MAXWELL

Exploring the EE departments
Wireless and Mobile Communications

Single-photon avalanche diodes
High accuracy photon detection

MIDI
The digital musical standard explained

Hier invoegen: p2NI.pdf

From the Board

Dear Members,

At this time it is already getting really cold, snow is falling and the roads are getting slippery. The last time I wrote a piece for the Maxwell the temperatures were warm and you did not need a thick coat to protect yourself from the cold. Since then a lot of activities have taken place.

The new yearbook has been presented. In this book the whole situation of the ETV last year is published. You can get your own copy at the ETV desk. As the Board we went to Wageningen to go "grond-boren", were we got to know the students of Wageningen. The DTC switched boards last quarter. We went to eat with them at the Breintje Beer to congratulate them and wish them luck this coming year. We visited a lot of Members of Honor of the association. It was interesting to talk to these people, because they could tell us about the study, the past of our association and the faculty. The commissioner of external relations and I went to a lot of important companies to talk about the excursions and everything they could do for us.

Every third Tuesday of the month our members enjoy a drink at Kobus Kuch. This is organized by the Kobus Kuch committee. Since the 19th of October we have a new committee and they invite you to come to the next drink. The drink is every third Tuesday of the month at the Kobus Kuch, on the Beestenmarkt.

We also went to a party in Utrecht, to socialize with the students there. If you want to join us at one of these parties or if you want to go to a party in a limousine you can always ask us. Of course we do give priority to the students who help us in a committee.

On October 22nd and 25th there were a lot of High School students who came to take a look at the TU Delft to orientate themselves in choosing the right university.

On the 9th of November we went to the Biomass Power Plant. We went with an entourage of 10 students from the ETV and from the association for Aerospace Engineering. It was an interesting experience to learn how we can build such

things, and to learn what a Biomass Plant does and how it works.

The Halloween after-drink was also a great success. We also had a Beaujolais afternoon where members could drink the newest wine of the season. Two of the Board members went to Novi Sad, Serbia to learn about the other Electrical Engineering student associations in Europe.

Last quarter there were two 105th anniversary events: the 21 game evening and the "Lustrum Voorproefje". Both activities were fun.

We noticed that at all the activities we see usually see the same people. It is nice to see that those people have discovered that our activities are interesting and fun to go to, but we still want to have a lot more people have fun during our activities and we want to know why they do not want to come. If you could tell us the answer we would be very pleased!

We will see you all at our future activities! On behalf of the entrepreneurial Board,

Tobias Dekker, President

Editorial

Maxwell is never finished. What I mean to say is, there is always work needed on the next edition even if work on the current one is being wrapped up. As a matter of fact, if that doesn't happen, we usually get in trouble. The most interesting articles are not rarely the ones that take at least a few months from conception to the moment we receive the finished article in our inbox.

The fact that work on Maxwell always continues became even clearer when I was doing my internship in the United States at the end of last year. Through Erik Theunissen, who wrote us an article on the topic of Avionics for edition 13.3, I was able to get in touch with a Delft alumn who is now a professor at Ohio University. I was working there on research for a project that was considering the use of infrared cameras on airplanes to give pilots a view of the runway under bad visibility conditions. Apart from the project, the internship gave me a great insight into the way Americans live, work and relax. Immersing yourself in a different culture also helps to see what defines your own culture. All in all it was a very fun, interesting and valuable experience.

While I was there I was obviously unable to attend our weekly meetings, so I only knew what was going on through emails being sent among the committee. However, proving that the Maxwell committee also works across borders, I was still able to deliver the cover story for Maxwell 14.1 about flexible solar cells.

As you can see, the committee didn't stop working after that, but continued working hard to get you this new Maxwell. But enough about work. Enjoy reading!

Maarten Kastelein
Editor

Contents

11

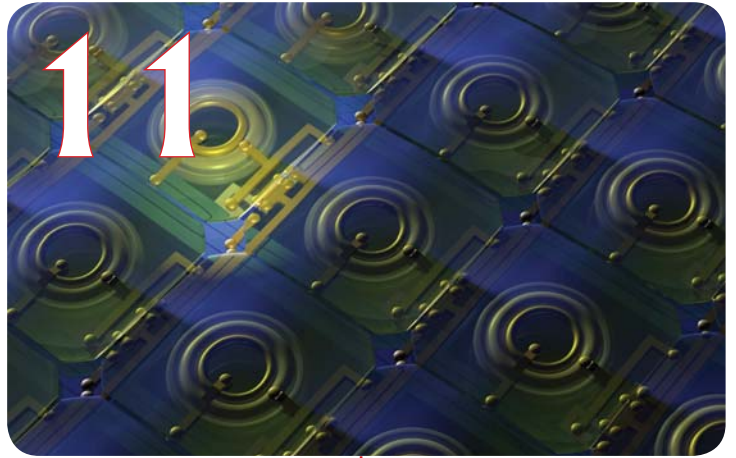**MIDI: the digital standard for musical instruments** 🇬🇧

16

SPADs: high speed photon detection 🇬🇧

Circuit bodging: The game of life 🇬🇧
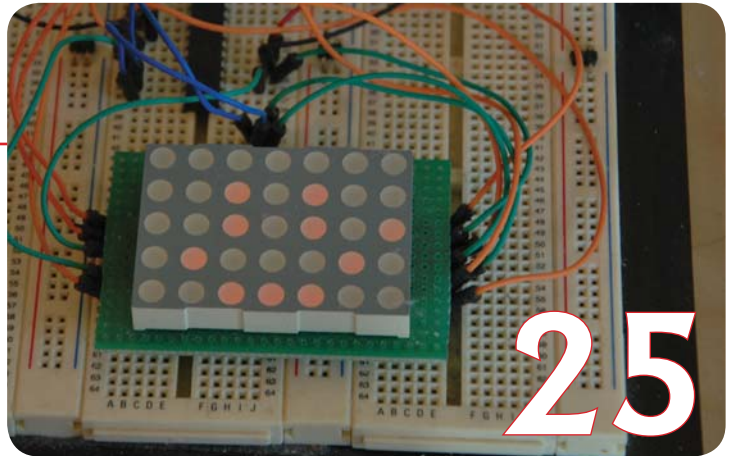
25

Newsflash
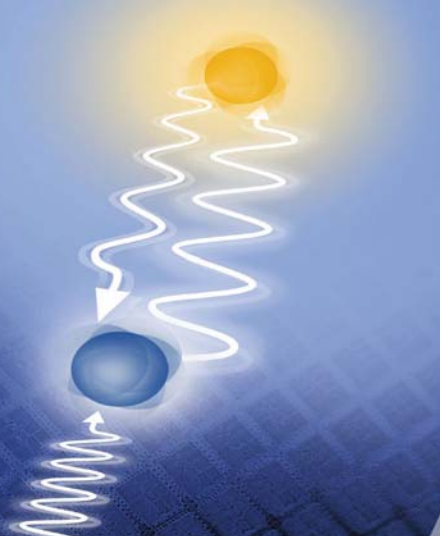
Beamsteering: aiming wireless communication signals to improve efficiency and capacity

Mobile devices like cell-phones, tablet PC's and E-readers use WiFi or 3G to communicate. Currently the antennas used in these devices send the desired signals at equal strength in every direction, which has two main downsides. Naturally, omni-directional communication means unnecessary power consumption, and secondly it causes a lot of interference, increasing the required network capacity.

Researchers from Rice University (Houston, US) have studied the effects and possible implementation of beamsteering. The principle is communication using a beam that is mainly aimed in the desired direction. There are two main variables determining the optimal operating point (using as little power as possible while maintaining enough capacity to ensure reliable communication) of beamsteering: the number of antennas used and the transmitted power.

Currently, the researchers have developed an algorithm called BeamAdapt, that approximates the optimal operating point on the client-side. Using four antennas – of a size that can alledgedly already be built into current mobile devices – and BeamAdapt, the researchers were able to reduce the power consumption by 55% in a simulation test. ⏚
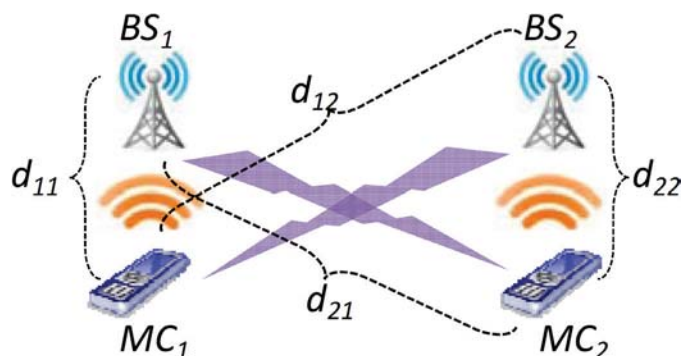
Figure 1: Two-link network with two base stations and mobile clients.

Nanophotonics: optical interconnects between chips for increased bandwidth

Conventional IC's use copper wiring for interconnects. This technique is enough to make supercomputers with calculation speeds in the magnitude of teraflops, but it is too slow to go to the next level: exascale (106 teraflops) supercomputers.

In order to overcome this problem, IBM scientists recently developed a technique that makes it possible to achieve these speeds. By replacing the traditional copper interconnects with a photonic network layer, the communication speed between chips can be sped up to 40 Gbit, which can greatly increase the overall speed of a multi-chip processor.

This is done using conventional CMOS fabrication techniques, adding a few relatively simple steps that add the nanophotonic components. Although these components could already be made, they needed to be assembled from multiple parts. IBM is able to manufacture these components with existing CMOS production lines.

At the moment, IBM succeeded in implementing the optical components for communication between chips. The next step is to replace the interconnects of chips themselves by optical ones as well. ⏚

Figure 2: Impression of the nanophotonic communication layer.

