MAXWELL

EFFICIENCY

WIRELESS GOING DIGITAL
Digital intensive wireless transmitters

BioCMOS
Efficient bioanalytical systems at the nanoscale

THE DEVELOPMENT OF ELECTRIC LIGHT
Aspects of efficiency in the production of electric light

From the Board

Commissioner of Education

Thomas Roos

Dear reader,

Our Educational year is passing by quickly and it has been another busy quarter!
I would, first of all, like to thank all the students that participated in a Focus group or EvaCie and gave their feedback on our Education. Without this feedback, our studies would be worse. Newer things like Brightspace are slowly being improved with your input and students are increasingly liking it more than the old Blackboard. You can always contact me (anonymously) if you have something about Education on your mind and want to make a difference!

Do you have a teacher that you particularly like? Perhaps a teacher that is so enthusiastic that he/she motivates you to study better, or just because his or her explanation is awesome. Every year students choose a new 'Teacher of the Year' to thank these great teachers. Keep an eye on *https://toty.etv.tudelft.nl/* for the online upcoming elections and rate your teachers!

I have also been engaged with the development of Zesje [1], the open source exam grading software that I introduced to you in the previous edition of the Maxwell. The development is going at a rapid pace and this tool has drastically lowered the time that teaching staff invest into grading exams while giving students' insight into the results and statistics of their personal exams for many courses.
Are you competent in front-end development with JavaScript or back-end development in Python and looking for a side job? The Zesje team is still looking for more help! Or are you a teacher who would like to try out Zesje for your own course? Contact me for more information.

Study efficiency and the speed with which students are finishing their program are becoming increasingly more valued by students. Studying efficiently and quickly requires careful planning, but that is not easy on your own. While you can always contact the Study Counselor for help with planning your courses, that is often not needed. Together with the Student Council and other Commissioners of Education from other Study associations, we have been working on an online tool to help students plan their personal study progress better. Coming to Brightspace soon!

[1]   Zesje [*https://gitlab.kwant-project.org/zesje/zesje/tree/react*]

Treasurer

Wouter Kayser

Dear reader,

The roll of the treasurer is to manage all of the expenses. Efficiency is always a big part in the decision-making process as we always want to maximize the impact that we can have. However, there is not any function which can translate the impact you have into a monetary value. This impact consists of many different variables, some of which are gained knowledge, gained friends and gained enthusiasm. However, there are many hidden variables that might have hidden positive or negative effects.

Because of this, it is absolutely necessary to discuss why we will be doing events and also evaluate afterwards. During the course of the last year, we also started evaluating the general progress and state of the association. These efforts are put forward by the long-term vision committee or also called the ViCie. This committee held four successful brainstorm sessions with participants that represented the different groups within. Soon we will be holding a more general online survey to get a larger sample size. The gathered data will then also be taken into account when making next year's budget. So exciting times are ahead!

Colophon

Editorial

Dear readers,

A couple of weeks ago, I've walked a trail in the snowy mountains of Bosnia. During this multi day hike, I needed to be efficient with everything. I could only bring a limited amount of weight in my backpack. For every small thing that I packed, I had to ask twice if it was really necessary to have with me.

Only a few natural springs were on the route, making it a must to be very efficient with my water. Cooking on a small gas stove with a limited amount of gas also required me to be efficient as you don't want to be without fuel and therefore have no food to eat.

A remote location in the mountains is not the only place where you have to be efficient. In this Maxwell you can read articles about efficient digital communication, efficient bioanalytical systems and RF energy harvesting for efficient use of road salt.

Enjoy reading,

Simon Verkleij

Dear readers,

We live in an era where we work more hours and feel more pressure trying to be more productive. Technology, meant to streamline our lives, saps our attention and snatches our time. Has the need for a more efficient operation ever been larger?

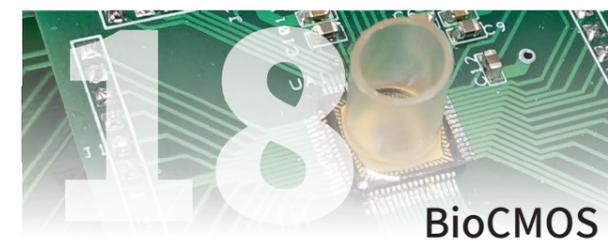Efficiency is being able to utilize resources at the lowest cost. And oh boy, are we the superheroes of it! In this Alumni edition of Maxwell, we bring you articles from engineers all around the world manifesting their work to achieve the best efficiency.

As you strive to become an efficient engineer, Stephen Covey's words are worth to live by, "You think effectiveness with people and efficiency with things."

Ainee Ansaari
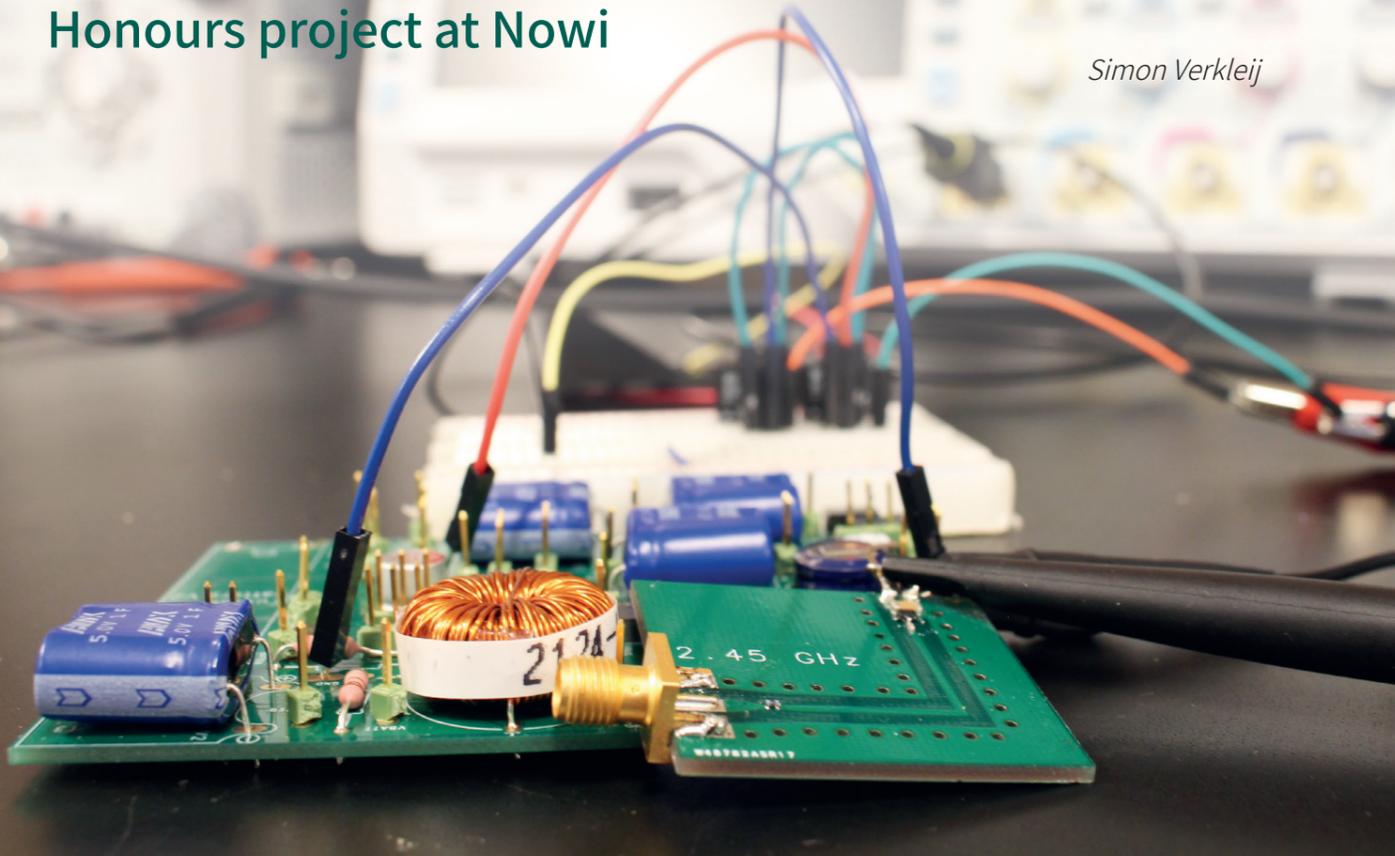
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RF energy harvesting
for efficient use of road salt
Honours project at Nowi

Simon Verkleij

In the winter the roads can get very slippery, causing many traffic jams and accidents. This can be prevented or at least decreased by using road salt. Every winter, on average 80 million kg of salt is used for the Dutch roads. The Dutch road maintenance agency, Rijkswaterstaat, determines when and where to spread loads of salt on highways and smaller roads. This is determined based on only a few measuring stations, making it a quite inaccurate estimate which results in spreading salt on more roads than actually needed. The use of road salt can be made more efficient by having measurements from more locations.

Sensors in the asphalt
By having temperature sensors directly in the road, the salt could be applied more precisely on different regions where it is needed. This makes the usage of road salt much more efficient since less of it is spilled on roads where it is not needed. Having the sensors in the asphalt means no practical way to replace the batteries and having cables to power the sensors would require the entire road to be broken open, resulting in high costs and a longer installing time. An ideal situation would be when the sensors do not need any cable and have no need to change the batteries.

Nowi Power Module
My honours project is done in collaboration with the start-up company Nowi, which is a spin-off of TU Delft. Nowi is developing a Power Module which uses external energy sources as an additional means of power for small sensors. This enables the creation of sensors that are
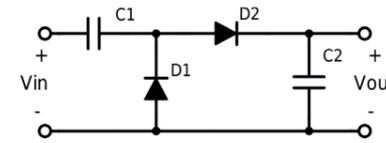

Figure 1. Single stage charge pump rectifier.

"The device is able to power different types of sensors in different environments using a range of energy harvesting and battery hybrid options."

either completely battery-less or hybrid battery sensors with a greatly extended lifetime.

Energy harvesting
In the case of the sensors in the asphalt, power from the radio frequency (RF) signals of the GSM band around 900 MHz is used. This RF power is harvested by an electromagnetic harvester. My project was about designing, making and testing this harvester. It uses an antenna to receive the GSM signals which are then converted into DC power by a rectifier. For efficient harvesting, the circuit has to be matched using a matching network.

Rectifier
For RF energy harvesting, the most commonly used rectifier topology is the charge pump rectifier (CPR). Its simplest configuration is the single stage CPR as shown in Figure 1.

In the negative half of the sinusoidal input voltage, the voltage over the left diode will be the same as the input voltage. When that voltage is higher than the threshold voltage of the diode, v_D, there will be a current flowing through the first diode which charges the first capacitor. During the positive half of the input voltage, there will be a current flowing from the first to the second capacitor, charging that second capacitor. The output voltage is $v_{out} = 2\,v_{in,peak} - 2\,v_D$.

The input voltage will be relatively low, since the harvested electromagnetic waves only contain little power. Therefore, to reach a high efficiency in the rectifier, it is important to keep v_D as low as possible. Schottky diodes have a low threshold voltage and a fast switching speed, making them widely used in RF energy harvesters.

Matching network
The harvested power is the highest when the antenna sees an impedance that is the complex conjugate of its own impedance. A typical impedance of an antenna is 50 Ω. This requires the impedance of the harvester to be 50 Ω as well, for the specified frequency.

The matching network determines the frequency where the harvester is matched. For each different frequency range, a different matching network is required.

Future plans
The sensors in the asphalt are just one of many possible applications of the Nowi Power Module. The Power Module has been designed to be multi-purpose. It is able to power different types of sensors in different environments using a range of energy harvesting and battery hybrid options.

Not only GSM, but also Wi-Fi, photovoltaic and piezo-electric energy can be used. The applications of the Power Module range from transportation, such as a GPS tracker, to health and agriculture, where soil monitoring and smart logistics is going to use a big amount of IoT sensors.

Recently, Nowi has received a R&D grant together with Qualinx from 'Provincie Zuid-Holland'. The aim is to further develop Nowi's Power Module and combine this into a demonstrator with Qualinx ultra-low power GPS module.

Nowi is currently looking for new talent to join the team. More information can be found on *www.nowi-energy.com* ⏚

Solar Boat Team
TU Delft Dreamteam

Olmar van Beurden

The TU Delft Solar Boat Team designs and builds a solar powered boat. The boat sails on hydrofoils, and thus essentially flies over the water. Our goal is to win the Solar Sport One competition, a competition consisting of five races: most of them in the Netherlands (Akkrum, Purmerend, Groningen and Leeuwarden), but also the grand finale in the bay of Monaco. Besides the competition we try to show the maritime industry that a lot can be achieved with solar energy, and industry not known for sustainability.

