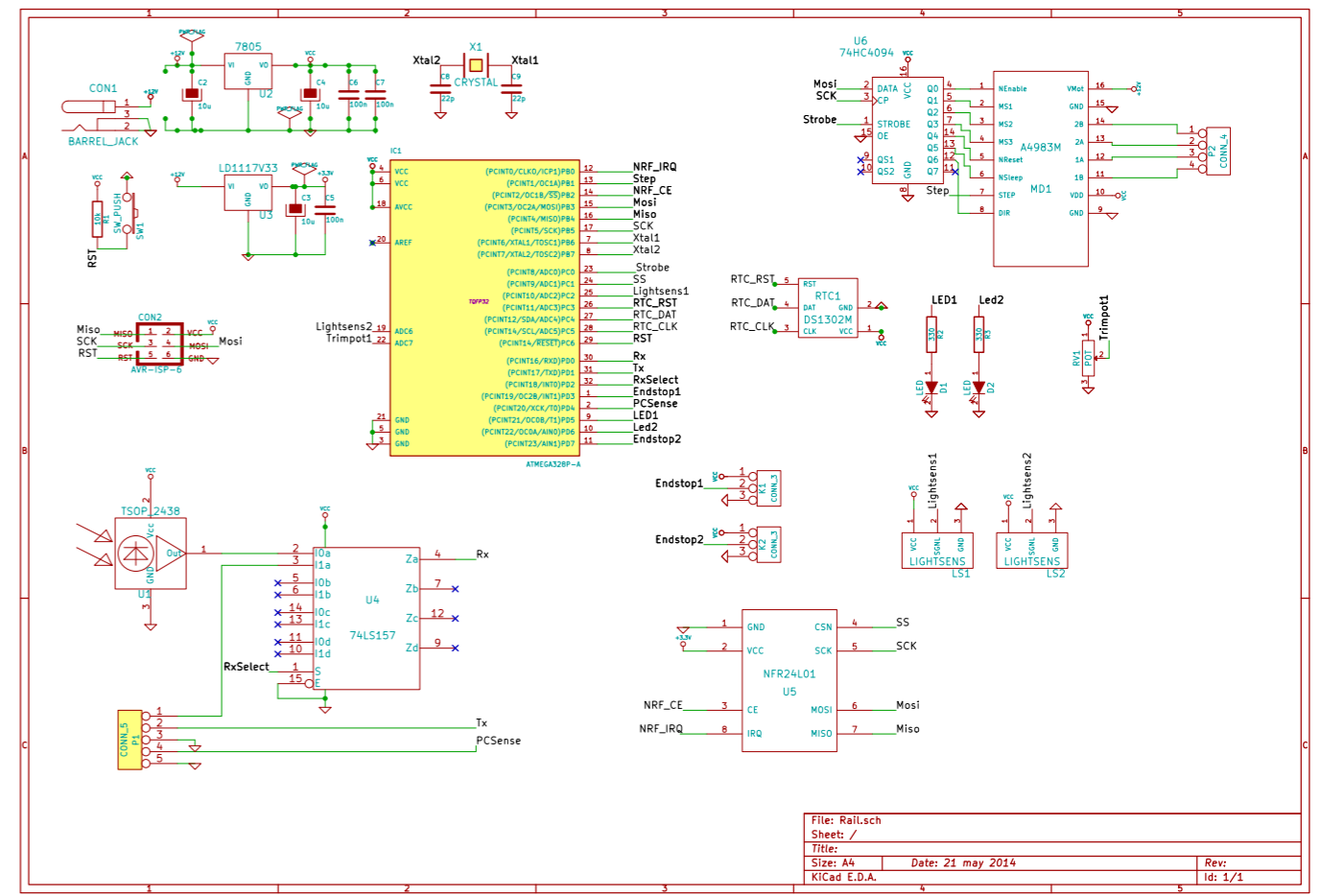
In order to calculate the time of sunrise on a microcontroller I had to:

1. first calculate the day of the year
2. Convert the longitude to Hours and calculate the approximate time.