Efficient data-storage using electromagnets

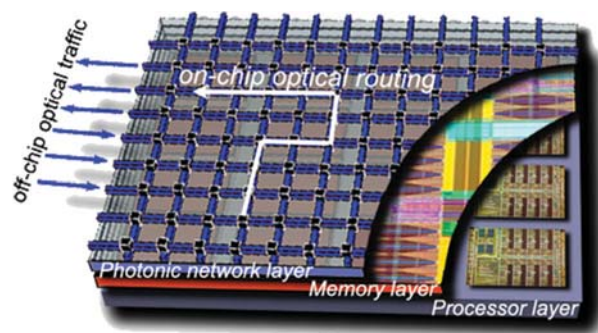It is common knowledge that magnetic data could be written with electric current - in fact, Peter Grünberg and Albert Fert received a Nobel Prize in 2007 for their research that led to this principle. The main problem with this method of magnetic storage was that it requires extremely high currents in order for the data to be written.

Physicists of the TU München stumbled upon a solution for this problem when they discovered a previously unknown magnetic structure in a manganese silicon-cristal: a lattice of magnetic vortices. Using 'spintronics' (utilising the magnetic field caused by the spin of electrons), the physicists were able to influence these magnetic vortices.

The interesting thing about this technique is that a current which is about a million times smaller than the one used in previous tests with current-driven data writing is enough to

Figure 3: A computer image of the magnetic vortices.

change the magnetic vortices in a measurable way, which allows very energy-efficient data-writing.

This technique was previously thought impossible, since electrons shouldn't have been able to change a magnetic vortex. Quantum mechanical effects, however, allow for an electron's spin to react to the vortices enough to make them start to move.

These magnetic vortices are very stable, but at the same time they are anchored in the material very weakly - allowing them to be changed easily by low currents. In time, this technique could be applied to make considerably faster and more power efficient hard drives. ⊕

'Invisible' tank using active camouflage

Modern military vehicles are camouflaged by painting them in an inconspicuous pattern, using the general colours of the environment. Naturally, this is not very sophisticated, as the terrain in which the vehicle should 'dissappear' constantly changes while driving - increasing the chances of being detected as well as risking both the vehicles and, more importantly, the soldiers driving them.

To make the next step in making military vehicles less noticable, a British company called 'BAE systems' is developing an active camouflage ("e-camouflage") system, and applying this system to several military vehicles, ranging from small, robotic reconnaissance vehicles to bigger, infantry-carrying ones. Ultimately, the system should be applicable to full-sized tanks as well (Figure 4).

To achieve active camouflage, the engineers used highly sophisticated electronic sensors

which are attached to the vehicle's hull. These sensors capture the surroundings of the vehicle in detail, sending them to the second part of the system: electronic ink. This 'ink', which is applied to the entire outside of the vehicle, then displays an image of what is behind the vehicle - in other words: what you would see if the vehicle would not be there.

The choice for electronic ink instead of more conventional display technology is made mainly because of the fact that electronical ink only requires energy while changing the image, so when the vehicle is not moving, the active camouflage system doesn't require any energy.

The project is still in development, so there is not much information on the resolution and refresh rate of that this system should be able to achieve. BAE systems claims, however, that working prototypes should be available in about four years. ⊕

Figure 4: Impression of the active camouflage system on a tank.

Activiteiten van de Electrotechnische Vereeniging

Siemens excursie
Auteur: Bas van Wee

Op dinsdag 9 november zijn we met acht leden naar Siemens geweest. Samen met de studievereniging VSV brachten we een bezoek aan Siemens en BMC Moerdijk. BMC Moerdijk is de eerste biomassacentrale van Nederland die werkt op kippenmest. We kregen eerst een uitgebreiden presentatie over BMC Moerdijk bij Siemens in Den Haag. Hier kregen we uitgelegd over hoe de centrale werkt en welke rol Siemens had in de bouw van BMC. De bouw van deze centrale besloeg een tijdsspanne van meer dan tien jaar, waarbij alle technische disciplines wel aan bod kwamen.

Hierna vertrokken we in business class naar Moerdijk waar we een rondleiding door BMC kregen. We begonnen bij de controle kamer. Van hieruit wordt de volledige centrale in de gaten gehouden. Dat gebeurt uiteraard 24/7. Buiten aangekomen waren alle installaties goed te zien. Meteen vielen ons de rook filters op. Hier gaat de rook na het verbranden door heen om alle schadelijke stoffen en as uit de uitstoot te halen. Hierna liepen we langs de losplaats voor kippenmest waar eerst de kwaliteit van de mest gecontroleerd werd. Mocht dit niet hoog genoeg zijn, dan werd er zaagsel bijgevoegd. Eenmaal binnen aangekomen was de enorme verbrandinginstallatie te zien. Hier wordt de mest in naar binnengepompt en verbrand. De ketel hing als het ware in de centrale. Zoals bij vele centrales wordt de warmte gebruikt om water om te zetten in stoom die weer een stoomturbine aandrijft, en die weer een generator aandrijft. Een driefasige synchrone machine uiteraard.

Het voordeel van deze centrale is dat er minder mest geëxporteerd hoeft te worden en dat er minder CO_2 uitstoot is. De BMC krijgt zelfs 10 euro per ton kippenmest om te verbranden. Ook is het voordeliger voor de boeren, die anders de mest voor 50 euro per ton naar het buitenland moeten brengen. Naar mijn mening was het een erg geslaagde excursie en ik ben een stuk wijzer geworden over andere manier van energie opwekken. ⏺

De lift was de enige plek waar foto's gemaakt konden worden. Desalniettemin een zeer informerende foto.

TenneT excursie
Auteur: Richard Spijkers

Het koste enige moeite om het terrein van TenneT Station Bleiswijk te vinden. Uiteindelijk kwamen we alsnog op tijd aan. Ter plaatse kregen wij een algemene presentatie over TenneT en net name de locatie Bleiswijk. Daarna kregen wij een interessante rondleiding over het terrein. Daar zoemden transformatoren van enkele miljoenen euro's op een karakteristieke 50 Hertz. Bovendien werd aandacht besteed aan de werkwijze en de veiligheid en instandhouding van het elektriciteitsnet. De nieuwe Wintrack mast, waarover in de vorige maxwell een uitgebreid artikel was, kwam ook aan bod. Na de lunch legde een Phd'er uit hoe de nieuwste techniek op het gebied van foutdetectie werkt. Daarna kregen we nog uitleg over het bouwen van de nieuwe Wintrack mast, en keerden wij huiswaarts. ⏚

De nieuwe WinTrack masten

Bij TenneT werden de nieuwste hippe hoogspanningsvoorzieningen te zien.

Lunchlezingen
Auteur: Richard Spijkers

Siemens

Voor het eerst in dit academisch jaar vonden lunchlezingen plaats, die dit kwartaal vooral op de Power master waren toegespitst. Siemens mocht de spits afbijten met een lezing over Smart Grids en de mogelijkheden om het huidige energiesysteem in Nederland te verbeteren. Nieuwe technieken op het gebied van energiebesparing werden toegelicht, als ook het idee om van elk individu een energieleverancier te maken. Elk huis heeft later waarschijnlijk een nieuwe CV, die zowel warmte als elektriciteit opwekt. Dit zorgt niet alleen voor een rendement van 100%, maar ook voor een snelle reactie op de flexibele vraag van energie. Als eigenaar profiteer je ervan, omdat je de elektriciteit voor een veel hogere prijs kan verkopen aan degene die het nodig heeft.

TenneT

Het tweede bedrijf dat een lunchlezing gaf, was TenneT. Deze lunchlezing ging vooral over het in stand houden van het Ne-derlandse elektriciteitsnetwerk. Een groot gedeelte is namelijk sterk verouderd en moet vervangen worden, waar de nieuwe Wintrack masten nu ook gedeeltelijk voor zorgen. Voorts was de heer Meijer een uitstekend voorbeeld van wat je kunt doen na je afstuderen: wel iets met Elektrotechniek, maar veel minder wat je hebt geleerd.

Movares/Infraflex

De laatste lunchlezing van dit kwartaal werd gegeven door Movares, georganiseerd vanuit Infraflex. Ze gaven een interessante toelichting op de tractiesystemen van treinen. In bijna elk land in Europa hanteert men een ander systeem om treinen aan te drijven. Movares is nu bezig met het ontwikkelen van een nieuw soort openbaar vervoer op middellange afstand en het verbeteren van de huidige complexe situatie van het aandrijven van treinen. De lezing werd afgesloten met een filmpje van tests en het uitdelen van fietslampjes. ◉

De olieborrel was erg leuk.

De kerstlunch was een groot succes! Hmmmmm.

ETV Mailing Lists

Ben jij op zoek naar een baan, stage- of afstudeerplaats? Schrijf je dan in voor de Bedrijven Mailings.

Op de nieuwe website van de ETV is de mogelijkheid gekomen voor maillijsten. Je kan je inschrijven in het menu 'Voor Leden' en vervolgens 'Maillijsten'. Hier vind je ook de mogelijkheid om je in te schrijven voor de EESTEC-uitwisselingen.

Are you looking for a job, internship or graduation project? Subscribe for the Company Mailings!

The new website of the ETV supports mailing lists. You can subscribe yourself through the 'For Members'-'Mailing Lists' menu.

Hier invoegen:
p11Frames
.pdf

SPADs in CMOS

When Physics Meets Engineering

More than Just Photodiodes

Single-photon avalanche diodes (SPADs) are a class of photodiodes biased above breakdown; in this mode of operation, known as Geiger mode, the devices are capable of detecting one or more photons with high timing accuracy. SPADs are useful in a variety of applications where picosecond timing accuracy, >100dB dynamic range, and high readout speed are requirements [1]. Integrating SPADs in planar silicon processes is a relatively recent achievement that has propelled this relatively unknown device onto quasi-stardom [2]. But, while the physics of solid-state SPADs is well understood [3], it is only with the advent of devices integrated in conventional CMOS processes [4], that the evolution onto smaller and smaller feature sizes has rapidly advanced to the point that it has now become possible to envision large imaging systems based on SPADs.