As a student team, however, it is also our goal to learn and push the limits of what is possible and reach maximum efficiency. We have a lot to win and essentially nothing to lose. With that in mind, we try to design most of the components in the boat ourselves and optimize them as far as possible.

Energybox

Our team is divided in the departments: Hull & Body, Dynamics & Stability, Driveline, and Electronics. Within the Electronics department, our focus is to make a reliable system that can deliver the energy from the solar panels to where it is needed in the most efficient way possible. Reliability is important, as it cannot win you the race, but you can very easily lose without it.

At the heart of the system is the Energybox. The Energybox houses most of the electrical systems, like the battery and many of the PCB's. The battery is a 1.5 kWh Lithium Ion battery, bounded by the rules of the competition. This year the battery consists of Sony VTC 6 cells capa-

"Reliability is important, as it cannot win you the race, but you can very easily lose without it."

ble of delivering currents of 30A constantly, but up to 80A for short periods of time.

Energy management

A lot of time designing within the department goes into the design of PCB's. Essentially the brain of the boat and possibly the most complex system of the boat is the Energy Management System (EMS). The EMS decides which systems are turned on and off, and communicates with all other PCB's in the boat, via CAN. The EMS makes sure energy is delivered to the systems that need it and shuts down those systems in case of emergency.

In-house MPPT

Since the boat is solar powered, there is a special box with Maximum Power Point Trackers (MPPT's). MPPT's find the point on the IV curve where maximum power

The Battery Management System (BMS) is directly connected to the EMS. The BMS is made to keep the battery balanced, meaning that all modules within the battery are at the same voltage. The BMS in our boat is passive, meaning that it dissipates abundant energy from the right modules.

is harvested and convert the voltage of the solar panels to that of the battery, so that the battery can be charged with energy. During previous years, commercially available MPPT's were used, but this year we are using in-house developed MPPT's. The boat has one MPPT per array of solar panels, making for a total of 11 MPPT's.

Control and logging

As mentioned above, the boat flies over the water on hydrofoils. To do this the hydrofoils need to be controlled in such a way that they keep the boat above the water, but without stalling it. Two PCB's control electric motors, which in turn control the pitch of the hydrofoils. Two sensors gather data to decide the pitch of the hydrofoils. One sensor is an ultrasonic sensor to measure the height above the water, the other sensor measures pitch, yaw, and roll, but also the acceleration in these parameters.

A system that is not only in the boat, but also has important parts on land is the logger. The logger itself is, of course, in the boat, but the data is sent over 4G to a

Figure 1. Render of this year's new Solar Boat design.

server. All data available saved there can then be analyzed from land. Also, an app is made that to look at that data.

The other electrical systems in the boat are

- the steer: communicating from a PCB with the EMS and height control;
- the dashboard: by which the pilot can turn on and off the motor, solar arrays, bilge pump, and circuit breaker; and
- the 24V system: powering all peripheral electronics, like sensors and communication.

The next Solar Boat

With that we hope to have given you some insight in the workings of the Solar Boat: specifically of the electronics within. Every year we try to make more and more of the systems ourselves instead of buying the commercial options available to reinforce the fact that we are a learning team that tries to optimize every last bit. This year the MPPT's are in-house designed, who knows what we will design next year? ⏚

Figure 2. Energy Box of the TU Delft Solar Boat.

Wireless going digital

Leo de Vreede and Morteza Alavi
Photo by Rob Bootsman

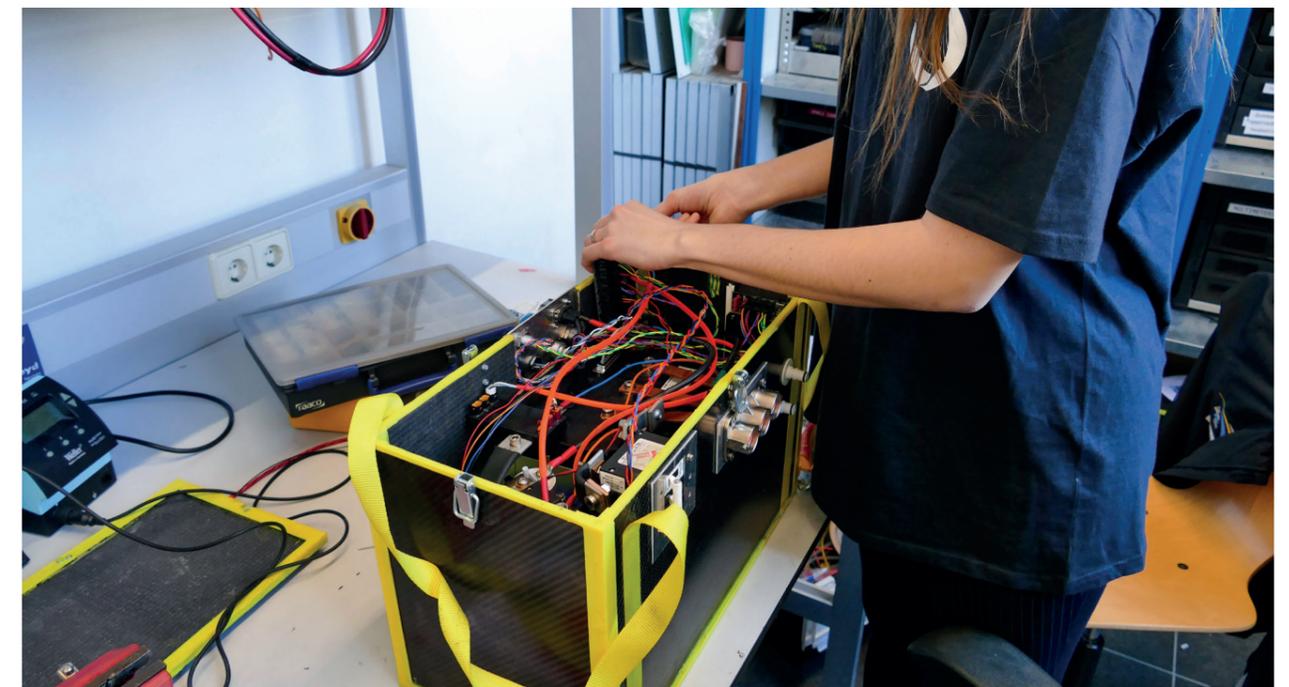Wireless infrastructure revenue for LTE (4G) was estimated to be US$ 26 billion in 2015 and is slowly declining since. On the other hand, already in 2020, the 5G infrastructure is expected to become a US$ 20+ billion market (Forbes, Sept. 22, 2017). Within the wireless infrastructure market, Base stations are the key building blocks and responsible for up to 60% of energy consumption of the total network; especially the transmit path (TX), including the broadcast power amplifier (PA), dominates the energy consumption. Wireless communication as a whole is estimated to be responsible for ~0.5-1.5% of the worldwide CO_2 emissions.

Future wireless networks

Wireless data traffic is growing exponentially. As a result, the currently available generations of wireless networks (2G, 3G and 4G) are expected to become constipated by 2020. To avoid this "data breakdown," new wireless technologies are needed that allow, a 1000x increase in data traffic while still being ecologically and economically viable.

To address this need, the evolutionary 4.5G and revolutionary, so-called, 5G - "fifth generation" wireless networks are currently being defined. These future wireless networks will utilize various techniques to reach the desired capacity increase, the most important techniques are depicted below in Figure 1.

For new wireless networks, two domains can be distinguished, namely the below 6 GHz wireless networks (intended for covering wireless cells from several hundred meters up to ~30 km of distance) and the so-called mm-wave links (e.g. at ~28 GHz), intended for covering up to ~200 m of meter distance between a base station and its mobile users, or serving as a high-speed "fixed" point-to-point wireless data link, to avoid the need of establishing a glass fiber connection.
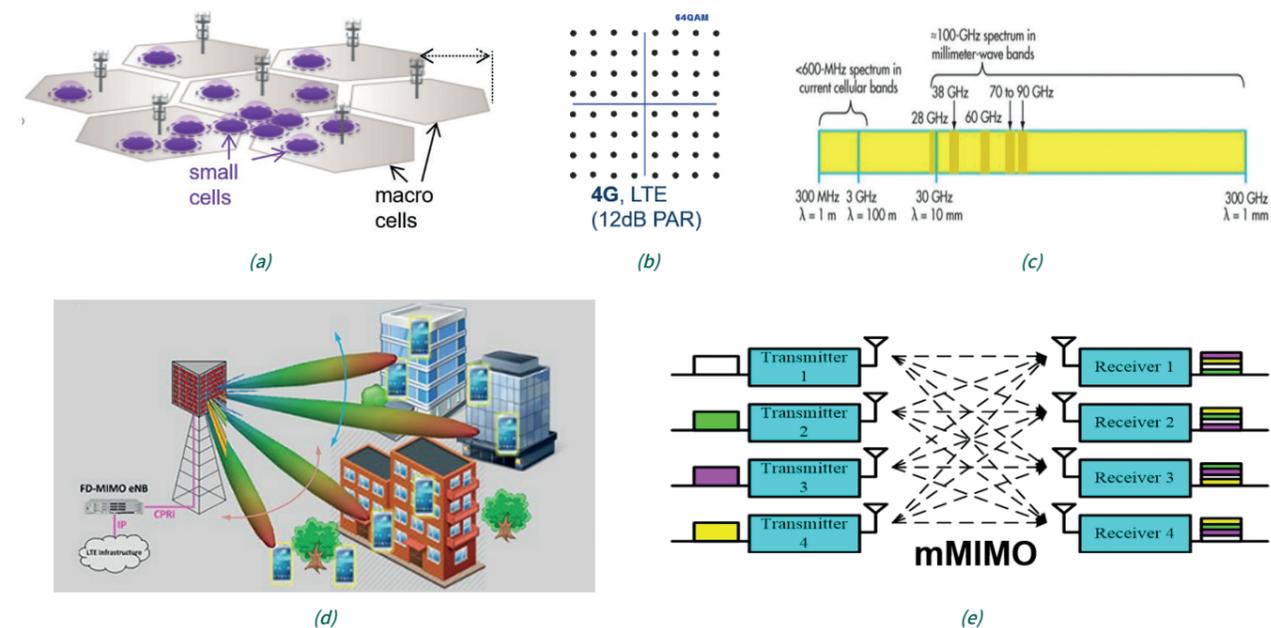
The biggest advantage of the "below 6 GHz networks" is that they do not require a line of sight between the connecting base station antenna and the user handset. As a result, they will continue to form the core of any (future) wireless service and provide the robust data links as we are currently used to.

In spite of the limited bandwidth availability below 6 GHz, due to combined use of the techniques of Figure 1 they will offer data rates up to 1 Gb/s and beyond to their users. 5G mm-wave hot spots are envisioned to provide the truly high-data rates (up to 10 Gb/s and beyond) for short range fast downloads or uploads of large amounts of data (e.g. movies and livestreams) in just seconds.

The introduction of all these "new" techniques to enhance data capacity, has large consequences for the underlying hardware. Namely, current wireless networks (2G, 3G and 4G) rely almost exclusively on large macro-cell base stations to cover a cell sizes with up to 30 km of radius, using typically 3 high power narrow-band transmitters (e.g. 40-100 W average) in 120-degree sector configurations.

In contrast, future wireless networks will feature much smaller cell sizes,

(a) (b) (c)

(d) (e)

Figure 1. Future wireless networks will feature a combination of multiple techniques to increase their capacity, namely, (a) the use of more and smaller wireless cells to allow frequency reuse and serve more users within a given area, (b) use of modulation schemes with more information per symbol, this requires higher signal quality, (c) use of higher signal bandwidths, e.g. through carrier aggregation or by shifting to mm-wave frequencies where more bandwidth is available (d) use massive multi-input/multi-output (mMIMO) transmitter-receiver (transceiver) configurations. By using many small transceivers, each connected to its own antenna (multiple) steerable "beams" can be created, enabling the spatial division of mobile users. (e) Alternatively, multiple "data channels" between the base stations and the user are created to enhance data throughput.

requiring many more base stations with lower transmit powers, while due to their mMIMO operation 64x or even 256x as many "low"-power transmitters and receivers are needed per base station. In addition, these base stations need to support wideband signals and carrier aggregation. This calls for a radical change in the design and implementation of wireless transmitters and receivers (transceivers).

Current base station technologies

All existing wireless networks use analog-intensive base stations, which suffer from low integration (the ability to integrate an entire system, e.g. in a single CMOS chip) due to a plurality of technologies needed.

Figure 2 shows a typical high-end base station transmitter lineup, which uses a FPGA to provide the digital base-band data, which is subsequently converted to the analog domain by a Digital-to-Analog Converter (DAC), followed by a low-pass filter and an IQ-mixer frequency up-conversion.

To achieve the desired transmit power, amplification through several pre-drivers and a highly efficient (3-way) Doherty Power Amplifier are used. In these configurations, the Doherty Power Amplifier (PA) consumes a lot of energy, but it also produces much useful RF transmit power.