3. Calculate the mean anomaly of the sun.
4. Calculates the sun's true longitude.
5. Calculate the sun's right ascension and convert this into hours
6. Calculate the sun's declination.
7. Calculate the sun's local hour angle and convert this into hours
8. Calculate local mean time of rising/setting
9. Convert this to the correct time zone.

As all of these calculation depend on the current time, the microcontroller will have to calculate all of them. This, together with the fact that I only understand most of it, makes me happy that the controller only has to do this once a day.

This is as far as I have gotten with this project, but I am sure I will finish it when I receive my PCB. I will still have to wait a bit before I can brag about my fusion powered wake up light, but I think I'll live.



<sup>1</sup> I could find four standards, there might be even more

# Scarface

*Author: Dieuwertje ten Berg*

I have been living in a student house for more than four years now. All that time I have shared a kitchen and bathroom with ten people, of whom eight guys. Sharing your space with a different species can be really frustrating, but also really interesting. And the discovery of yesterday evening is one in the category interesting. I was brushing my teeth, and one of my housemate was shaving. And you know what, a guy shaving is quite similar to a woman putting on make-up.



I shall explain my thought a bit more deeply. First of all, there are a few ways (as most of you know) for a guy to shave. Electric or with a razor, but for now I would like to focus on shaving with a razor. The razor is comparable with the tools a woman uses for

“A guy shaving is quite similar to a woman putting on make-up.”

her make-up, it's like a foundation brush. So these really nice flip out razors (you know, the kind that James Bond uses) are like the most fancy brushes that you can buy from MAC. And there are less fancy razors and there are also less fancy brushes. And as always with the differences in quality and prices, people have different preferences. Everyone has to discover their own preference. There was a discussing in my flat once, about razors and shaving cream. And before I knew, there were like six different razors on the table, different kinds of shaving creams and oils. I never knew that there were so many products on the market. And this is again really similar to make-up. I have tried over ten different foundations, just to find the one that has the perfect shade and

makes my skin look flawless. And with every foundation came the search for the perfect method to use the product. Some products work better with a brush and others work better with a sponge.

But the thing made me realize the similarities the most, was the way that my housemate was putting on his shaving cream. You know, when a woman puts on her make-up, she makes all these weird faces just to get every corner and make it perfect. When a guy is putting on shaving cream, or shaving, he makes the exactly the same weird faces. And it is actually kind of funny to watch.

“Things that might have nothing to do with each other, can be more similar then you would think.”

So the moral of the story, things that might have nothing to do with each other, can be more similar then you would think. And that makes me wonder what hidden difference and similarities there are out there. It might help us understand things better.

And the second moral; I'm so happy that I don't have facial hair. If I would have to shave my face it would probably be a blood-bath. I would totally look like Scarface or the Joker. No, make-up is way more save, a nice soft brush to swipe your face with, no blood involved. And if you don't like the result, you can just take it off!

“I'm so happy that I don't have facial hair.”