Author: Prof.dr. E. Charbon

The engineering journey that led researchers to CMOS SPADs was one that lasted several years with a number of intermediate, often suboptimal solutions. The first challenge in building a SPAD is prevention of premature edge breakdown that occurs in sharp edges at the boundaries of the implants, where the electric field is high. To reduce the electric field in regions at risk, one generally reduces the doping locally. The design of doped regions has to be done carefully to prevent that the depletion regions developing at high bias voltages extend too far under the active region or that the doping differential is to small to prevent edge breakdown. Due to the standardization of CMOS processes, the choice of doping profiles is often limited, and the engineer must become creative to better combine what is available to achieve the desired result, with a minimal impact to performance. This is why many researchers decided to opt for dedicated processes that could be continuously optimized for SPADs [2].

Moore than SPADs

We chose a different route and pursued exclusively standard CMOS technologies, so as to be able to ride Moore's Law in terms of miniaturization and density growth. The rationale was that if performance had to be traded off for size, it would be possible to recover that performance loss, at least partially, with design and digital signal processing techniques. The techniques generally used in CMOS processes have in common the reduction of the electric field at the edges and everywhere else in the

device, so as to maximize the probability that the avalanche is initiated in the center of the multiplication region. This is the region where the critical electric field for impact ionization is reached and, possibly, exceeded.

The edges of the junction must be protected from high electric fields, to avoid premature edge breakdown (PEB). Figure 1 (left) shows one of the most common SPAD structures, a ring-shaped
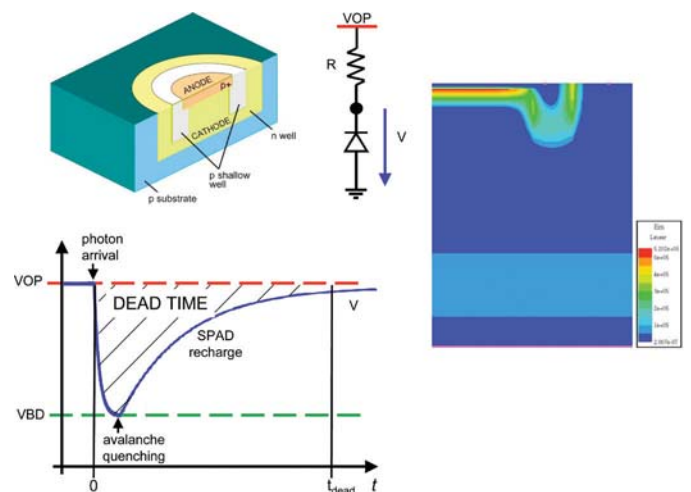

Figure 1: Premature edge breakdown prevention mechanism in planar and semi-planar processes (see text). Clockwise: a 3D cross-section of a SPAD, the schematic of passive quenching circuitry, a simulation of the electric field distribution around the guard ring in idle state, an electrical response of the SPAD from idle state to photon absorption.

junction with a lightly doped guard ring for PEB prevention. A complete characterization of this type of device is found in [5].

SPAD Farms

Ideally, the optimization of SPAD structures should occur by way of design and modeling, and validated through simulations, both at the process and device levels. However, since process parameters are often undisclosed to designers, these tools, though useful, may prove a panacea to the real solution: test structure design. This is why designing a SPAD in a new CMOS process more often requires several iterations and continuous optimization work over the years.

In our designs we used all the breakdown prevention mechanisms shown in Figure 1, whereby special care was given to the layer mask selection and to the size of the guard ring implants. Even though PEB is effectively suppressed, the resulting SPAD may still exhibit high dark count rates. This is generally due to band-to-band tunneling that is greatly dependent on the doping profiles of the layers where the multiplication region is confined. While doping levels should be kept within appropriate limits, they should not be too low, to prevent the depletion region to extend to other regions of the device, thus creating an ohmic contact to them, and consequently preventing proper biasing to achieve Geiger mode of operation.

In general, there exist configurations that enable the design of SPADs with no modifications to the process, thus enabling the design of large SPAD array chips in standard CMOS technologies. However, typical SPADs implemented in CMOS are the result of a lengthy optimization process generally involving at least one so-called SPAD farm. SPAD farms are systematic studies of typically two or three families of structures implementing different guard rings or detection paradigms. For each family of structures, a number of parameters, typically three, are varied in a systematic and logical fashion, so as to facilitate testing future designs. The testing of the farm is usually accomplished in several steps involving process, supply voltage, and temperature characterization (PVT). The most promising structures are also equipped with integrated quenching and decoupling electronics, so as to test the dynamic and saturation properties of the devices. A small SPAD farm is often added in every new design, so as to skip development steps and continue improvements.

From one Working SPAD to a Complete Image Sensor

Once a SPAD is fabricated, the challenges of making an image sensor are far from over. In fact, quenching and recharge mechanisms also need to be designed in the same technology.
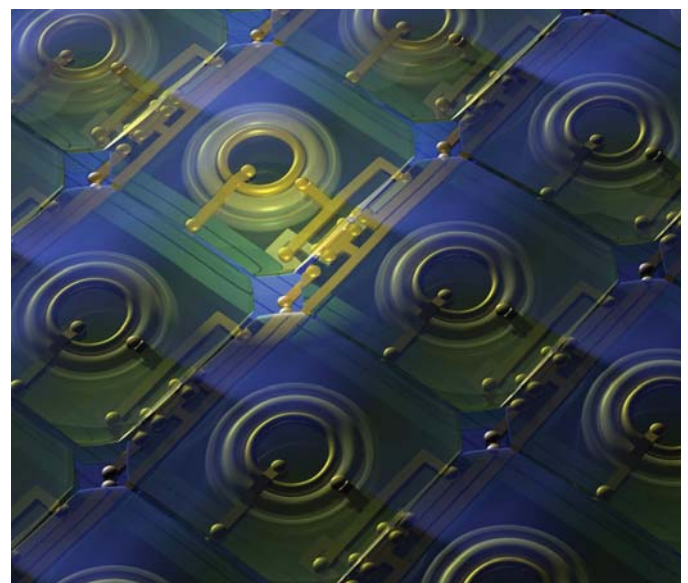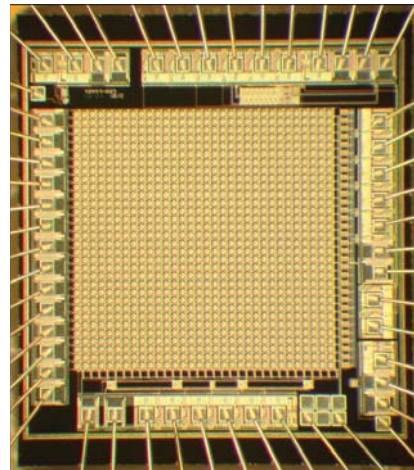

Figure 2: Artist's rendering of an imager based on a SPAD array with microlenses for partial fill factor reclaim. On top the photomicrograph of the first reported large-scale SPAD array [5].

The quenching circuitries stop the avalanche thus preventing the destruction of the device, while the recharge circuitries prepare the SPAD for the next detection cycle by raising the bias voltage again to the initial stage. Two modes for quenching and recharge exist: active and passive. In active mode, active circuitries are used to control the process. In passive mode, the avalanche current is passively controlling the process by way of a ballast resistive device. The advantage of using an active quenching and recharge is a better control of the detection cycle and in particular of the overall time spent in the quenching and recharge, known collectively as dead time. Dead time is an important parameter, as it determines the maximum count rate of a detector and thus the saturation intensity. A variety of active quenching and recharge circuits can be found in the literature whereby the differentiating factors are complexity as well as dead time programmability and stability. One of the most important considerations in the selection of the best »

possible recharge mechanism is simplicity, when it comes to miniaturization.

Individual SPADs are characterized by their sensitivity, measured as photon detection probability (PDP), the noise performance, measured as rate of spurious pulses due to thermal events, or dark count rate (DCR). Other parameters include timing jitter, also known somewhat inappropriately as timing resolution, afterpulsing probability, and, as mentioned earlier, dead time. These parameters have appeared in the literature for individual SPADs and SPAD arrays implemented in a variety of CMOS processes. See [6] for a review.

Outlook for SPAD Arrays

When implemented in an array, other performance measures become relevant to the quality of the imager. Besides dead time uniformity, timing jitter uniformity and PDP uniformity, as well as DCR uniformity and crosstalk have to be accounted for and properly characterized [5]. PDP of course will also be a function of the input wavelength. In CMOS SPAD implementations, the sensitivity range is mostly in the visible spectrum, with somewhat reduced near infrared and near ultraviolet PDP.

Crosstalk may be electrical and/or optical. Electrical crosstalk is the interference between pixels. It may be caused by a temporary drop of sensitivity and DCR in a victim pixel due to the drop of excess bias voltage. The latter, in turn, may be caused by a neighboring aggressor pixel as an avalanche is triggered. Similarly, substrate noise originated in one or more pixels may be picked up by the victim pixel and a spurious avalanche may thus be triggered. Optical crosstalk may occur when an avalanche is triggered in the aggressor pixel. By impact ionization, several photons may be emitted, thus causing a victim pixel to detect it. While electrical crosstalk is strongly dependent on the design of supply lines and of substrate noise rejection measures, optical crosstalk may only be influenced by the number of carriers involved in an avalanche and by pixel pitch.

All these issues are becoming more and more relevant with the introduction of deep-submicron SPAD implementations that show more of the non-idealities of their larger counterparts but at a much larger scale, due to the potential of more massive arrays being implemented in CMOS [7].

ACKNOWLEDGEMENTS

REFERENCES

[1]   E. Charbon, *"Will CMOS Imagers Ever Need Ultra-High Speed?"*, IEEE International Conference on Solid-State and Integrated-Circuit Technology, 1975-1980 (2004).

[2]   S. Cova, A. Longoni, and A. Andreoni, *"Towards Picosecond Resolution with Single-Photon Avalanche Diodes"*, Rev. Sci. Instr., 52(3), 408-412 (1981).