As such, it masks the power consumption of all preceding blocks and the overhead to linearize (or pre-distort) the transmit chain. Since all analog circuit functions need to be optimized for gain, linearity and power consumption, design and testing are very labor intensive and costly, while the realized hardware in the end can be only used for one particular application and/or frequency band.

Future base station technologies

Due to the diminishing transmit powers, when staying with the previous described analog approach, the power consumption of the final-stage transmitter will no longer dominate. In fact, the power consumption of the DAC and the linear up-conversion chain and pre-drivers will dominate (see also Figure 2).

Actually, the situation is even worse, since all circuit functions in the up-converion chain need to behave linear, they are using class-A operation, yielding a relatively high-power consumption that is constant and does not depend at all on the actual data traffic.

Furthermore, the poor integration compatibility, the frequency-band limited nature, high development and production costs, and the fact that many, many more transceivers will be needed for the same coverage of the current network. All yield to the conclusion that without significant concept changes, future wireless networks would face a much higher energy consumption / ecological impact, at higher fabrication and operating costs than the current networks.

The search for new base station architectures

With the above as background, an intensive research started for new revolutionary base station architectures that can offer the desired functionality while being more energy efficient, highly inte-
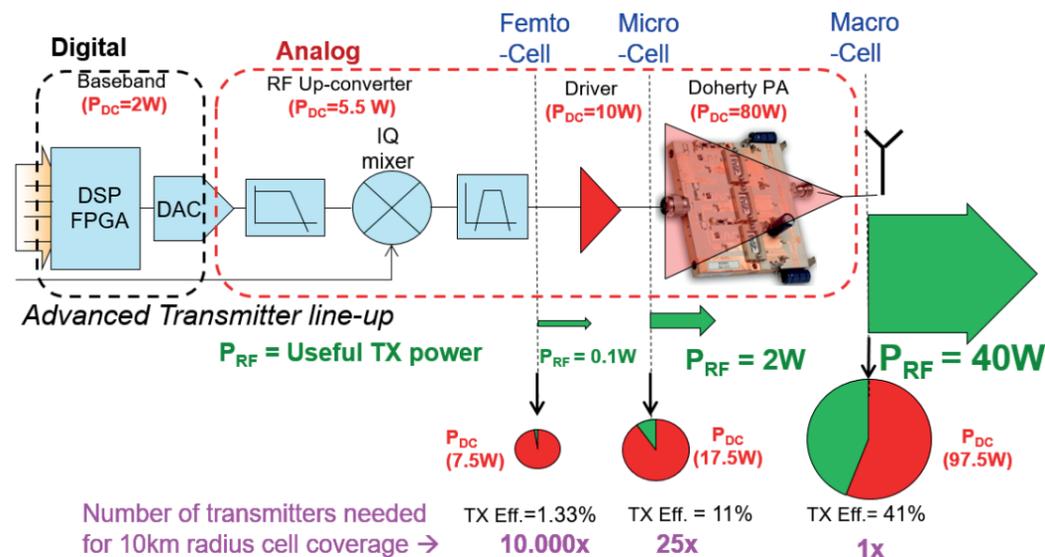

Figure 3. New digital intensive Polar Transmitter architecture using non-uniform segmentation, overdrive control and multi-phase clocking of the (segmented) final transistor stage. This yields an intrinsically linear conversion of the binary amplitude code word (ACW) to RF output amplitude (AM) and phase (PM), as can be seen from the ACW-to-AM and ACW-to-PM transfer functions, the realized circuit can provide signals with up to -50 dBc ACPR without using any pre-distortion.

grated and can be produced at low cost. This yielded the national research project SEEDCom (HTSM) and the European project EAST (Catrene), which aim at least in part (the scope of EAST is larger), the development of digital intensive transmitter architectures.

This research direction has been recently enabled by the ever-continuing technology scaling of advanced CMOS as driven by the Moore's Law, which predicts that ideally every two years, a digital function implemented in CMOS experiences a factor √2 improvement in speed, a fac-

tor 2 reduction in area and a factor 2 in power consumption. This trend has enabled very compact circuits that allow ultra-fast switching at very low power consumption, as such facilitating to merge the traditional DAC, baseband filtering, up-converting mixer and driver line-up all within a single digital function, called the Radio-Frequency DAC (RF-DAC), or when considering the receive path Radio-Frequency ADCs (RF-ADC).

It is indeed these circuit functions that allow moving the interface between the digital and analog domain (almost)

completely to the antenna interface, as such, changing complete (transceiver) systems from "analog" to "digital" intensive. Embracing this "digital-intensive" (or mixed-signal) research direction offers many advantages, namely; from the technology point of view, "System-on-Chip" (SoC) realizations become much more straightforward, since the plurality of IC technologies related to the implementation of traditional analog TX chains is no longer needed.

Furthermore, because digital circuits do not rely on linear operation, their ▷

Figure 2. Typical analog intensive high-end macro-cell base station line-up. Note that when truncating the transmitter chain at a lower power level, for example, to address the needs of a smaller cell base station, the required DC power becomes lower, but also the related system efficiency, while more base station nodes are needed to cover a similar geographic area.
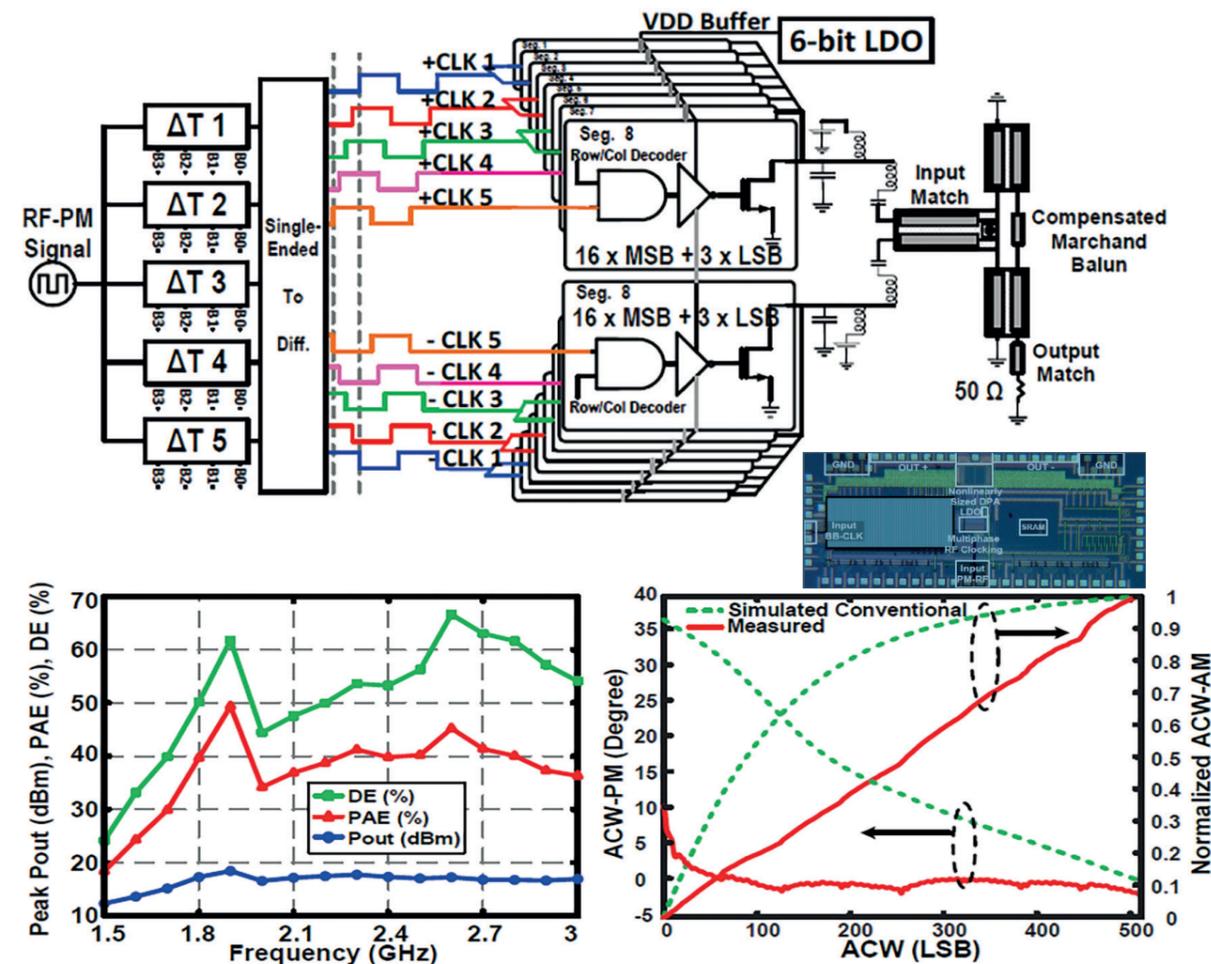
operation is hardly affected by noise, while they do not need any quiescent current. Consequently, the required new digital circuit functions can be made very energy efficient, while the area needed for their integration is much smaller than their analog counterparts and scales down in size and power with each new generation of advanced CMOS technology (e.g. 40, 28, 22 and 16 nm).

With all these promises above, one could wonder if there are any challenges left to

cur. In addition, smart power combining functions need to be created to meet the desired output powers. Consequently, in order to create useful solutions smart RF-DAC and RF-ADC structures are needed.

Within SEEDCom and EAST, various novel digital-intensive TX architectures have been developed, realized and extensively tested. Highlights are a digital intensive architecture that can replace the traditional (non-linear) analog final-stage PA. By using non-uniform segmentation,

Two of these phase-shifters are used in the bits-in - RF-out full TX line-up demonstrator. This design features a fully integrated digital Doherty transmitter architecture to increase its efficiency and has on-chip pre-distortion. It consists of 2x 106 transistors (excluding memories) and is world's first complete baseband bits-in RF-out digital Doherty Transmitter published.

All the principles/concepts developed within the SEEDCom and EAST projects

> *"Within SEEDCom and EAST, various novel digital-intensive TX architectures have been developed, realized and extensively tested. Highlights are a digital intensive architecture that can replace the traditional (non-linear) analog final-stage PA."*

solve when going into this new "digital intensive" research direction with related high-performance ADC and DAC architectures. However, the contrary is true. Although (digital) switching itself, at least in theory, does not consume power, changing the potential of any capacitive loaded interconnect or CMOS devices does.

Since these circuits, and their controllers rely on many digital gates, their switching algorithm should be implemented in the most effective / smart manner. Reaching high signal accuracy, imposes several challenges in device matching and IC layout implementation. Furthermore, converting the digital bit stream signal into the RF counterpart in transmitter side generates unwanted quantization noise and sampling spectral replicas. Straightforward sampling in a receive path yields folding in of other disturbing signals and noise.

Moreover, although the digital gates itself operate non-linear, the overall transfer from such an ultra-high speed data converter and its embedding in the overall-system MUST behave extremely linear, otherwise severe data corruption will oc-

overdrive control and multi-phase clocking of the (segmented) final transistor stage, an intrinsically linear conversion of the binary bits to RF counterpart has been established by correcting the ACW-to-AM and ACW-to-PM transfer (patented) which is depicted in Figure 3. Furthermore, a new wideband fully-digital Cartesian RF-DAC has been developed that features harmonic rejection techniques to improve its linearity, as well as, lowers signal degradation due the interactions with the non-linear final stage PA (Figure 4).

This digital architecture allows complete elimination of the traditional analog up-conversion chain and the filter in front of the final stage (still analog) PA, while consuming less than 10% of the energy of what is needed for the traditional analog approach. This achievement was awarded with the 1st place in the best student paper competition of 2017 RFIC Symposium and yielded also a patent application. Furthermore, a very accurate wideband I/Q RF-DAC phase modulator was realized suitable for polar TXs, which yielded a student finalist position in the RWW2018 Radio Wireless Week.

receive already high interest from the wireless industry and follow-up projects are already under definition / committed. The realized demonstrators show that bright, hardworking MSc and PhD students, introducing new inspiring architectures/concepts, can make a difference. Consequently, they will impact to the architecture of future wireless communication systems, which will offer higher functionality at a lower CO_2 footprint and cost.

Acknowledgement

Figure 4. Examples of ELCA student designed digital intensive wireless transmitter line-ups. a) Digital intensive wideband Cartesian RF-DAC pre-driver that does not pre-distortion or calibration and allows elimination of the filter preceding the PA showing carrier aggregation. b) A fully integrated digital polar transmitter with on-chip wideband phase modulators and power combiner, featuring on-chip pre-distortion and Doherty efficiency enhancement. The total chip consists of more than 2x106 transistors, memories excluded.

ASML Technology Scholarship
Interview with Lennart Noordsij

Lennart is in his first year of the master Computer Engineering and has an ASML Technology Scholarship. In this interview he explains what this scholarship is and why he wanted to apply for it. He also explains how you can apply for it.