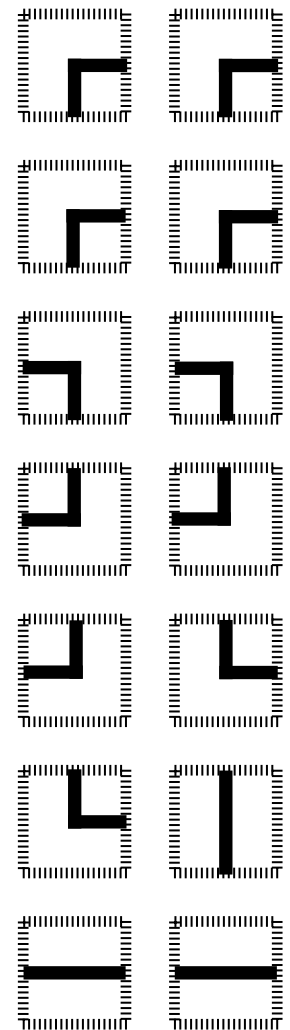
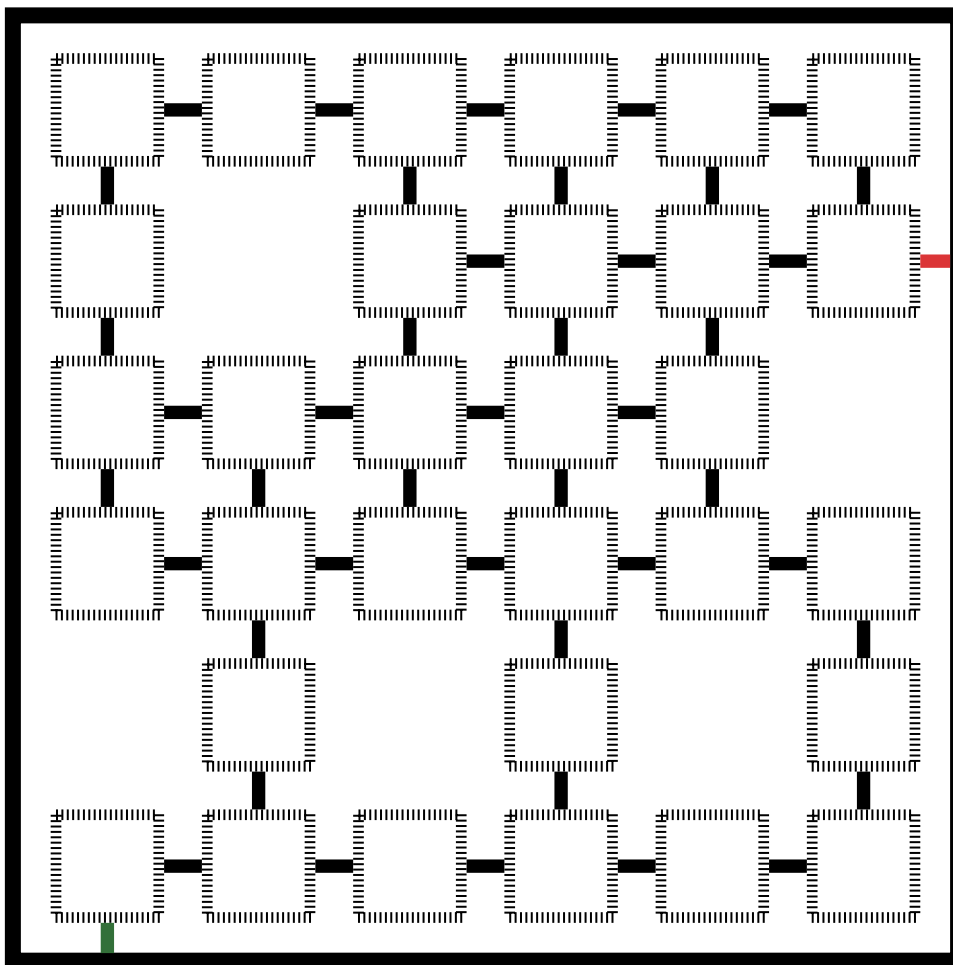
So, that were my crazy thoughts for this time. Hopefully I haven't insulted too many people with my comparisons, or roped you off your 'manly feeling' when shaving. But maybe there can be a little bit more patience when the make-up of your girlfriend/housemate/sister/mom takes a bit longer, because you wouldn't leave the house with a halve shaved face either.

Love,

Dieuwertje


# Puuzle

*Author: Truusje*



## Vierdenkar

Truusje bought some old junk from the vierdenkar for her project. What first seemed like a treasure, appeared to be broken ICs which purpose is now only to conduct electricity from one port to another. The circuit board appears to be partially broken as well, since a few spots are completely unusable. Despite the huge setback, Truusje tries to make the best of it and wants to create a “circuit” that connects the green input to the red output. The circuitboard is built in such a way that the ICs can only be put on the circuit board in the orientation displayed in the picture above. If Truusje wants to get the most out of her money and use every IC, in how many different configurations can she do it? Mail the amount of possibilities with every possible configuration to [truusje@scintilla.utwente.nl](mailto:truusje@scintilla.utwente.nl), and maybe you will soon be the proud owner of a delicious cake.



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