[3]   A. Spinelli and A. L. Lacaita, *"Physics and Numerical Simulation of Single Photon Avalanche Diodes"*, IEEE Trans. on Electron Devices, 44(11), 1931-1943 (1997).

[4]   A. Rochas et al., *"Single Photon Detector Fabricated in a Complementary Metal–oxide–semiconductor High-voltage Technology"*, Rev. Sci. Instr., 74(7), 3263-3270 (2003).

[5]   C. Niclass, A. Rochas, P.A. Besse, and E. Charbon, *"Design and Characterization of a CMOS 3-D Image Sensor based on Single Photon Avalanche Diodes"*, IEEE Journal of Solid-State Circuits, 40(9), 1847-1854 (2005).

[6]   E. Charbon, *"Single-photon Imaging in CMOS"*, SPIE Optics+Photonics, NanoScience Engineering, Single-Photon Imaging, (2010).

[7]   M. Karami, M. Gersbach, E. Charbon, *"A New Single-photon Avalanche Diode in 90nm Standard CMOS Technology"*, Optics Express, 18(21), 22158-22166 (2010).

Contact details Edoardo Charbon:
e.charbon@tudelft.nl
HB 17.310
phone +31 15 278-3667
fax +31 15 278-6190
cas.et.tudelft.nl

The facultary student council

Author: Erik Roeling

Faculty student council update

In the previous Maxwell we published an article about the general activities of the student council. In this article, we would like to inform you about our recent activities and tell you a bit more about some of our 10 main point of concern.

Recent activities

These past few months the Financial situation of the faculty was one of the topics that had a relatively high priority. This is because the faculty has to present a budget for the next year in January. While doing this our main point of concern is the education. They may cut expenses, but education cannot be neglected or compromised. We also talked about the financial reassessment. It is (slowly) being implemented as we speak.

Besides this important point, the new lecture halls have drawn our attention. As most of you will know this summer the university renovated two of our lecture halls. Unfortunately there are some things that need fixing and they need to be fixed soon. We made a list of all the problems and looked for solutions. Unfortunately this is harder than we anticipated, because the lecture halls are not owned by our faculty but by the university.

The beautifully reconstructed Ampère lecture room.

But that is not all; we are also trying to let people know there is a student council and why we are here. A few of the things we do to accomplish this is publishing in Maxwell and giving a short talk before your classes. This we do because there are still too many people that do not know of our existence.

Moving on, last month we recieved some complaints about the lockers. They seemed to be in use all the time. To solve this, the lockers will be emptied each morning so you can only use them during the daytime. It is our opinion that more lockers should be available during daytime from now on.

Dean Rob Fastenau.

Maybe you already know, but since January we have a new dean. The student council has spoken to him and we are of the opinion that he will be a fine dean. His name is Rob Fastenau. Prof. Dr.ir. Fastenau studied Physics at TU Delft where he gained his doctorate in 1982. After his doctorate he worked as researcher and research group leader at Philips Research in Eindhoven and in Sunnyvale, California. In 1995 he transferred to Philips Electron Optics, which later merged with FEI Company. For the past ten years he has served on the board of directors at FEI Company, market leader in electron microscopes. During that time FEI expanded greatly, not in the least because of its fast-paced, successful product innovation. ⏚

MIDI over USB

Towards the end of the 1970s, electronic musical instruments became far more affordable and widespread, and as a result their use became more prevalent. However, most instruments from different manufacturers communicated differently, and as such many rock bands included a keys section with the keys player surrounded by pianos and keyboards. It soon became obvious that it would be useful to be able to control multiple instruments with one keyboard and MIDI was born.

Author: Ben Allen

Before the advent of digital signal processing, most synthesisers were large analogue behemoths, with multiple small units such as LFOs and filters built into the same enclosure (see figure 1). The user then used patch cables to string units together and create a specific sound. This is the origin of the word 'patch', which is used to mean an array of settings within a synthesiser or effects unit to create the required effect. Many analogue enthusiasts still exist today, but mainly in a hobby or specialist audio niche, and it is no longer mainstream. Most keyboard players will agree that a small 19 inch rack unit is much easier to carry than a large wooden cabinet. These days, a rack the size of an old analogue synth can hold ten or fifteen different synthesis modules, a far more economic setup.

Figure 1: An average analogue synthesiser from the 1970s.

What is MIDI?

MIDI stands for Musical Instrument Digital Interface. Instead of outputting a waveform, an instrument or sequencer (known as a controller) sends control messages to the target device.

EVENT VALUE	MIDI CHANNEL	PARAMETER 1	PARAMETER 2
4 bits	4 bits	1 byte	1 byte

Figure 2: The composition of MIDI messages.

MIDI messages consist of simple 3-byte messages, which means that MIDI is robust and suitable for use in a musical environment where timing can be critical.

Figure 4 shows the possible event types, and the subsequent interpretation of the provided parameters. Observing the table, a typical MIDI note on message would be *"0x91 0x3C 0xFF"*. In human readable format, this means *"Note on, channel 1, note 60 (which corresponds to central C), with a velocity of 127."* Note that the velocity parameter is a signed 8-bit binary value.

The data transfer rate is surprisingly slow, a meagre 31,250 bits per second. Regardless, this is is fast enough for musical use, but can result in macroscopic delays when using long chains. This has led to the development of MIDI-thru ports, where data is reproduced regardless of its intended recipient. Before MIDI-thru, messages intended for devices on different channels had to be processed by the first device in the chain, first determining if the message needs to be passed along and then reproducing it on its MIDI-out port. This behaviour invariably creates delays and the protocol was subsequently amended.

Now add computers into the mix

Nowadays musical tools are available to everybody for reasonable prices. Sequencing software like Ableton Live or FruityLoops Studio is available in cut-down versions for under US $100. Specialised hardware units can be replaced in a home studio with software synthesisers, most commonly

adhering to Steinberg's VST (Virtual Studio Technology) standard. Of course these would be useless in an on-stage environment, as a computer crash would halt an entire performance. In these situations, a dedicated hardware unit is by far the best option, but in the studio or at home, computers are ubiquitous in the field of music. As such, a MIDI-to-computer interface was required.

Game Ports

When computer sound cards like the AdLib or Sound Blaster cards were first released, they usually included a 2-row D-Sub 15 connector for use with game controllers. This port contained two pins for MIDI in and MIDI out, and before the introduction of USB this was the primary method of connecting MIDI devices to home computers.

Universal Serial Bus

The Universal Serial Bus is something that almost everybody will be superficially familiar with. Anyone who uses a computer will have used it, even if they don't consciously realise it. The precise description of how the USB protocol is implemented and how data is transferred is beyond the scope of this article, but to understand how MIDI data is transferred all one needs to keep in mind is that USB transfers data in packets. After initial communication between the MIDI USB device and the USB host controller, the interface with Digital Audio Workstation (DAW) software is supplied by the USB device driver. Simply put, the device driver recieves MIDI data encapsulated in a USB packet. This is then extracted from the packet and sent to software controlling the MIDI device.

Expanded possibilities

Of course, this has greatly extended the range of different devices available. MIDI was implemented with controlling devices remotely in mind; this allows you to change parameters within a synthesiser module with the same MIDI controller. With the advent and proliferation of DAW software as primary method

of recording and producing music, there has been an increase in demand for MIDI-based devices to control parameters within the software. As such, many different devices have been developed to accomodate this demand. However, they have traditionally been large, expensive, and require an external power supply.

Scaling things down

Building a home studio in the past has required an entire room dedicated to the production of music. In today's world, this is still the standard way to do things for those who can afford both the money and the space, but this is obviously not an option for most people. In recent years, there has been a trend towards producing small, affordable MIDI controllers, such as the Korg Nano series, pictured above in figure 3. These units are about the same width as a 13″ laptop computer, which gives them a huge size advantage for those who wish to control their DAW software with sliders and knobs instead of the mouse, but don't have space for something the size of an analogue mixing desk. The cost of such a unit is around € 50, making them inexpensive enough for anyone. With the smaller size there is of course the disadvantage of reduced functionality, and those looking for a mixer unit with motor controlled faders should look elsewhere, but for the average person wanting to add some musical inspiration to their workspace, these small-sized, affordable MIDI controllers fit the bill exactly. ⏻

EVENT TYPE	VALUE	PARAMETER 1	PARAMETER 2
Note off	0x8	Note Number	Velocity
Note on	0x9	Note Number	Velocity
Note Aftertouch	0xA	Note number	Aftertouch value
Controller	0xB	Controller number	Controller value
Program change	0xC	Program Number	Not used
Channel Aftertouch	0xD	Aftertouch value	Not used
Pitch Bend	0xE	Pitch value (LSB)	Pitch value (MSB)

Figure 4: MIDI event table

DUURZAAMHEID

We moeten anders gaan denken, werken, consumeren, …

Duurzaamheid is een sleets begrip geworden. Een begrip ook, waarin je zo ongeveer alles kwijt kunt, en dat bijgevolg bijna betekenisloos is. Toch komt het in gesprekken met TNO'ers steeds weer naar voren: sleets of niet, duurzaamheid is pure noodzaak. Een kwestie van overleven, niet meer en niet minder.

Auteur: Eric le Gras

Drs. Peter Bosch, projectleider klimaat bij TNO, zet het op een rijtje: 'Er dreigt schaarste aan water, fossiele brandstoffen, productief land en vitale materialen. De mensheid neemt steeds meer ruimte in beslag voor zichzelf en dat gaat ten koste van natuur en biodiversiteit. Daarnaast is de klimaatsverandering nog lang niet gestopt. Dat alles kan bovendien de verhoudingen binnen en tussen naties verstoren, wat tot onbestuurbaarheid, onlusten, of zelfs oorlog kan leiden.'