What exactly is the ASML Technology Scholarship?

It is a scholarship for technical students who want to do more than only studying. You get coaching from a personal ASML mentor and you get to meet other students. There are many aspects that make it very interesting. The scholarship itself consists of a financial support of €5000 per year for both years of your master and personal development trainings, which are very interesting.

Why did you want to apply for the ASML Technology Scholarship?

I did not really know that it existed until I found it out through the lunch lecture of ASML. I saw that it was money and trainings, but there was not much that you needed to do for it, except apply and be a good student. I thought I am going to do my masters anyways, why not try?

> *"The scholarship itself consists of a financial support of €5000 per year for both years of your master and personal development trainings, which are very interesting."*

What do you enjoy the most of the scholarship?

Meeting other students who also get the scholarship, because there are excellent students from all disciplines. The trainings are also very interesting. Normally, when I would go to a communication training I would think: I can talk, what is the big deal. But these trainings are very good and I was impressed every time that I have been there. It can really help me in

my day to day life and professional life. It is pretty cool to get to know all these things which you don't normally take as easily. After each training we also go to dinner with the group, which is a lot of fun.

What does the selection process look like?

The first round will be a round where you send your resume and they will see if you are interested or not. They will check if your field of studies is relevant, because they have a select list of masters, which can be found on the website. They will also check if you have at least 7.5 as grade point average and if you did more than studying, so extracurricular activities.

After that round there is a video interview, which is very awkward. The interview consists out of four questions on your screen and you have like a minute to think and one or two minutes to record your answer for each question. I think they are looking at if you are a bit fluent in talking. I think they also want to look at your motivation for doing the scholarship.

After the video interview you get the assessment days at ASML. You get to do a group assignment to simulate a company environment. This way they can see how you behave in a group, how you communicate, how good your ideas are and how you behave in a meeting. They really want to draw you out of your shell, so they give some high pressure assignments which are very hard to complete in time. This will show how you behave under pressure.

Where do you see yourself in 3 years?

That is always an interesting question. I am now doing the master Computer Engi-

neering and I do enjoy it, but I do not see myself as a very in depth knowledgeable computer engineer later on. I found the trainings of ASML about soft skills and project management really interesting. Therefore I am probably going a bit more to the management side.

Do you want to work at ASML?

That is an interesting question as well. I have not seen anything work related at ASML yet. In the trainings we always focus on the training itself. On the assessment days they showed the building and what they are doing there, but I have not been to a recruitment event. So I have not really looked in if I want to work at ASML or not, but I like the kind of corporate atmosphere. When getting the scholarship, you are not forced to do an internship or work at ASML. They trust that you know if you like to work there after two years of trainings.

How can you apply?

I went to the website that was on the flyer that they gave us at the lunch lecture. What you can also do is contact the campus promotors. The campus promotor of EWI is Kevin van der Mark. And one of the other campus promotors is Floris van der Gronden who is also a scholarship student this year. He can help you even more because he has done the procedure himself.

If people are interested in applying but do not know how, they can always contact me or other scholarship students they know.

Do you have any final tip for people who are still doubting about doing this scholarship?

For me it was 'why not'. If you are going to do your master and you have a high grade point average, you want to see what corporate life is like or want to get more development in other areas, such as communication, then why not. Even if you do not get the scholarship, they will explain why you have been rejected and you will know how a selection process works. It also helps you to get prepared to job interviews, to know what people will expect from you.

You can apply for the ASML Technology Scholarship via *workingatasml.com/scholarship*
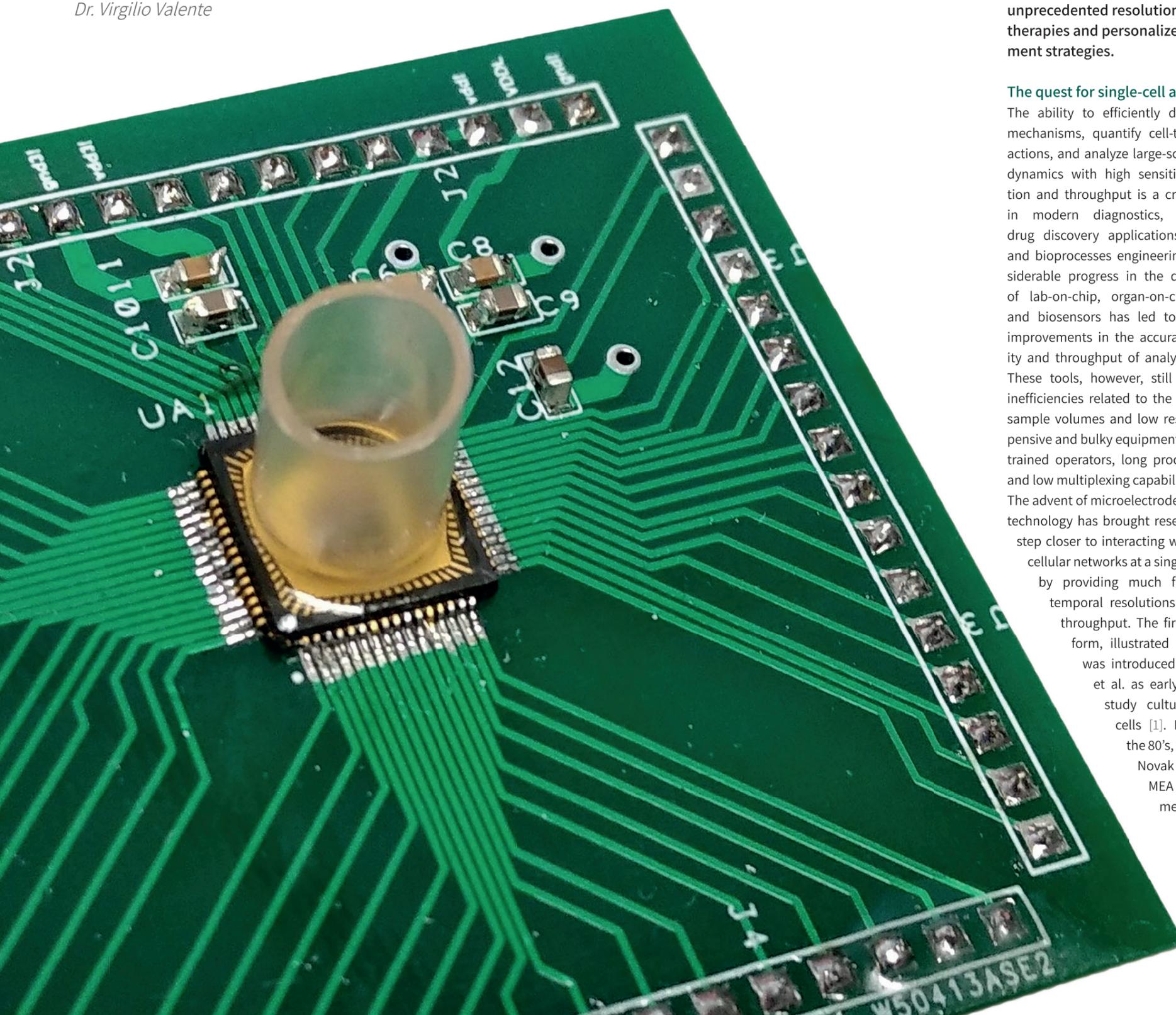
ASML
Be part of progress

BioCMOS

The convergence of biology and semiconductor technology for the development of efficient bioanalytical systems at the nanoscale

Dr. Virgilio Valente

The new frontier in smart and efficient diagnostics and analytics is represented by the fusion of semiconductor technologies and electrochemical sensors. BioCMOS devices, also known as Lab-on-CMOS or CMOS biosensors, consist of microelectronic interfaces with integrated high-density sensing elements. On top of these elements, biological and chemical assays can be directly performed, limiting considerably the need for additional external units. The Bioelectronics group is currently developing BioCMOS microsystems that target applications, including lab-on-chip and organ-on-chip platforms, point-of-care devices, implantable and injectable smart biosensors. By leveraging the distinctive features of modern complementary metal-oxide semiconductor (CMOS) technology, we can develop complex yet compact microelectronic bio-devices capable of interacting with biological networks at a cellular and molecular scale with unprecedented resolution and sensitivity. BioCMOS technology promises to play a key role in defining future targeted therapies and personalized medicine, cost-effective drug discovery and development, and efficient disease management strategies.

The quest for single-cell analytics

The ability to efficiently decipher cell mechanisms, quantify cell-to-cell interactions, and analyze large-scale network dynamics with high sensitivity, resolution and throughput is a crucial aspect in modern diagnostics, bio-sensing, drug discovery applications, genomics and bioprocesses engineering. The considerable progress in the development of lab-on-chip, organ-on-chip devices and biosensors has led to substantial improvements in the accuracy, sensitivity and throughput of analytical assays. These tools, however, still suffer from inefficiencies related to the use of large sample volumes and low resolution, expensive and bulky equipment, expert and trained operators, long processing time and low multiplexing capabilities.

The advent of microelectrode array (MEA) technology has brought researchers one step closer to interacting with complex cellular networks at a single-cell scale, by providing much finer spatio-temporal resolutions and higher throughput. The first MEA platform, illustrated in Figure 1, was introduced by Thomas et al. as early as 1972 to study cultured cardiac cells [1]. Later on, in the 80's, Wheeler and Novak adopted MEA platforms to measure extra-cellular field potentials from brain slices [2]. Thanks to the early promising results, MEA systems are currently routinely used in research labs worldwide. Figure 2 shows an example of a commercial MEA system featuring 64 uniquely addressable electrodes to monitor spontaneous activity of cultured cerebellum.

Passive MEA systems, however, are limited in the number of available stimulation/recording electrodes (on average < 1000 sites), the obtainable spatial resolution (>20 μm) and the presence of large parasitics, associated to the connection of the external circuitry, which degrade the signal quality. Due to these limitations, researchers often resort to the use of highly computational signal interpolations to reconstruct low-resolution electrophysiological recording into high-density 2D and 3D maps [3].

CMOS-MEAs at the heart of BioCMOS devices.

The adoption of CMOS technology has enabled the development of high-density MEA systems (>10^3 sites) with an unmatched subcellular spatial resolution (<20 μm) and a degree of functional complexity and automation comparable to specialized laboratory equipment. Fabrication of MEAs can now be fully integrated in a semiconductor (CMOS) process. This makes CMOS-MEAs extremely attractive, not only for their scalability and achievable resolution, but also for their potential low cost when mass produced. The emerging field of CMOS-MEA has presented numerous opportunities in applications beyond neural and cardiac electrophysiology, including diagnostics, DNA sequencing, molecule and particle detection and manipulation. Particularly in the field of diagnostics, arrays of ▷
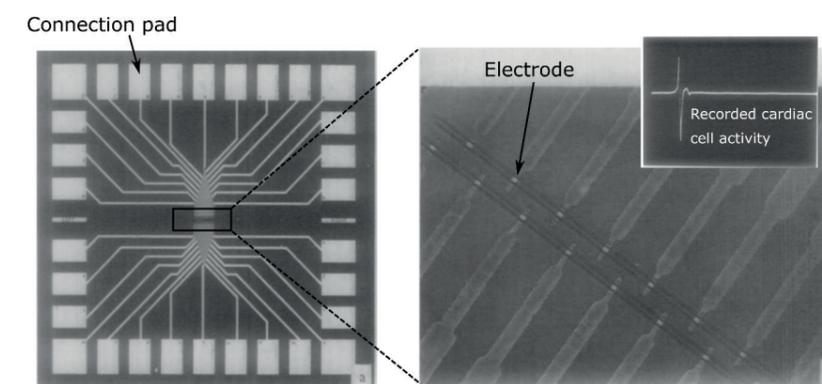
Connection pad

Electrode

Recorded cardiac cell activity

Figure 1. First MEA device developed in the 70's to record electrical activity of cardiac cells. Adapted from [1].

64 Electrode MEA system

Spontaneous activity of single units

Ch 26

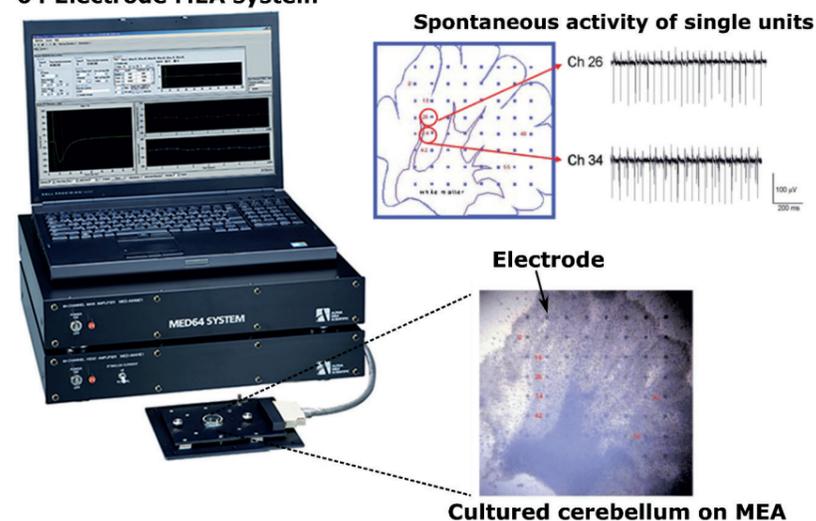Ch 34

Electrode

Cultured cerebellum on MEA

Figure 2. Typical commercial MEA recording system. Adapted from www.med64.com.

micro-sensors have been successfully integrated in CMOS technology to achieve single-cell resolution. This readily translates to ultra-low limits of detection and extremely low sample volumes (down to micro or nanoliters). Figure 3 shows one of our BioCMOS devices featuring an array of 1024 electrodes of 15µm pitch and capable of operating with microliter samples. CMOS-MEA platforms are now capable of achieving sensing capabilities comparable to specialized and expensive laboratory equipment, at a fraction of the size and the cost. A wide spectrum of electrochemical assays have been consistently performed directly on CMOS-MEA devices, including electrical impedance spectroscopy (EIS), cyclic voltammetry (CV) and chronoamperometry (CA). EIS is a particularly attractive method that can be readily implemented on BioCMOS devices and provides rich information about cell concentration, cell attachment to the electrode surface, cell morphology and size. An alternative sensing strategy that is widely adopted for cell detection and monitoring is based on capacitive sensing (CS), whereby local differential changes in capacitance across the MEA are correlated to the presence of molecules on top of the electrodes. This method greatly reduces circuit complexity at the cost of limited

accessible information compared to EIS. CS has been lately successfully adopted to perform electrical impedance-based

imaging [4], [5]. Figure 4 shows impedance-based images based on differential capacitance values that allow to differentiate between different types of cells. The two key challenges in the development of BioCMOS devices are the integration of different sensing modalities on the same chip (e.g. electrical and chemical) and the conflicting requirements between ultra-high-density sensing elements and low-noise and low-power. Recently, we have proposed a CMOS-MEA that accommodates EIS and CS sensing, while preserving a high electrode count and low-noise and low-power consumption. This result was achieved, thanks to the adoption of compact front-end circuitry very close to the electrode (in-pixel) and original circuit-sharing techniques to limit the impact of the readout circuit on the area and the power consumption of the chip. This level of integration enables the

"CMOS-MEA platforms are now capable of achieving sensing capabilities comparable to specialized and expensive laboratory equipment, at a fraction of the size and the cost."
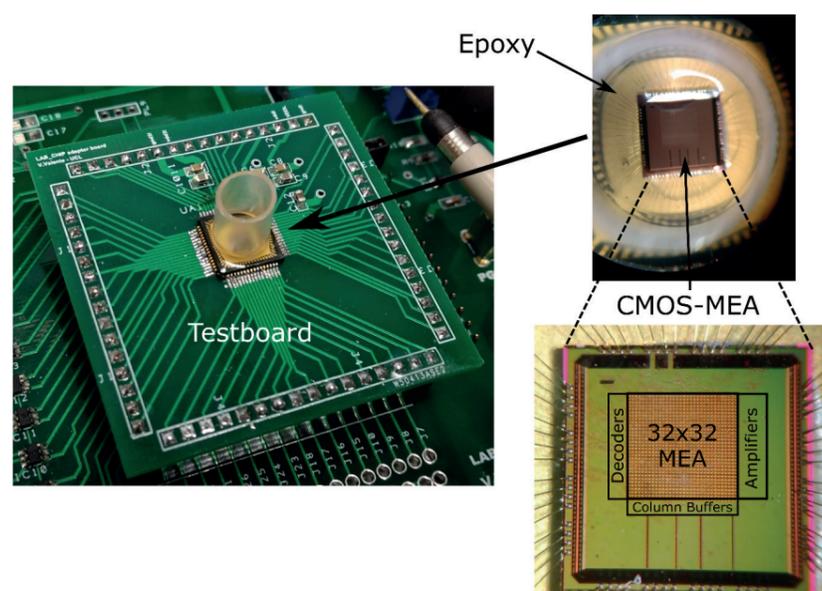

Epoxy

Testboard

CMOS-MEA

Decoders   32x32 MEA   Amplifiers

Column Buffers

Figure 3. Example of a 32X32 CMOS-MEA chip that can perform both EIS and CS depending on the application. Each sensor is 15x15 µm² and the chip measures 10 mm² [Adapted from Valente et al. Manuscript in preparation].

CMOS-MEA   **Nanoelectrode**

2 µm

25 nm

500 nm   0

Impedance images

10 µm

Dielectric particle

Conductive particle

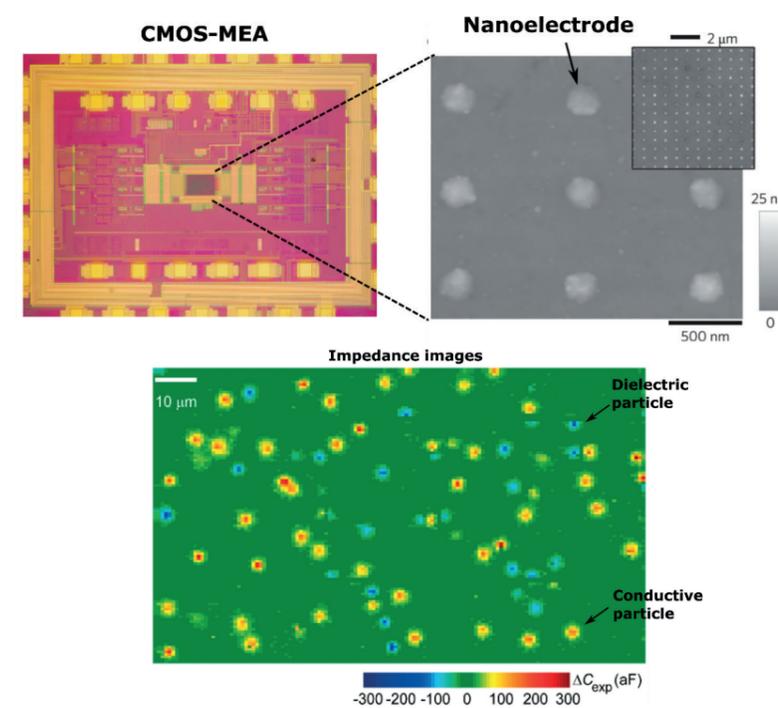-300 -200 -100 0 100 200 300 ΔC_{exp} (aF)

Figure 4. Impedance-based cell imaging based on capacitive changes across a 256x256 electrode array. Adapted from [6].

development of analytical platforms for a full spectrum of applications, including impedance microbiology, impedance imaging, cell detection and analysis [6].

Outlook

Our work on BioCMOS platforms is currently evolving in two main complementary directions: one concentrates on increasing the density of the electrodes, whereas the other focuses on providing multi-modality and multi-parameter analytical systems. The former approach

is motivated by the scientific need to investigate large populations of cells and neurons and their interaction at network scale. The latter is driven by the requirement to develop patient-specific diagnostic tools by efficiently combining complementary sensing modalities (electrical, chemical, mechanical and optical), historically limited to specialized and expensive equipment. These developments guarantee to support the evolution and progress of future analytical biotechnology and devices including lab-on-chip, or-

gan-on-chip, microfluidic and biosensor devices.

With its unique features, BioCMOS technology is paving the way to better disease detection and management and promises to play a key role in the definition of targeted therapies and personalised medicine, cost-effective drug discovery and development and efficient disease management.   ⏚

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The development of electric light
Some aspects of efficiency in the production of electric light

Otto Rompelman

In a contribution of a group engaged in the historical aspects of electrical engineering, it shouldn't come as surprise if the history (or etymology, for that matter) of the word efficiency is given some attention.

The term efficiency is directly related to the term effect, which comes from the Latin ex (from, resulting from) and facere (to do, to make). Hence, effect is the result of an action. In the Concise Oxford Dictionary, the term efficiency is described as "the state or quality of being efficient, (Mechanics & Physics) ratio of useful work done to total energy expended or heat taken in". Hence, the term efficiency introduces a relation between two issues: roughly spoken: "the work done versus the actual result". In the Concise Oxford dictionary, the field of application is already confined to Mechanics/Physics, which means that we are rapidly inclined to think of effective power related to total power (power factor). In this contribution, we will briefly discuss the evolution of the efficiency when converting electrical energy into light.

How electric light evolved
In the past two centuries, the conversion of electrical energy into (visible) light has shown a tremendous increase in efficiency, i.e., the fraction of electric energy that is converted into light, often expressed in terms lm/W (lumen per Watt). The remaining energy is converted into lost heat. In the early nineteenth century, it was discovered that an electric current passing through a thin filament could produce light (e.g. in an incandescent light bulb). However, the efficiency of an incandescent light bulb is in the order of 2 - 3 %. The efficiency could be improved to around 5 - 10 % by placing the filament in a high-pressure halogen filled bulb. In particular, a quartz bulb showed to be the most efficient since this allows for much higher filament temperatures. A different principle for the production of light is used in the electric arc lamp, in which an electric arc causes vaporized carbon to produce an intense light stream. The efficiency of this lamp is in the order of 5 – 10 %. Again, the remaining energy produced heat. A problem with the latter light source is the production of a significant amount of UV-light, which makes it hazardous if a direct view of the actual arc

is possible. Figure 1 shows a carbon arc lamp as present in the EWI Historical Collection. Two individual carbon electrodes are shown as well.

A much higher efficiency could be obtained with the fluorescent lamp, developed in the twenties and thirties of the last century. These lamps are mercury vapor filled glass tubes with a phosphor

Figure 1. An electric arc lamp and two carbon rods as present in the historic collection of the Faculty EEMCS (photo: Han Geijp).

coating on the inside. An electric current generates UV-light which causes the phosphor coating to glow in the visible part of the spectrum. The efficiency of this light source is in the order of 30 %. This improvement led to the production of Compact Fluorescent Lamps (CFL) that could easily replace filament lamps. Some examples of fluorescent lamps, a CFL-lamp and a typical LED-bulb (to be discussed below) are shown in figure 2.

So far, electrical production of light could be envisaged as the production of heat with light as a (highly desired!) side effect. In the early 70's of the last century, it was shown that in some semiconductor PN-junctions photons are produced under the influence of an electric field. The device showing this behavior was called LED (Light Emitting Diode). These first LED's, however, were useless for practical applications as a light source since they produced just one color. However, in terms of efficiency, the principle was very promising. It was only in the first decade of this century that practical (i.e. producing broad spectrum visible light) LED-based lamps could be produced. Nowadays, LED-based lamps are flooding the market and are more or less becoming a standard, which is not surprising if we realize that their efficiency is in the order of 50 % or more and that they produce some 150 lm/W, with experimentally even 200 lm/W!

In summary, the efficiencies of different light sources are shown in the table. Interestingly, the order in which they are listed corresponds to the historical order of appearance.

Tabel 1. Different light sources with their efficiency.

Type	lm/W
Electric arc	3
Incandescent	14
Halogen	17
CFL	55
LED	150

Figure 2. An electric arc lamp and two carbon rods as present in the historic collection of the Faculty EEMCS (photo: Han Geijp).

Reactive and non-linear light appliances
So far, we have discussed efficiency in terms of the light producing the fraction of energy dissipated by the device. This energy is usually delivered by the electrical network (mains). In case of linear resistive devices (i.e. exhibiting a linear relation between applied voltage and resulting current, and no phase shift between voltage and current), all delivered energy is dissipated by the device (in the form of both heat and light). Incandescent light sources are linear resistive devices.

Halogen lamps, CFL's and LED-lights cannot directly be connected to the mains but need a (usually built-in) converter to transform the 230 V 50 Hz AC voltage into a suitable voltage or current. These converters give rise to reduced efficiency, which is due to their reactive and often, non-linear load to the network. Therefore, when discussing the efficiency of these devices, we have to introduce another factor of interest, i.e. the *power factor*.