Bosch kan ergens een dreigende ramp hebben vergeten, maar de boodschap is helder: duurzaamheid is geen hobby van geitenwollensokken-types maar pure noodzaak om te overleven. En al lijken de problemen gigantisch, er zijn wel degelijk oplossingen. Die zijn deels te vinden in de techniek, in slimme innovaties die kunnen leiden tot huizen die geen energie verbruiken maar opwekken, tot emissieloze wijken of tot alternatieven voor schaarse energiebronnen of materialen.

Maar helaas, daarmee zijn we er niet. Daarop wijst dr. Rob Weterings. Hij is niet alleen teamleider Duurzame innovatie bij TNO, maar ook trekker van het thema 'duurzaamheid' in het Strategy & Change programma van TNO en HCSS, programmamananger van het Comptetentiecentrum Transities (een samenwerkingsverband van het Kennisnetwerk Systeeminnovaties, TNO, SenterNovem en het ministerie van VROM) en auteur van een recent advies over duurzaamheid voor de SER. Weterings wijst erop dat duurzame innovatie ook betekent dat we ons anders moeten gaan gedragen. Duurzaamheid vraagt om nieuwe samenwerkingsverbanden tussen bedrijven, om het verleggen van geldstromen, om een overheid die ruimte biedt aan bedrijven die komen met nieuwe oplossingen voor maatschappelijke problemen, om meer klantgerichtheid bij de ontwikkeling van innovaties. In feite moeten we volgens Weterings compleet anders gaan denken, werken, consumeren en recreëren.

People voorop

Om orde te brengen in die overvloed van problemen, maatregelen, belangen en meningen zijn om te beginnen harde feiten nodig, vindt Toon Ansems, MSc die levenscyclusanalyses, oftewel beoordelingen van de milieueffecten van productieketens, opstelt: 'Ik geef een voorbeeld. We hebben een studie naar worteltjes gedaan. Wat is beter: vers in een papieren zak, verpakt in blik, glas of

karton of net als soep verpakt in laminaat zakken?'

De resultaten waren verrassend. De gezondheidsverschillen waren gering; vers bleek minder goed voor het milieu dan je zou denken. Ansems: 'Vooral doordat er tijdens het transport van verse worteltjes flink wat verlies optreedt vanwege beschadigingen. Als je op de kosten let, dan scoren vers, glas en blik goed. Voor het milieu is vers slechter en maakt het verder weinig uit. Nog een voorbeeld. Veel mensen denken dat je apparatuur zo lang mogelijk moet blijven gebruiken. Maar als je een oud bakbeest van een televisie hebt, dan kan het de moeite waard zijn om die te vervangen. Nieuwe modellen zijn veel energiezuiniger en dat is beter voor je portemonnee en – als je oude televisie netjes verwerkt wordt – ook voor het milieu.'

Eigenlijk speelt er in de bouw net zoiets, zegt prof. dr. ir. Chris Geurts, binnen TNO specialist voor het innovatiegebied Duurzaam bouwen: 'Duurzaamheid bestaat uit de P's van People, Planet en Profit. People, de mens, staat voorop en dat is terecht. Worteltjes die niet goed smaken, zijn net zo min duurzaam als huizen waarin niemand wil wonen.' Bij woningen en bedrijfspanden is op het gebied van duurzaamheid een wereld te winnen: 'Voorbeelden genoeg. Tien procent van de nieuwe dakpannen is bij aankomst op de bouwplaats kapot. De klei die daarvoor is gebruikt, kun je niet hergebruiken en het is natuurlijk ook zonde van het geld. Bouwafval maakt veertig procent uit van alle afval in Nederland. Als je dat beter hergebruikt, dan zet dat zoden aan de dijk.'

Daarvoor zijn nieuwe samenwerkingsverbanden nodig: 'Als de bouw en de energiesector nauwer gaan samenwerken, liggen er vooral voor bestaande gebouwen kansen op het gebied van de energie-efficiency. Dan moet je wel zo'n

300.000 woningen per jaar aanpakken; zo snel gaat het nog lang niet.' Dat stuit wel weer op bezwaren van huurders en verhuurders, die niet zitten te wachten op een huurverhoging. Geurts: 'Daarom zie ik veel in totaalpakketten. Als je naast een lagere energierekening ook een tweede toilet krijgt, dan begrijp je die huurverhoging beter. En houd rekening met de vergrijzing. Een slaapkamer op de begane grond is duurzamer dan een slaapkamer op de eerste verdieping.'

Moreel besef

In de bouw spelen nog andere problemen, zegt dr. Arnold Tukker, die niet alleen voor TNO werkt maar in Trondheim ook hoogleraar Duurzaam innoveren is: 'Veel van de technologie voor duurzaam bouwen is er al. Daarom moeten we, terwijl we innovaties blijven ontwikkelen, concreet aan de slag. In de praktijk lukt dat niet altijd. Gemeenten willen de grondwaarde maximaliseren en daarom moeten aannemers en installateurs overal beknibbelen. In de nieuwbouwwijk waar ik woon, zijn geen voorzieningen voor vloerverwarming aangebracht. Nu hakken sommige bewoners zelf sleuven in het beton. Veel standaardkeukens die de aannemer erin heeft gezet, zijn er weer uitgeslagen. Duurzaam is anders.'

Technisch kan er veel, maar vaak ontbreekt het beleid, zegt Tukker: 'Ik wil niet met doemscenario's komen, maar de urgentie is er. Je moet dus weten waar de drukpunten liggen, hoe je iets kunt bereiken. Je ziet dan vaak dat burgerlijk normbesef en machtige sleutelspelers zoals supermarktketens, bouwmarkten of grote elektronicawinkels een combinatie vormen die het verschil maakt. Max Havelaar en Wereldwinkels hebben sinds de jaren zeventig voor een behoorlijk moreel besef in de markt gezorgd. Grote bedrijven willen geen problemen, ook niet in de toeleveringsketen. Ze verduurzamen die ketens dus en zorgen vaak al voor groene, eerlijke producten in de schappen. TNO heeft goed inzicht in hoe je zulke systeemgerichte veranderprocessen kunt aanjagen. En operationeel kan TNO helpen bij kwaliteitsborging en certificering.'

Biochemicus dr. ir. Ben van Ommen kiest rechtstreeks voor een benadering vanuit de ethische hoek. 'We moeten terug naar het besef dat je als persoon onderdeel bent van een systeem en dat er meer is dan eigenbelang op korte termijn. Als je voor anderhalve euro een kilo kip koopt bij Karel de Knaller, dan negeer je de echte prijs. Net als in de celbiologie: alle eiwitten en genen zijn onderdeel van een samenhangend cellulair systeem. Zodra een eiwit of gen zich onafhankelijk gedraagt, sterft de cel of wordt het een kankercel.' »

Van Ommen is lid van de Wetenschappelijk Raad voor Integrale Landbouw en Voeding en luistert met 'rode oortjes' naar wat zijn mede-leden aandragen: 'Alle oplossingen die alleen uit technologie voortkomen, hoe mooi ook, zijn uitstel van executie. De rol van het individu is essentieel. Hoe kies je voor duurzaamheid? Door betrokkenheid, door een relatie. Die is met voeding letterlijk ver te zoeken. Een gemiddeld voedingsmiddel reist ruim 8200 km voor het op je bord ligt.'

Het gaat om systemen en producten die herkenbaar zijn voor de consument, zegt Van Ommen dus in feite. Drs. Suzanne de Vos houdt zich bezig met de productiekant van de duurzaamheid, en zegt hetzelfde over productieketens van bedrijven: 'Bedrijven zijn een belangrijke schakel in de keten van grondstofwinning tot productgebruik en afvalverwerking. TNO heeft studies gedaan voor het portfoliomanagment van chemische bedrijven. Welke markten die bedrijven bedienen en de manier waarop ze hun producten pro-

duceren, is van invloed op het duurzaamheidsprofiel. Niet-duurzame producten vormen een risico, en omgekeerd bieden duurzame producten kansen.' Volgens De Vos kun je als bedrijf die kansen verzilveren door de productieketen duurzamer te maken: 'Dat begint bij een meetbaar en wat ons betreft kwantitatief inzicht in de effecten van keuzes op het gebied van Planet, maar ook van Profit en People.'

Grondstoffen

Ook geoloog drs. Henk Pagnier besteedt aandacht aan de menselijke kant van duurzaamheid, hoewel zijn ideeën over alternatieven voor fossiele energiebronnen direct te maken hebben met de P van Planet. 'Aardwarmte is duurzaam en in opmars.'

Volgens Pagnier lopen er in Nederland zo'n zestig vergunningsaanvragen voor de winning van aardwarmte; er worden al kassen mee verwarmd: 'Het gaat om winning op twee kilometer diepte. Maar als je dieper gaat, dan is de temperatuur

hoog genoeg om stoom op te wekken en daarmee elektriciteit te produceren. Dat kan in Nederland op een verantwoorde en veilige manier. Ik verwacht wel dat we kritische vragen zullen krijgen van het grote publiek. Maar als we rekening houden met wat er onder de mensen leeft, dan valt het goed uit te leggen.'

Het duurt nog wel even voor aardwarmte massaal toepasbaar is. Vooreerst moeten we het hebben van fossiele brandstoffen en die raken onherroepelijk op. Net als veel andere grondstoffen, zoals onder andere metalen die nodig zijn in batterijen of in allerlei elektronica. Drs. Jeroen Heres is programmaleider Strategy & Change bij het aan TNO gelieerde Den Haag Centrum voor Strategische Studies (HCSS), dat onder andere onderzoek doet naar de opkomst van China: 'Dat land ziet het belang van die grondstoffen. Zo is er een exportrestrictie afgekondigd voor neodymium. Dat is een zeldzaam aardmetaal dat nodig is voor de fabricage van permanente magneten. Deze zijn

zeer belangrijk voor de fabricage van efficiënte elektromotoren en windturbines en daarmee voor de ontwikkeling van alternatieven voor het gebruik van fossiele brandstoffen. Daar zie je hoe schaarste en duurzaamheid elkaar raken.'