First, consider a device exhibiting a reactive load. It is well known that the real power P (as dissipated by the load) is related to the apparent power S (as delivered by the mains) through:

$$P = S \cos \phi$$

in which ϕ represents the phase shift the between voltage and consequent current. See figure 3. The so-called power factor η is now defined as:

$$\eta = \frac{P}{S} = \frac{VI \cos \phi}{VI} = \cos \phi$$

where V is the effective value of the applied voltage and I the effective value of the resultant current. Obviously, $\eta \leq 1$. However, if the load is non-linear, things become a bit more complicated. In a non-linear load the current is distorted. This means that the periodical mains voltage V gives rise to a number of harmonic components I_n ($n = 1,2,3,4,...$) such that the RMS value of the total current I follows from:

$$I = \sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + ...}$$

where I_1 is the first harmonic (same ▷

Apparent power S
Reactive power Q
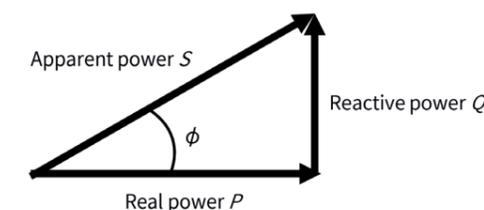ϕ
Real power P

Figure 3. The power triangle with ϕ the phase shift between applied voltage and the consequent current.

frequency as the mains voltage V). A measure for the harmonic distortion is THD (Total Harmonic Distortion), obeying:

$$THD = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{I_1^2}$$

Since only the first harmonic I_1, being in synchrony with the applied voltage, contributes to the consumed power P, the power factor now becomes:

$$\eta = \frac{P}{S} = \frac{V I_1 \cos\phi}{V \sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}$$

$$= \frac{\cos\phi}{\sqrt{1 + (THD)^2}}$$

When no harmonic distortion is present, $THD = 0$ and consequently $\eta = \cos\phi$.
In conclusion, the power factor η is reduced with:

- increasing phase shift between voltage and current.
- increasing harmonic distortion.

Early fluorescent tube appliances had typical power factors of 0.3. LED-appliances also showed poor power factors, mainly due to a high THD. This heavy distortion introduced serious noise on the mains, a reason for incidental disturbances in equipment sensitive to RF-interference.

Though a poor power factor may be of less importance when only a few LED-systems are employed, undesired reactive power and/or RF-interference can be introduced if a large number of incandescent light systems are replaced by LED systems. Fortunately, over the recent years the converters for driving LED-light systems have drastically improved, so that, nowa-

days they show power factors in between 0.9 and 0.95.

Conclusions

In this contribution, it has been shown that the development of light sources has shown a drastic improvement when looking at the efficiency of the conversion of electrical energy into light. Care should be taken when the appliances form a reactive and/or a non-linear load to the mains network, because this may introduce loss of efficiency. This may be overcome by appropriate measures as is usually the case nowadays.

Acknowledgement

The Studieverzameling (the historic collection of the faculty EEMCS), which can be found in the basement of the low rise building since November 1969, houses an extensive collection of nostalgic, mostly electronical, equipment.

The collection includes various objects in which electrical engineering took such an important role in our lives. Developments in sound and vision, calculators, typewriters, telephony, photography, high voltage, radar technology, navigation systems, measurement and control equipment, vacuum tubes and computer, just to list some topics. Also a lot of books, magazines and documentation are in the collection.

The historic collection of EEMCS is open for visits on Mondays from 10:00 till 16:00. The volunteers will welcome you with much enthusiasm.

From the Study Collection EWI: PASCAL (Philips Akelig Snelle CALculator) from the end of the 50s. This computer once was the fastest computer in the world. It consists, among other things, of 1250 dual triodes, 10000 germanium transistors and 15000 germanium diodes. In operation it uses approxamatly 10kW.

Energy efficiency improvement
in the world power transmission & distribution system

Eavin Antony (Texas A&M University)

Since time immemorial, the power industry has been driven on the law stated by Lord Kelvin (1824-1907) to steer system design that recognizes and considers both, cost and energy losses:

"The annual cost of transmitting energy may be divided under two heads: (1) energy lost in the conductor itself, which is approximately proportional to its cross-section; and (2) the interest and depreciation on the capital". [1]

It is without doubt that cost-effective efficiency improvements are more likely to sit well with utility grid operators, consumers, and legislators rather than modernistically extravagant yet, technically feasible improvements.

From Figure 1, though the overall power transmission and distribution losses may seem to be a minimal percentage, 8.2% losses of the total 23844 TWh of power generated in 2014 [3] translate to a loss of around 1955 TWh annually around the world. Thus, it calls for efficiency improvements in the overall electricity transmission and distribution system.

Technological developments have definitely improved the T&D system but reducing these losses are not an easy task since most of them involve many interacting phenomena. These phenomena cause the reduction of losses on one line or grid to cause increased losses or costs elsewhere. Additionally, transmission limits and market prices along with country policies play a major role too.

HVDC vs HVAC
A majority of the transmission losses and limits are heavily dependent on high-voltage alternating current (HVAC) lines. In comparison, high-voltage direct current (HVDC) lines have 25% lesser losses and about 2 to 5 times the current carrying capacity of an HVAC line at the same voltage [4]. Thus, HVDC has emerged as the preferred transmission technology for long-distance bulk power supply.

The Rio Madeira HVDC system, installed by ABB in 2013-2014, is a 6,300 MW ± 600 kV HVDC transmission system in Brazil. It was commissioned to deliver power from hydro power plants on the Madeira River in the Amazon Basin to major load centers in southeastern Brazil. The lines covered a distance of 2,375 km through various terrains making it the longest HVDC transmission system in the world [5].

In Figure 2, there is a critical distance at which cost associated with HVDC begins to be better than HVAC lines but with the advent of newer systems such as ABB's HVDC Light technology [7], this critical distance has reduced dramatically while still maintaining the benefits of HVDC. HVDC Light can be used to transmit electricity in power ranges from 50 – 2,500 MW

Figure 1. World Electric Power Transmission and Distribution Losses (% of output) [2].

by using overhead lines or through underground and subsea cables. It is used for grid interconnections and offshore links to wind farms and oil and gas platforms. Its main characteristics include:

- Independent power transfer and power quality control
- Faster restoration after blackouts
- Powerful damping control using P and Q simultaneously
- Increased transfer capacity in the existing system
- Reduced power losses in connected AC systems

Distribution Load Management
Typical distribution systems are designed by considering future loads in an area.

However, over time, customers may change and add equipment causing the 3 phases to be not in balance anymore. This causes a significant rise in neutral wire losses and in the distribution transformer. Neutral wire losses can be reduced by considering various customer demand response programs [8], load balancing using various optimization methods [9], etc. For distribution transformer losses, using a full-wave three-phase converter mitigates the problem to an extent.

In the configuration shown in figure 3, the capacitor lets energy to be taken from one phase and applied for a brief period of time later to another. Even though there may be a neutral current in the ▷
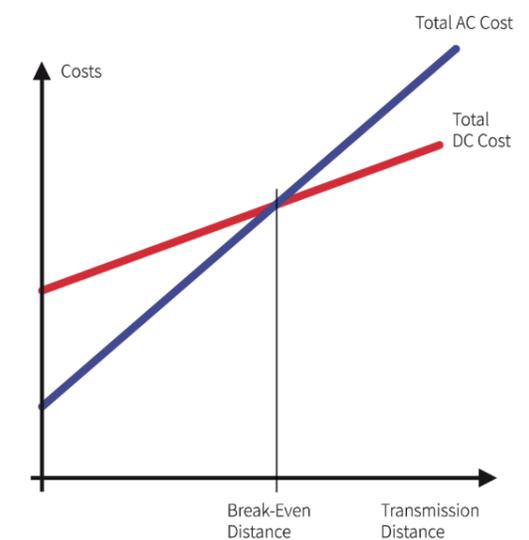

Figure 2. Investment costs vs Distance of HVDC vs HVAC lines [6].

line, the power electronic devices are configured to achieve balance in the phases at the transformer.

Self-Healing Reconfiguring Distribution Systems

Real-time system reconfiguration can be employed to switch to another line when one line is heavily loaded (increased losses) and this may be done based on various parameters such as fluctuating market prices [11], classic non-linear optimization techniques in smart radial distribution networks [12], injection of distributed generation networks into the grid [13], etc.

The favorable reconfiguration algorithms are predominantly academic because of challenges that include dependency on heuristic techniques that require multiple iterations and may not be suitable for real-time applications. Moreover, they do not assure an optimal solution. However, Schweitzer Engineering Laboratories (SEL) has devised a method of distributed control using communications as shown in figure 3. While the SEL 351S and the SEL 451 relays are monitoring overcurrent
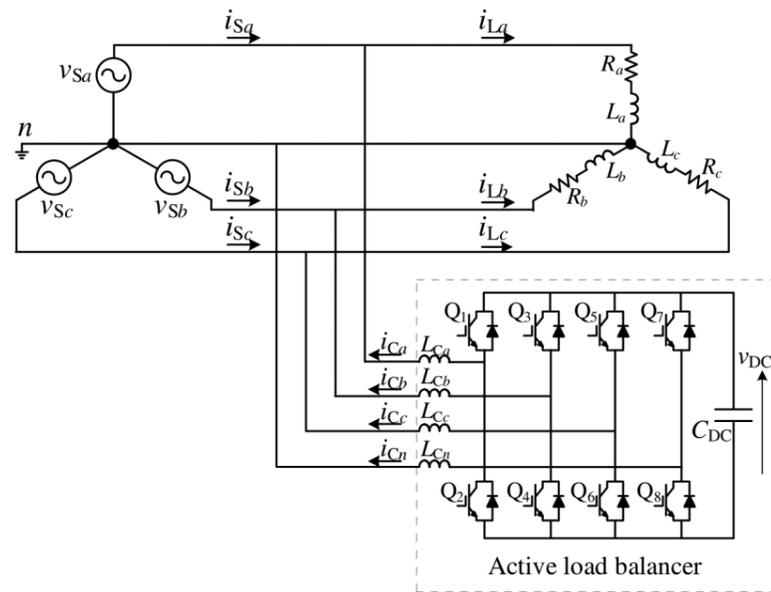

Figure 3. Phase-Balance electronics [10].

values, the SEL 2431 is used as a voltage regulation controller. The SEL 651R and 651RA (Advanced recloser control) are also constantly communicating with the other entities in the system. The SEL 734B (Advanced Monitoring & Control system) can be preloaded with control schemes or custom controls that employ automation

logic that allows it to make intelligent decision based on fault detection and voltage values from both sides of the recloser [14].

Intelligent Substation Design

A majority of line losses also arises from improper substation design leading to overloaded buses, transformers, unnecessary tripping of relays etc. Though better training could be given to present engineers or future engineers-to-be, the trend is moving towards the use of intelligent substation designs. This is a model-centric approach that combines physical and electrical design disciplines while enabling tools essential for electrical substation design. Unlike the graphics-only drawings made with traditional CAD software, intelligent substation model drawings comprise of entities that possess properties of the equipment they represent, the wiring connections they support, and the engineering principles that govern their respective design.

Bentley Corporation has revolutionized the substation design market with their Bentley intelligent substation design software that can be used to produce Green-
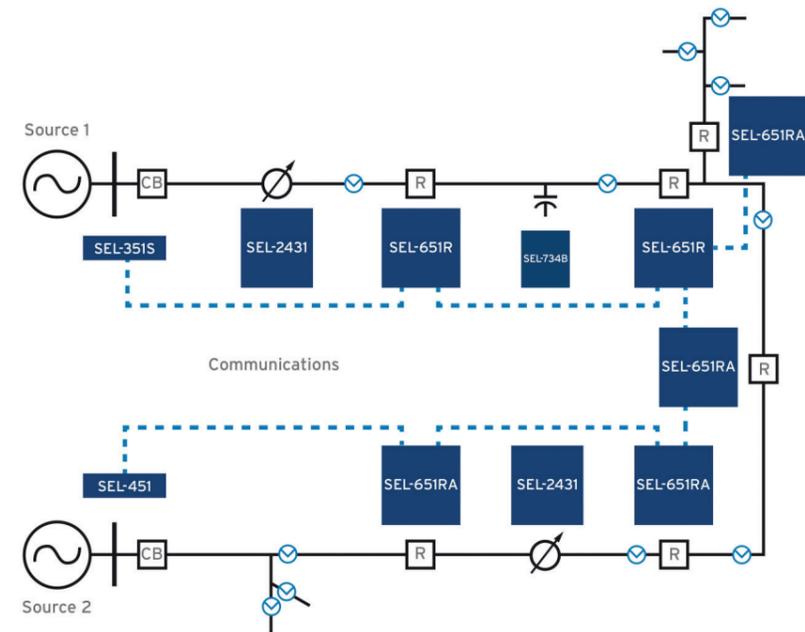

Figure 4. SEL Distribution Network Automation [14].

field and Brownfield designs up to 40 percent quicker [15]. This also promotes rapid project collaboration and coordination that aids the unison of electrical and physical design which results in lesser rework, truncate faults, and augment collusion with cross-referenced 3D layouts and electrical drawings.

Impact of Government Policy

The US Department of Energy (DOE) started an initiative to implement new efficiency standards for distribution transformers [16]. These transformers are the most omnipresent and typical piece of electrical equipment which makes it an integral

point of upgradation. The DOE's standards covered majorly two basic types of electric distribution transformers: liquid-immersed transformers (installed on utility poles or those on concrete pads in residential subdivisions) and low-voltage dry-type transformers (installed in new buildings).

The regulated standards had a decent impact on the efficiency of a given transformer – about 4% over the present transformers [17]. But this small increase over the countless transformers across the country will result in a substantial improvement to the tune of 50 TWh and net

consumers about $3.7 billion over thirty years.

The Future

In an era, even when we're pushing towards the use of superconductors, control of power flow with FACTS, installation of interconnected HVDC systems, etc., the establishment of a completely smart and efficient power system may seem a distant reality. There are plenty of academic-grade improvements that can essentially improve this dire state of power systems. However, to push towards a cleaner and efficient grid, the need for smarter engineers and small, yet effective goals by progressive policymakers is of prime importance. ⏚

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The wonderful world of quantum computing

Prof. Koen Bertels

Every so many years or even decades, someone makes a suggestion that inspires a lot of people to start working on, in our case, the technical implementation challenges for building a quantum computer. The suggestion was made by the famous, Nobel prize winning American physicist, Richard Feynman. He claimed that if we want to deepen our understanding of the quantum physical world, we should build a computer that works on those principles. This created the field, Quantum Computing. The core idea is to use the quantum phenomena such as superposition and entanglement such that we could have unparalleled compute power by doing so.

The power of Quantum Computing

The essence of any quantum computer is the qubit, or the quantum bit. In contrast to the classical bits, a qubit can also be in either the $|0\rangle$ or $|1\rangle$ state. However, the qubit can also be in a superposition state which in this case it would mean that it is both $|0\rangle$ and $|1\rangle$ at the same time. When applying any kind of quantum operation on the superposition, it is applied on the superposition state at the same time. One can also combine two qubits, each in superposition, with each other resulting in 4 states. Combining 3 qubits gives one eight states. The formula 2^N then computes how many states one has in the combination of n qubits. When one would have 300 of good qubits combined in that way, one would get a number which is bigger than the estimated number of atoms in the known universe. And the same principle stays applicable: any quantum operation is then on the total amount of combined states in total. So, quantum physics gives us massive parallelism, which gives us compute power multiple orders of magnitude bigger than any of the existing supercomputers in the world.
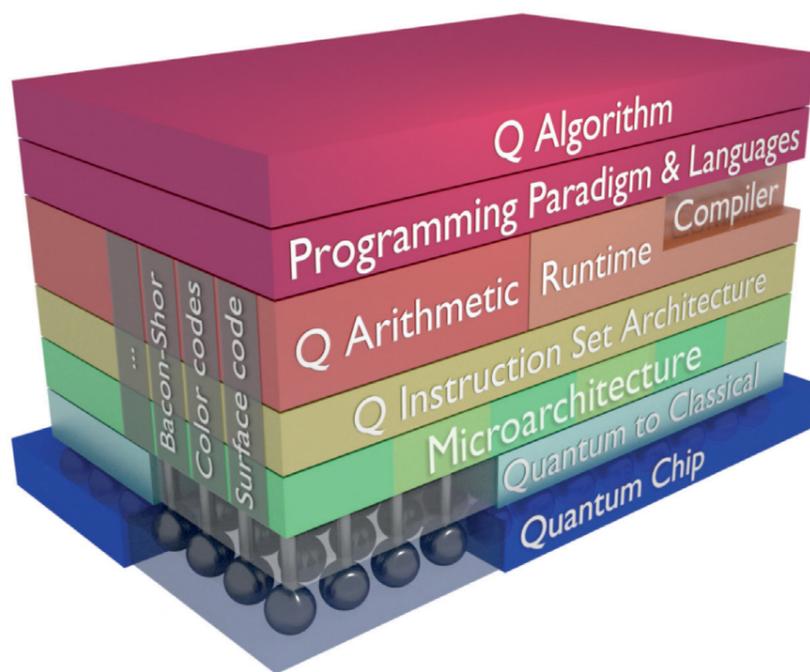
Challenges in Quantum Computing

However, there is no such thing as a free lunch. When one wants to know the result of the computation, one needs to measure the qubit state and unfortunately such a measurement has a destructive effect on the superposition state and will return only the value of one of the states. So how can one guarantee that the final result is measured from the selected state and also can one be sure that it is correct?

> *"…quantum physics gives us massive parallelism, which gives us compute power multiple orders of magnitude bigger than any of the existing supercomputers in the world."*

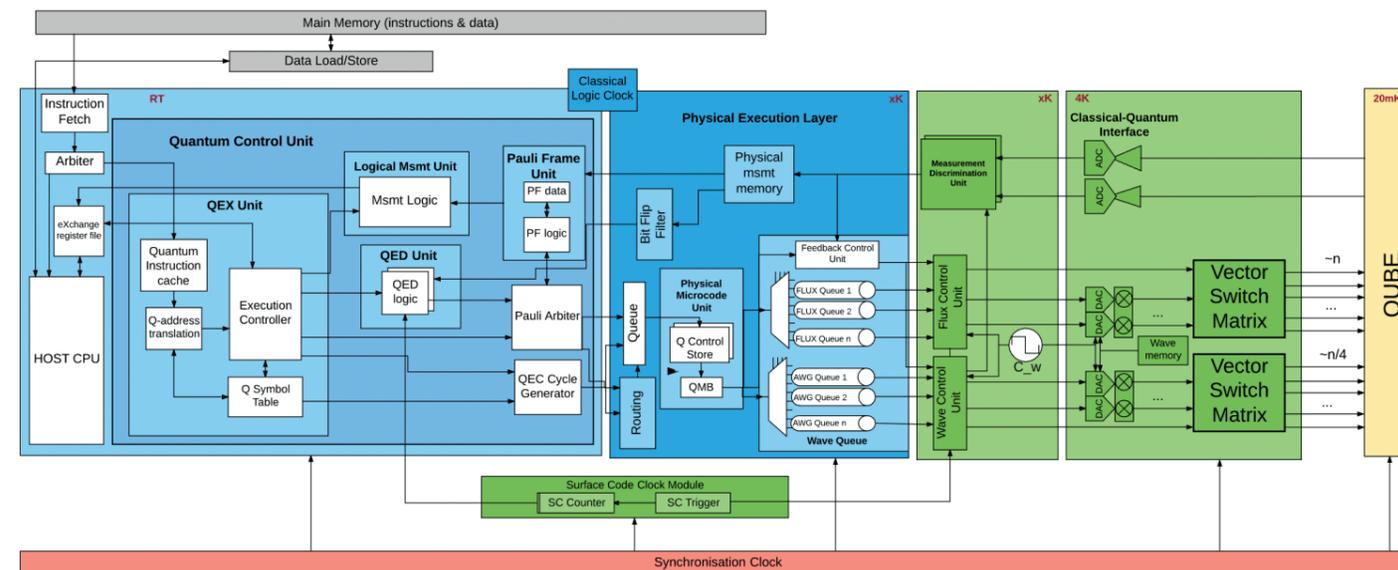***Figure 1.** Quantum system stack.*

As explained before, quantum computing has the exceptional compute power but it also computes in a non-deterministic way. A single qubit state is described as follows:

$$|A\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$$

where the alpha and the beta are the amplitudes which when combined as follows:

$$|\alpha|^2 + |\beta|^2 = 1$$

So, the alpha and beta represent the probability with which either the $|0\rangle$ or $|1\rangle$ will be measured and the quantum algorithm manipulates or computes the new values for alpha and beta. So, if the $|\alpha|^2$ value is 0.7 then that means that in 70% of the measurement cases the $|0\rangle$ will be measured but also that in 30% of the cases, the $|1\rangle$ state will be produced as the result. This is the non-deterministic part of the quantum computer. This also implies that one needs to run the quantum algorithm more than once and collect all of the obtained measurement results. The state with the best amplitude or probability will then have the highest frequency of occurrence in the measurement and will thus be accepted as the final result. This is the second property, besides the non-deterministic behavior, of the quantum device namely that you need multiple executions to have sufficient trust in the final measurement.

Now that we know what the core characteristic of a quantum computer is, we can start thinking about what it means when one tries to build one. Just like, when building a classical computer, one can envision that also the new quantum computer will consist of different components and layers that collectively provide the compute power that we are looking for. The first decision to make is whether we are really making an independent computer or rather the component of a new kind of supercomputer. Given that the quantum phenomena are really very error prone and need very cold temperatures to be generated and used, the most likely first candidate architecture is a clas-

> *"…Given that the quantum phenomena are really very error prone and need very cold temperatures to be generated and used, the most likely first candidate architecture is a classical processor combined with a quantum accelerator and deployed in the cloud."*

sical processor combined with a quantum accelerator and deployed in the cloud. This is exactly what we started doing, resulting in the cube as shown in Figure 1.

The highest layer is the quantum algorithm where end-users are formulating the quantum algorithms that they want to execute. Just like in the classical case, any algorithm needs to be expressed in a programming language. The Quantum Computer Architecture group of EWI has developed an open source programming language, OpenQL which allows to express typical quantum gates belonging to some of the universal gate sets. That code can be combined with, for instance, part of the main application written in C++, such that two instruction sets can be targeted, namely the classical one and the quantum one. The OpenQL compiler will ultimately translate the source code in an assembly language, called QASM. The QASM language was originally developed by Nielsen and Chuang to generate the quantum circuits (that they discuss in their book) in LaTeX, but which is redefined by us in a full-fledged quantum assembly language.

As said above, the quantum ▷

***Figure 2.** The quantum micro-architecture*

"It is in this part that the technology dependent parts are expressed and where the differences in the targeted quantum technology can be formulated."

(co)processor has a series of basic instructions it can execute, and which are part of the Quantum Instruction Set and ultimately supported by the micro-architecture.

That quantum micro-architecture, shown in Figure 2, fulfils the same role as the classical one but the components of that design do completely different things than their classical counterparts.

What is similar are components such as a (quantum) instruction cache, the (qubit) symbol table and also the presence of a micro-code unit is included. The micro-code approach is responsible for the translation of the QASM instruction in the lower level signals that need to be sent to the quantum chip. It is in this part that the technology dependent parts are expressed and where the differences in the targeted quantum technology can be formulated. The next layer is then the interface layer where the digital pulses are translated into the appropriate analogue ones and then executed on the quantum chip. It is still an open research question: how much of the micro-architecture will be put at lower temperatures rather than room-temperature. The lowest layer is then where most of the quantum computing scientists are working, namely the development of increasingly larger number of qubits in any of the target technologies.

Development horizon for Quantum Computing

QuTech is one of the only research centres in the world where physicists with electrical engineers collaborate to build such a system. The time horizon is still going to be 10 to 15 years before any real-world device will be available. However, companies that potentially are interested in the use of such a device need to start now before the necessary know-how is developed, tested and made ready for commercial exploitation. ⏚

Jens Arnbak
Telecom professor & regulator

Jos Weber and Gerard Janssen

In memory of ETV Honorary Member em. prof. dr. Jens Arnbak († 20th of February 2017), this piece portrays his valuable contribution to the field of Electrical Engineering and the ETV, for which we are forever thankful.

In 1986, Delft University of Technology made an excellent choice by inviting Jens Arnbak to become Professor in Telecommunications at the Faculty of Electrical Engineering. Until then he held the same position in Eindhoven. Being educated as a physicist, his original focus was on engineering aspects of transmission systems and networks, but besides the technological side, he also developed a great interest in and profound knowledge of other dimensions of telecommunications, such as regulatory, legal, and societal aspects. In 1994, he was also (part-time) appointed at TU Delft's Faculty of Technology, Policy and Management to explore these areas.

His talents were spotted in The Hague as well, where he was a member of various committees advising the government on, e.g., computer crime and the PTT autonomization. He was the first chairman of the "Onafhankelijke Post en Telecommunicatie Autoriteit" (OPTA), the Dutch regulator for postal and telecommunications industries, during the exciting times at the turn of the millennium, featuring some great clashes with KPN-CEO's at the dawn of competition in the telecommunications market. Based on his splendid reputation, he was elected the chairman of the European Regulators Group (ERG), which was established as an advisory group to the Commission in 2002.

Through all these years, he always continued enthusiastically teaching and supervising TU Delft students on topics like telecommunication techniques and transmission systems engineering. He was very much involved in student activities, by advising on excursions, chairing symposia, joining study trips, etc. Therefore, he was nominated Honorary Member of the Elektrotechnische Vereeniging (ETV), only five years after his arrival in Delft. A long-standing tradition was the annual dinner at his home in The Hague, where he hosted (together with his wife and sons) the resigning and entering ETV boards.

Jens Arnbak, originally from Denmark (Aarhus, 1943), was well recognized for his services to the Dutch society. He received a knighthood ("Ridder in de Orde van de Nederlandse Leeuw") from the Queen. His farewell symposium in 2008 was very well attended. Unfortunately, Jens was diagnosed with Alzheimer's disease soon after his retirement. In spite of his illness, he remained the gentle person he had always been. He passed away in February 2017, but his spirit lives on in the telecommunications world, through his family (his youngest son Axel is a renowned cyber security expert) and through many students and colleagues who have been inspired by him. ⏚

Exchange to Estonia
Study Abroad

Ludo van den Buijs

As part of my master's program I was able to do my specialization at the Technical University of Tallinn (TTU) in Estonia. It would be a semester in which I would get to know a different country, study new topics and find out what it is like when you are really on your own.