Die schaarste kan leiden tot conflicten, zelfs tot oorlog. 'Daarom moeten er alternatieven komen en daarin kunnen Nederland in het algemeen en TNO in het bijzonder een belangrijke rol spelen. We moeten wel keuzes maken. Oplossingen voor de dreigende waterschaarste en alternatieve brandstoffen zouden mogelijkheden zijn.'

Innovatiekloof dichten

Dr. ir. Richard Smokers werkt mee aan het verwezenlijken van zo'n alternatief: de elektrische auto. Die is relatief stil, lokaal emissievrij en biedt de mogelijkheid om te rijden op duurzaam geproduceerde energie. 'Maar ze zijn nog duur in aanschaf, hebben een beperkte actieradius en de oplaadinfrastructuur ontbreekt. We moeten beginnen met nichemarkten, waar de voordelen opwegen tegen de kosten en gebruiksnadelen, en van daaruit opschalen.'

Amsterdam wil bijvoorbeeld voor 2015 binnen de ring van de A10 zo'n 10.000 elektrische auto's laten rijden om de luchtkwaliteit te verbeteren. Vervoerders als TNT zien in elektrisch vervoer mogelijkheden om te vergroenen en daarmee marktaandeel te winnen. Wanneer productie-aantallen stijgen, zal de prijs van batterijen en voertuigen dalen. Smokers: 'Er ontstaat pas een businesscase voor grootschalige toepassing als de kosten laag genoeg en de voertuigen aantrekke-

lijk genoeg zijn. De overheid kan helpen met een fiscaal beleid dat duurzame producten aantrekkelijker maakt dan niet duurzame producten.'

De boodschap is duidelijk. TNO'ers noemen duurzaamheid noodzakelijk en mogelijk, maar we moeten wel radicaal ons gedrag veranderen. Daaraan schort het, maar ook daarvoor zijn oplossingen. Maak duurzame producten en duurzaam gedrag concurrerend en aantrekkelijk, zei Smokers al. En zorg voor een betere aansluiting tussen wetenschappers die innovaties bedenken en ondernemers, voegt Weterings daaraan toe: 'Er zijn genoeg goede ideeën, maar die komen niet altijd van de grond. Dat is de innovatiekloof en TNO kan helpen om die te dichten. Het nieuwe Strategisch Plan van TNO draagt niet voor niets de titel 'Innoveren met Impact.' ⏚

TNO innovation for life

Exploring the EE groups
Wireless and Mobile Communications

In the upcoming Maxwells, we will report on one of the many groups inside our faculty, giving you a general look and also some MSc-students' experiences. Up first: the Wireless and Mobile Communications group, situated on the 19th and 20th floor.
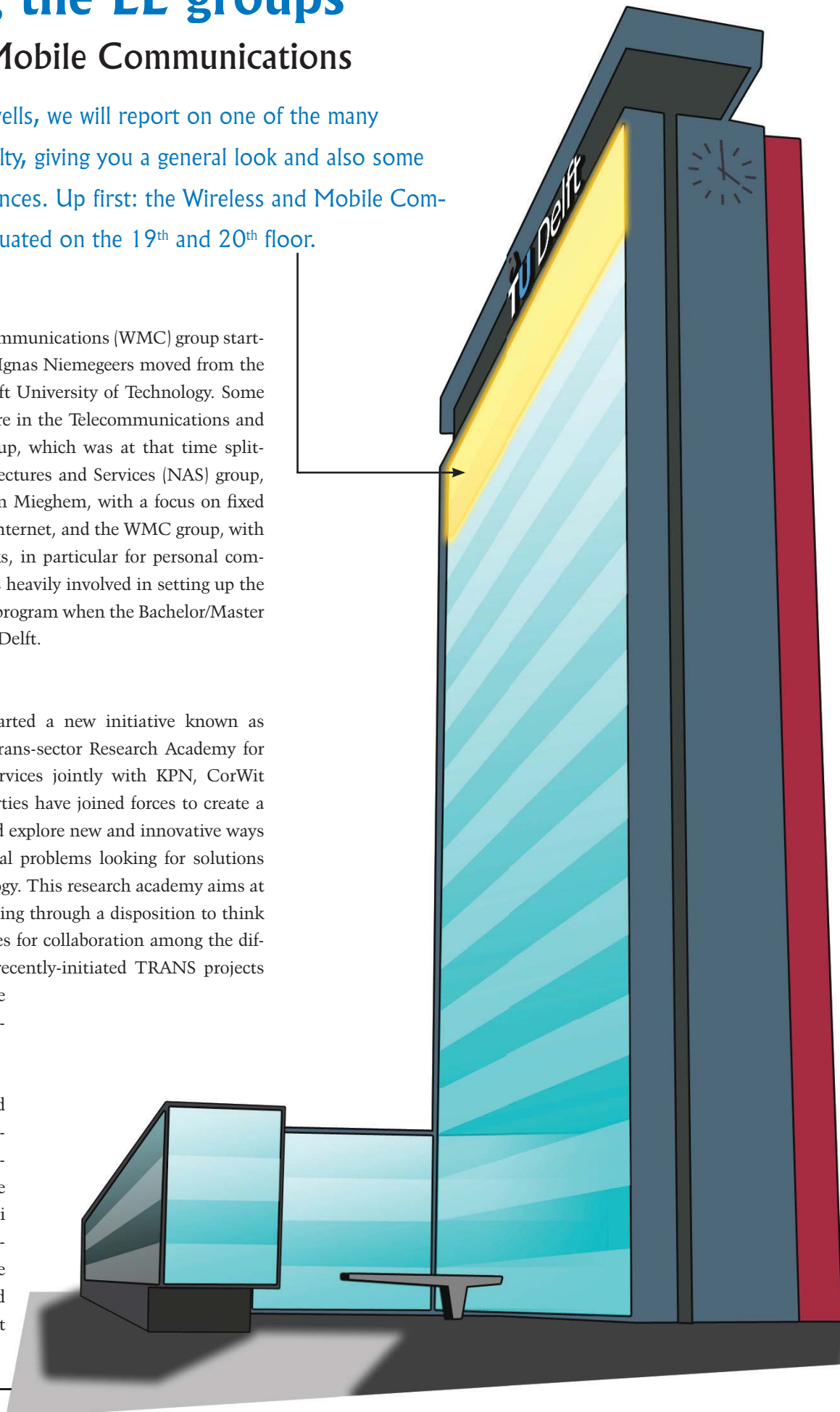
History

The Wireless and Mobile Communications (WMC) group started in 2002, when Professor Ignas Niemegeers moved from the University of Twente to Delft University of Technology. Some of the roots of the group were in the Telecommunications and Traffic-Control Systems group, which was at that time split-up into the Network Architectures and Services (NAS) group, chaired by Professor Piet Van Mieghem, with a focus on fixed networks, in particular the Internet, and the WMC group, with a focus on wireless networks, in particular for personal communications. The group was heavily involved in setting up the Telecommunications M.Sc. program when the Bachelor/Master structure was introduced in Delft.

Research

In 2008, TU Delft has started a new initiative known as TRANS which stands for Trans-sector Research Academy for Complex Networks and Services jointly with KPN, CorWit Fonds, and TNO. These parties have joined forces to create a research academy that would explore new and innovative ways in addressing today's societal problems looking for solutions with state of the art technology. This research academy aims at advancing the public well-being through a disposition to think creatively about opportunities for collaboration among the different sectors. One of the recently-initiated TRANS projects in the WMC Group is the Cognitive Collaborative Networked Platforms (CCNP)

Presently, we are accustomed to dedicated network architectures as shown in Figure 1. Such applications are designed based on a priori known requirements. However, we do not know the requirements of future ad hoc applications in different
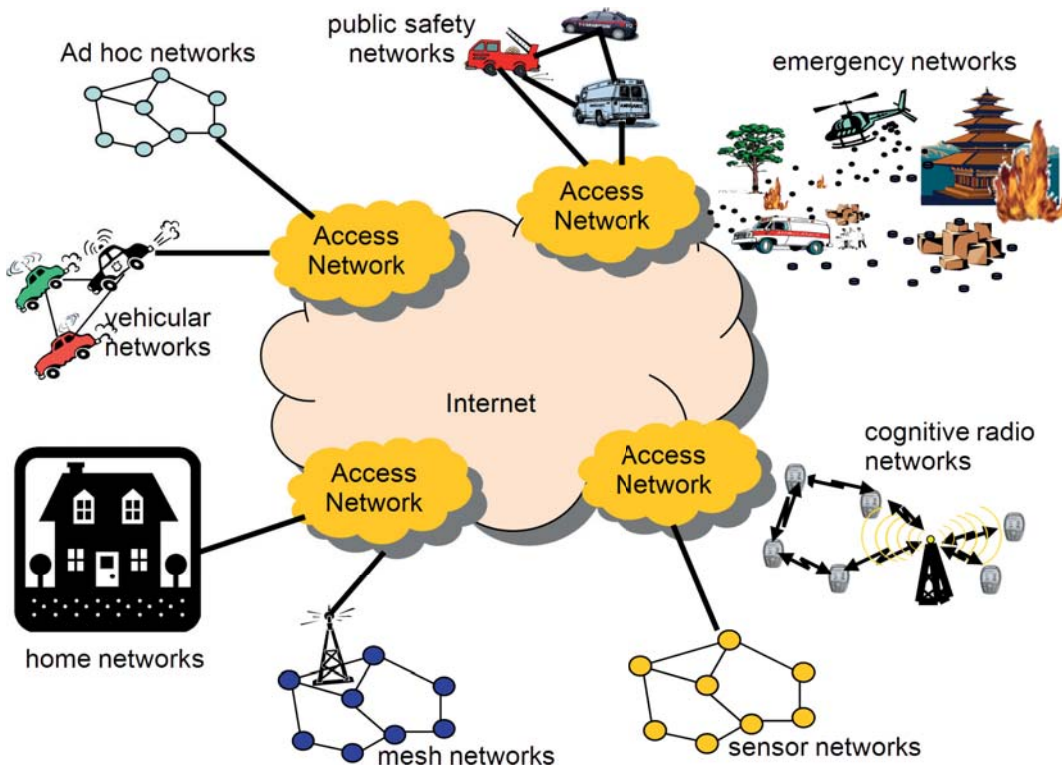
Figure 1: A perspective on the present Internet.

green. Therefore, employing smart signal processing and communication techniques is of paramount importance. To this aim, transmitter and receiver diversity, statistical communications, cooperative communications, cognitive radio and network coding are among the related hot research topics being studied at the WMC Group.

International Collaborations

The WMC Group is a member of the HERMES partnership to develop visions of and ways to implement the future of communications, to speed-up the definition of forthcoming technologies and to provide easy access to a broad range of cutting edge expertise. The WMC Group also contributes to the eMobility initiative which aims at reinforcing Europe's leadership in mobile and wireless communications, which have created unprecedented possibilities for people to communicate and have become a key driver of economic growth. »

business sectors. An adequate solution is to make the network intelligent to make decisions and resource assignments in the presence of incomplete, inconsistent, maybe misleading or malicious information, conflicting or inconsistent high-level objectives, drastically and instantaneously changing operational conditions, high complexity, and spatio-temporal dynamics. In CCNP, context information obtained from sensors and devices combined with user preferences, applications and history are used for adaptively producing decisions at several protocol layers on how to create the best communication substrate. What best is depends on the objectives and goals such as reliability versus energy efficiency. CCNP will provide a substrate to trans-sector applications in which actors from multiple sectors collaborate closely and as such gain significant added value. With this perspective, CCNP provides a seamlessly unified cognitive architecture as shown in Figure 2.

As more and more ICT-enabled systems rely on wireless communications, those systems pose serious environmental concerns themselves. The Intergovernmental Panel on Climate Change developed some scenarios where a raise in global mean surface temperature is projected around 2–6.4% above levels by 2100. In these scenarios, increased incidences of floods and droughts, and a rise in sea level of up to around one meter between 1990 and 2100 are foreseen which will impact the Netherlands. Through ICT-enabled abatements, the emissions could be reduced 15%. However, the ICT-systems must also be
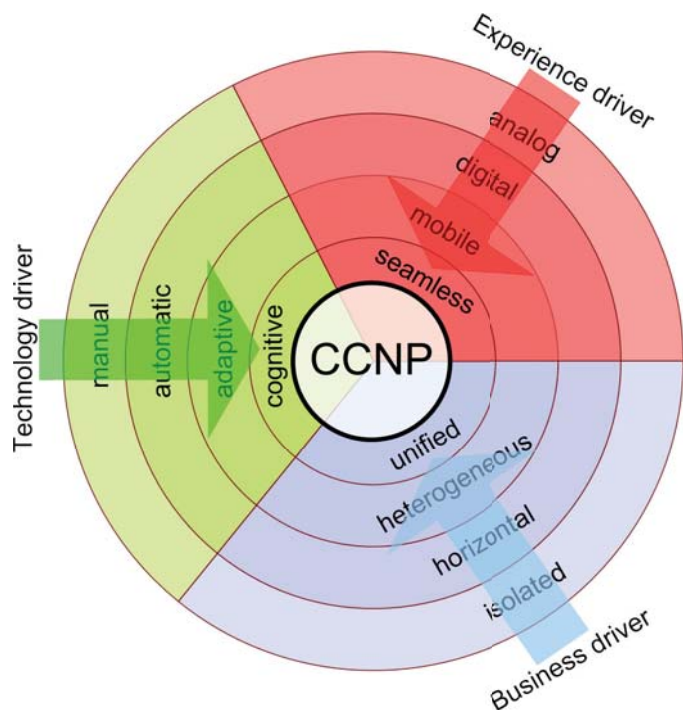

Figure 2: Experience, technology and business drivers for Cognitive Collaborative Networked Platforms (CCNP).

Social Activities

Social events are often organized through or in collaboration with the Dispuut TeleCommunicatie (DTC). In recent years, the emphasis has been on bringing the Dutch and the foreign students closer together, as well as the students and the staff. One way of doing so was by organizing joint sports events, followed by drinks and bitterballen. ⏚

Figure 3: Moments in the volleyball and badminton events organized by the Dispuut TeleCommunicatie (DTC) for telecom students and staff on June 11, 2009.

Experiences from MSc students

Shahab Asoodeh

I started my master studies in telecommunication in September 2008 at the WMC Group. In the first year, students are usually busy with courses which are to be taken in quarters. As the first impression, I felt a bit scared of being obliged to take courses in quarters instead of semesters (although some courses are given in semesters). At the end of the first year, I got an interesting overview of many courses in different areas in telecommunications whereby I could choose more clearly which area I would like to work on. In this sense, quarter-based system is more efficient than semester-based one. The huge diversity of research areas in the department of telecommunication is another thing that I enjoyed especially in the first year when I was about to start my master thesis. Students have plenty of options for their thesis work within telecommunications engineering ranging from radar and microwave to statistical signal processing. Nevertheless, I was totally free to opt for other institutes within or outside The Netherlands for my master project. TU Delft has many bilateral agreements with other leading universities by which students can exchange easily. ⏚

Figure 4: Impressions of the MSc-room on the 19th floor.

Arash Khatibi

Studying at TU Delft, which is a prestigious university with a lot of modern facilities, helps me increase my knowledge, technical and personal skills. I became a team-player through the group projects that I had in the first year of my study. On several occasions, I had given presentations which helped me improve my communication skills and increased my self-confidence. The international community made me familiar with different cultures, and now I have friends from all over the world. I am working on my thesis which is about power efficiency in event-driven wireless sensor networks. Although the concept of event-driven networking is known, an additional wake-up receiver may significantly change the energy efficiency of the communications systems by a cooperative dual stack. In this work, I try to devise a mathematical model for energy efficiency and validate it through simulations. ⏚

Lustrumweek 1 (21 maart - 26 maart)

Maandag	21:	Onderwijsdebat & Kroegentocht
Dinsdag	22:	Groot Dictee der ETV
Woensdag	23:	Cabaretavond
Donderdag	24:	Sportdag
		Zusjesborrel
Vrijdag	25:	Lustrum rally
Zaterdag	26:	Installatie Ereleden

MAXXIMAL

Lustrumweek 2 (16 mei - 21 mei)

Maandag	16:	Veiling
		Lustrumreceptie
Dinsdag	17:	Excursie
Woensdag	18:	21 Diner
Donderdag	19:	Sportdag
		Barbecue
		Karaoke
Vrijdag	20:	Uitbraklunch
Zaterdag	21:	Lusturm Gala

Hier invoegen:
p26Vanderlande.pdf

Cooking with...
Jaap Hoekstra
Broccoli-cheese pie with carrot-salad
for students

I have been making this pie for over 20 years and it remains a hit. However, I always had to make three of them to make everyone happy. You should know these directions: oven at 225 degrees in the middle and wait about 25 minutes until the pie is done and the top is brown.

Ingredients

- Springform of 26 cm
- 300 g broccoli (cook first)
- 4 slices puff pastry
- 3 eggs, 1/8 liter whipped cream
- 150 g grated old cheese
- 100 g sliced ham
- Pepper to taste / salt

For the salad:
- 2 carrots grated, 2 tablespoons raisins

About Jaap Hoekstra

Jaap Hoekstra was born and still lives in Amsterdam. He has a master degree in physics and a PhD in electrical engineering. He (co-)authored over 100 papers, and 6 book chapters. Currently, he teaches in the first, second and third year of the bachelor electrical engineering, and a master course on nanoelectronics. He is managing the practical facilities at the Drebbelweg ("Building 35"), and is chairman of the employee participation group of the faculty. Recently he published the book: "Introduction to nanoelectronic single-electron circuit design", Pan Stanford Publ., 2010.

Eet smakelijk!
Enjoy your meal!

Circuit Bodging

The line between computer science and electrical engineering is a characteristically fuzzy one. A computer cannot function without an electrical engineer to design its hardware, but is useless without software to run on said computer. The ultimate marriage of these two fields is the microcontroller. These cheap-and-cheerful packages are often inexpensive but allow circuits to be implemented that would otherwise become overly complicated and cumbersome. In this edition of circuit bodging, the author would like to present one example of a circuit made simple by implementation of a microcontroller. Our project this edition: the Game of Life.

Author: Ben Allen

The game of life takes place in an infinite two-dimensional plane of distinct cells. Every cell can be either alive or dead, and its state is determined by its neighbours. Time is measure in steps or "frames", and for each frame the status of a cell is determined by a few simple rules.

- Any live cell with fewer than two live neighbours dies, as if caused by under-population.
- Any live cell with two or three live neighbours lives on to the next generation.
- Any live cell with more than three live neighbours dies, as if by overcrowding.
- Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.

The inital pattern is called the "seed". For each frame, a new state is determined for each cell, determined by the state of its neighbours in the old frame. Births and deaths happen simultaneously, and as such each new generation is a function of the previous one. These rules are applied repeatedly to determine the next state.

From Rules to Instructions

Now we have established the rules for our game of life, we need to consider how to implement them in a circuit. Software in this instance is fairly generic, and so is not critical to the selection of components.

The most important decision to make is the display method to use. This directly influences how many I/O lines will be necessary to control the display and as such influences the choice of the microcontroller used. Here we're using a Knightbright 5x7 red LED matrix, as it incorporates all the LEDs into one display, an aesthetic advantage. By setting a row high and a column low, an LED lights up. This has the disadvantage that individual LEDs cannot be addressed without scanning the display. The end result is that, because we have to turn LEDs on column by column, the overall brightness will be reduced.

Next comes the choice of microcontroller. In this instance, the author used a PIC18F2455 because it has sufficient I/O's with a few to spare. This leaves the option of expanding the circuit, for instance by implementing a Hitachi HD44780-based display for easy-to-read debug messages. Any project where a microcontroller has 6 or ideally 7 I/O's spare can be outfitted with a simple text display during development. This is a great technique for debugging as it makes program flow (or lack thereof) easier to spot, and in most cases decreases development time.

The astute reader will no doubt remark that the choice for a microcontroller is not self-evident, and they wouldn't be wrong. No doubt the circuit would function perfectly when built from
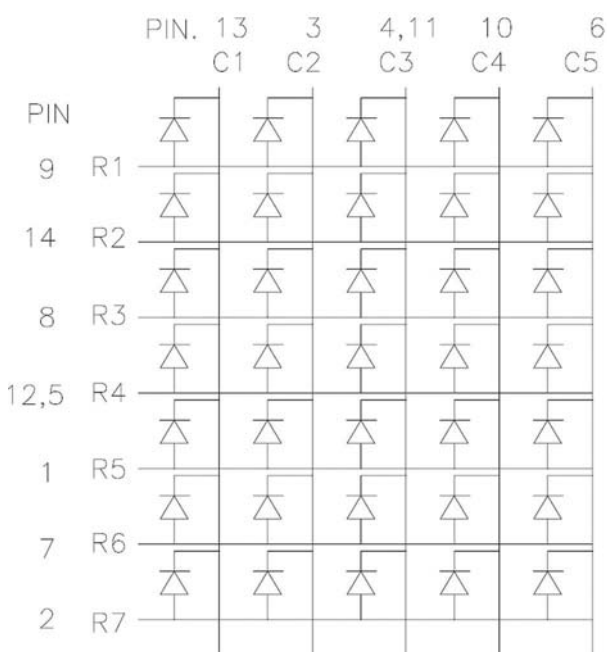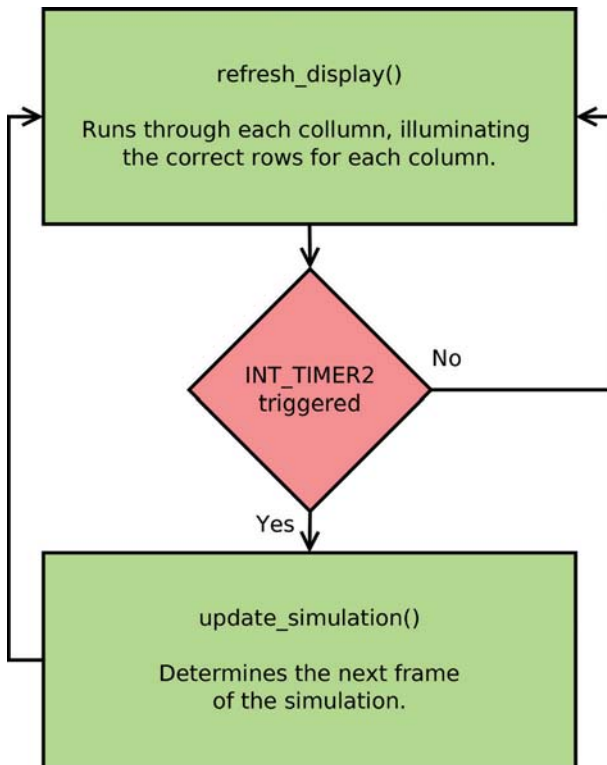

Figure 1: The layout of the LED matrix.

Figure 2: The basic flow of the Game of Life software.

discrete logic components or on an FPGA. The difference is that not many people have access to FPGAs, and even if they do, a $2,50 microcontroller is somewhat more suitable for a project like this than a $50 FPGA.

Software

When one thinks carefully about what needs to happen, we reach a fairly straightforward conclusion: there are two processes that need to run to make a Game of Life work.

- The display needs to be updated continuously so the user can see what is happening.
- The simulation needs to be updated to display the next frame. This happens at a fixed rate, say once every 500ms.

As such, the program can be implemented as two functions, called as necessary. The next step is evaluating when what has to happen. These constraints are already mentioned above. As such the main loop of the program does nothing but call the refresh_display() function. The update_simulation function is called whenever timer2 overflows, generating an interrupt and calling the function. Timers in PIC microcontrollers increment every clock cycle, and can be loaded with a specific value to determine the time before the interrupt triggers. This functionality is displayed in the flowchart of Figure 2 but please note that the INT_TIMER2 interrupt can be triggered at any arbitrary

point during the display refresh cycle and is not solely checked at the end of refresh_display.

What is an interrupt?

An interrupt is just that: an interruption. Imagine talking to someone over coffee when suddenly your phone rings. The call is important and you accept the call, excusing yourself from your company for a moment. You deal with the call, sit back down and continue the conversation. This is exactly how interrupts work in microcontrollers. When something important happens and that specific interrupt has been enabled, this event moves the microcontroller's program counter to the beginning of the interrupt code.

In conclusion

As-is, the software reads the seed from the current_frame array as it is set in the software editor and runs the simulation from there. Ideally, the user should be able to pause the simulation and input a new seed state to the microcontroller before the simulation continues. Another problem with the circuit as shown is that the LEDs whilst running by themselves are sufficiently bright, but when they only have about 20% duty cycle they become too dim. The solution would be to switch the LEDs with a set of transistors to remove the PIC's internal current limiters from the equation. Even so, the LEDs used have a maximum current rating - obviously frying an LED array won't do much good for its brightness.

In the end this is a software project for the most part. Connecting a display to a microcontroller, while being potentially confusing because of the many I/O lines, is hardly a task that requires a degree in engineering. However, being able to use a microcontroller to simplify a circuit design is a skill that most engineers, and their potential employers, should find valuable. Imagine realising this circuit with discrete logic components, and it should become clear why microcontrollers are immensely and practically useful devices. ⊕
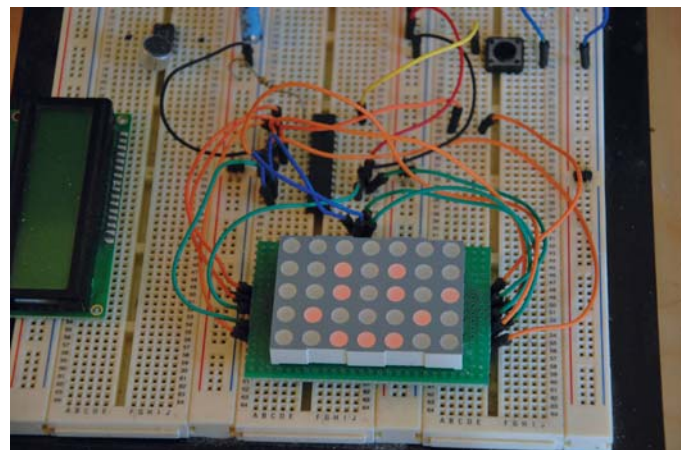

Figure 3: The Game of Life circuit on a breadboard

Column

Max Geljon, MSc.
Former student and
Researcher at TU Delft

Coffee as a catalyst

When I was just a kid, once in a while I went to church with my grandmother. Not that I had a very good idea what people were talking about in church, but there was plenty of stuff to see and to hear. Exactly what you need when you are young and curious. After church, habit obliged us to return home to my grandfather, who usually made coffee. He prepared milk, including the cream, without the fancy tools we have these days. Just a small pan and something to stir with. He found out that you can heat the cups on the edge of the filter holder, as there was a bit of steam coming out of the machine at that area. Nowadays, we might as well call this 'cappuccino' and people spend vast amounts of money for a machine that can do what my grandfather has been doing as long as I live. Ever since those days, nothing can compare to 'Opa ze bakkie' (grandfather's cup of coffee).

Of course, times have changed and what was 'much more milk than coffee' when I was young has turned into 'pure black' after studying in Delft. However, I discovered that one very important aspect of drinking coffee never changed. Maybe the adventures of my grandfather as a baker, bus driver or survivor of the Second World War where scientifically not so valuable, but the concept of storytelling, talking and discussing over coffee adds more to your scientific career than you might think. Coffee as a catalyst, in a nutshell.

First of all, think about how many times you have been struggling with a problem for hours and hours. For some reason, you have to stop struggling to make time for eating and a bit of sleep. When you come back, you have another look at the matter and you realise that the solution was staring right at you from the beginning. Just a cup of coffee and a 10 minute break would have had the same effect as your struggling for hours...

In the scenario sketched so far, there are no other human beings involved yet. Now let us add some people to this hypothetical situation. A (boy/girl)friend, roommate, a colleague, a relative. Not only will you experience the advantages already described, but now there is some social interaction added to the equation. Either people will help you distract your mind for a minute, they will ask you what you are doing currently or what is bothering you. No matter who you talk to, two totally different eyes are looking at your work or your problem now. They force you to zoom out a bit, to explain the bigger picture. Not seldom, this is the moment where you realise yourself where you went wrong. If that is not enough, the most silly suggestion might trigger a brilliant solution.

Now I have just explained the benefits from an economical point of view. If these would be the only benefits, I would be highly romanticising coffee. You do not always have a problem that needs to be solved, and problems are not always related to business. Nonetheless, nothing has to be left unspoken while drinking coffee. Besides its problem-solving capabilities, there is relaxation of the mind, relief of heart, a more diverse social life and a lot of appreciation to be harvested. If you learn how to unlock the 'advanced mode' of coffee, that is...

Hence, coffee is creating a highly beneficial platform for problem-solving and social interaction. You might have underestimated the power of coffee and moreover, it has nothing to do with caffeine. I have seen too many places around the world where coffee is considered just a waste of time or a way to stay awake. Stop locking yourself up on your room and get away from your computer once in a while. Even better, team up with friends, colleagues or both and you will find how much efficiency coffee will bring for all. On top of that, it tastes darn good too! Needless to say, feel free to choose tea, hot chocolate or any other liquid instead and do not forget to experiment with some (typical Dutch) cookies. I wish you good luck.

Hier invoegen:
p31Technolution.pdf

Hier invoegen:
p32Siemens.pdf