The way exchange students choose their destination differs a lot. Some students have dreamed of visiting a specific country or culture for a long time, some want to use their time abroad to learn a new language and others make their decision based on the specialization they want to do. I personally belonged to the last group. I always knew that I wanted to spend a semester abroad and I knew that I wanted to specialize in internation-

electrical engineering offers a very strong analytical foundation from which you're able to pursue many directions of study. I didn't want to blindly continue with an electrical engineering master's program and thus considered the other options I had. I decided to pursue the master's program, Engineering and Policy Analysis, at the TPM-faculty. The program is meant for students with a technical bachelor's and combines advanced modelling courses

> *"You might be wondering why an electrical engineer wants to specialize in international relations…"*

al relations. In Tallinn, I would be able to follow a set of varied courses regarding international relations and thus the decision was easily made.

You might be wondering why an electrical engineer wants to specialize in international relations. A bachelor's degree in

with social and political courses to tackle international grand challenges like the energy transition, super infectious diseases and the refugee crisis.

The courses I participated in tackled various aspects of international relations focusing on different regions as well as dif-

ferent aspects of international relations like the role of oil and gas. While these courses weren't technical in nature, I did certainly notice the benefit I got from my electrical engineering background. During my bachelor's, I was taught how to approach a problem analytically and this aided me in finding patterns and logical developments in understanding the historic developments within the EU or to understanding the role different cultures play in their respective foreign policies.

What added more value to these classes was the variety of experiences my teachers had. Some of them grew up in the Soviet Union, one had done research for NATO, one had worked for the energy department of the Iranian government and yet another had been the Ambassador of the Republic of Moldova in Estonia. This allowed them to include their own perspectives in their teachings which added a lot to my experience.

Furthermore, their respective network allowed for us to speak to the Ambassador from Spain during the Catalonian independence movement, to listen to the Ambassador from the Republic of China (Taiwan) and to visit the office of the Estonian president.

Tallinn itself is a beautiful city to live in, most importantly because of the historic medieval city center. Even though the Old Town of Tallinn is the focus of the local nightlife, it is not hard to imagine what the city must have looked like in medieval times. From the original city walls to the small streets, it almost felt magical when you walked through the city gates from the modern city center to old town.

Perhaps even more impressive than the medieval history is the impression the occupation of the Soviet Union has left on the city. Once you learn more about this period and the peaceful independence movement of Estonia following the occupation (I highly recommend watching "The Singing Revolution" if you want to learn more about it), it becomes more visible. From the Russian Orthodox Church towering over the Estonian parliament on the other side of the street to large concrete blocks used to block Soviet tanks from entering the city still lying next to the road, the rich history of the city is visible everywhere you look.

Furthermore, Tallinn serves as a great starting point for additional traveling. Not only are there direct busses to the capitals of the other Baltic states, but it also only takes two hours to reach Helsinki by boat. Moreover, once you have a tourist visa, it easy to reach St. Petersburg as well.

There is a very active international student culture at TTU. The only organization comparable to the Dutch study associations is the International Erasmus Student Network (ESN). They organize a lot of activities and can help you out with any questions you might have. The benefit you have as a TTU student is that there are two ESN organizations active in Tallinn: one in the city center available for all

international students in the city and one focused on TTU students. Partially thanks to their efforts, a tight community was easily formed. What I especially enjoyed is that the smaller social groups that developed in the beginning of the semester heavily overlapped after a while, because of this you would constantly get introduced to new people. Some of the people I could laugh the most with I only met in my last months.

All in all, I am very happy with my decision to study in Tallinn for a semester. I was able to apply my analytical thinking taught at electrical engineering in a different way and gain a better understanding of the dynamics of international affairs. Furthermore, it allowed me to see much more of the world and meet a lot people from all over Europe.

Project: Clap activated switch
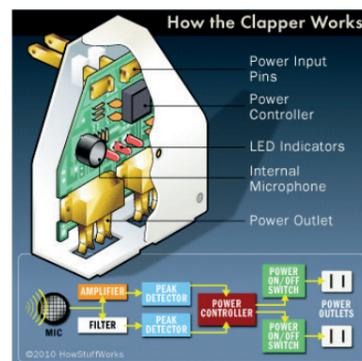## "Clap on! Clap off!"

Eray Albayrak

During the 80's, a sound activated power outlet was introduced in the United States. First appearing in an American television ads with the slogan "Clap On! Clap Off! The Clapper!" it was a product with a high popularity. The concept was a device which made it possible to power on or off appliances with the comfort of not having to leave your place. When introduced, it was a fun little gadget, but it had many troubles, for example, the device was meant to be activated just by clapping, but all loud sounds had an effect. How does the Clapper work? A microphone picks up an audio signal which is then filtered and processed by a power controller, which switches the connected power outlets on or off. For its time, it was a simple and cheap solution for remote controlling appliances. Luckily, technological improvements have brought us to easier and more reliable methods.

Not being a success, the Clapper still introduced an interesting concept, sound activated remote controlling. In this project we will build a similar circuit with a microphone, some common passive components and the infamous 555 timer to switch on a led by just a simple clap. Looking at the schematic, the circuit consist of 2 parts: the sound detection and the processing.

The sound is detected by a microphone which triggers transistor T1 to be turned on. Resistor R1 determines the sensitivity at which T1 switches, a variable resistor could be used to adjust this. If T1 is turned on, T2 is turned off. This will turn on T3, causing the trigger of the 555 to be activated. By just using the microphone and transistors, you could turn on a led for a short amount of time, but this is not our intention.

To be able to have the LED stay on, we need a flip-flop. Luckily it is possible to use the 555 timer in bistable mode, which gives it two possible outputs: High and Low. To get this mode, we need to use the configuration used in the schematic.
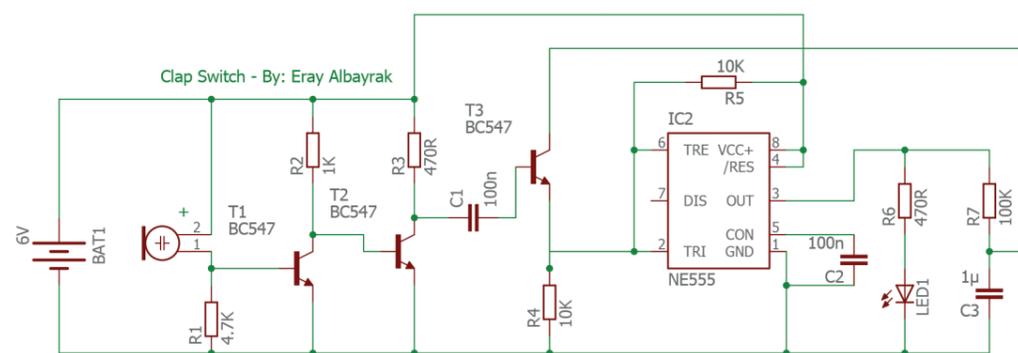

Through a feedback from the output to T3 we are able to trigger the 555 when sound is detected and keep the state High or Low accordingly.

This project is cheap to build and can be completed in just an afternoon. It can also be adapted very easily to suit your needs and interests. For example, the LED can be exchanged for a buzzer to be used as an alarm. Or connect a relay to the output to get the intended function the original Clapper had, but be careful when working with mains electricity. ⏚

https://home.howstuffworks.com/clapper.htm

Components list:
- 1x Battery holder (4 AA)
- 4x AA battery
- 1x condenser microphone
- 3x NPN transistor (e.g. BC547)
- 2x 470 Ω resistor
- 1x 1K Ω resistor
- 1x 4.7K Ω resistor
- 2x 10K Ω resistor
- 1x 100K Ω resistor
- 2x 100 nF capacitor
- 1x 1 μF capacitor
- 1x Led
- 1x 555 Timer (e.g. LM555)
- Hook up wire
- Perfboard

Research of Electrical Energy Storage Systems
Advertorial

Huisman continuously develops new equipment using the latest technology, like the use of electrical storage, resulting in cost savings in fuel and operating costs, and with low greenhouse gas emission and noise levels.

Energy storage, using a super capacitor, has already been applied by Huisman in electrical heave compensation systems, see Figure 1. For applications with lowering operations, it is possible to configure an Electrical Energy Storage System (EESS) to absorb the regenerated energy, rather than dissipating it in braking resistors which is the norm. In case of lifting loads under high accelerations, power demand can vary quickly and stored energy can provide extra power to reduce the power peaks of the generator.

Figure 1. Super capacitor-based energy storage.

Benefits of energy storage
Huisman studies found that an energy storage system can bring advantages like:
- Reduction of the amount of power to be transported from the generator to the equipment. EESS acts as additional power reserve during peak loads close to the end consumer;
- Stability improvement of the electric network caused by slow response of the generators to load demand (voltage and frequency drops during peak load requirements);
- Reduction of the risk of black out by operating EESS as a UPS (uninterruptable power supply) and in case of blackout enables quick power system recovery, faster than the response of an emergency generator;
- Peak shaving by implementing an EESS reduces the total required installed power and can lead to a better properly sized generators;
- Generators can run at their optimum speed which directly brings fuel saving and reduction of NOx emissions, soot particles and greenhouse gasses;
- Reduction of maintenance costs by running engines at nominal speed. For some diesel engines it is not recommended running at low speed due to excessive wear.

Figure 1. Huisman's off-shore installation, where EESS technology can be applied!

Selection of energy storage type
Selecting an energy storage system starts with the system requirements: high power or high energy amount. Energy is the ability to do work and power is the rate of doing work. The relation is stated in the following formula: Energy [kWh] = Power [kW] x time [h]. If a system requires high energy amount then it must be able to store a lot of energy, preferable in a small volume. If a system needs high power then it must be able to store and release energy quickly.

Research and application
It is important that clients will see the opportunities of the EESS technology for marine applications directly by cost savings and operating risk reduction during operations. EESS has a great potential to bring a better and more advanced system in the near future as clients demands. Huisman is ready to implement the EESS in our products. ⏚

Electrip

David de Gruijl

On Tuesday, the 13th of February, twenty-four Electrical Engineering students, including me, left Delft to explore the company culture in Germany and Denmark. During the Electrip, second year bachelor students get the chance to explore a broad range of applications in our field and get a better view of what it is like to work in a company as an Electrical Engineer.

Our first stop: Philips in Hamburg. We visited a research facility for MRI, CT and Röntgen scans. It was a research center as I had always imagined. The researchers were extremely smart and the contrast between our suits and the socks in sandals of our guides was a comical observation.

During the next days, there were many more companies to visit. At Lufthansa, we saw the 300 million euro private jet of the sultan of Brunei and the old plane of Gaddaffi, which had bullet holes that needed to be restored for the new Libyan government. At Energinet, we saw the control panel for the entire electrical power grid in Denmark and at Oticon (a hearing aid company), we were able to experience the most sophisticated surround sound system I have ever witnessed.

In Denmark, companies seemed to take good care of their employees. Almost every company had their own cafeteria, which served a lunch buffet for everyone in the company. The companies were definitely not greedy in this regard. Amazing salads, roasted chicken and even caviar passed my stomach during the event.

At every company, we got to talk with employees and ask critical questions about their work. It was great to see the mixture of company cultures and how each company welcomed us in their own unique way. There are many companies I did not mention, but I can affirm that every one of them gave me new insights. The Electrip was an amazing experience and I would like to thank everyone in the committee for organizing it for us!

AME

Activities

KPN Workshop

On Wednesday, the 21st of February, KPN visited the ETV and brought with them a workshop about making your own IOT application.

Using a Wemos D1 mini and a 3v3 ultrasonic distance sensor, we first made a device that could plot the measured distance and set off an alarm in the serial monitor when an intruder was detected. Next, we started using the Wi-Fi capabilities of the Wemos D1 to send data to an online service and thus, communicating with our device over internet.

By then, all the individual parts were completed, and the only thing left to do was to integrate all components using "If This Then That". After that, the device was completed and, whenever an intruder was detected, the owner would be notified by sending him/her an email.

To celebrate our now much better protected homes, we went to the /Pu. While enjoying a few cold beers, had a chance to ask the employees of KPN everything about their work and what would be in stock for us if we decided to work there.

Bram den Ouden

Parents' day

On Saturday, the 24th of February, the annual Parents' Day for first year electrical engineering students, and of course their parents, was held at EWI. At 12 p.m. there was a reception with coffee and tea, followed by a short introduction to the program of that day by William Hunter and the Dean of EWI, John Schmitz. The group was then split in two, one half would stay to have a lecture by professor Wouter Serdijn, the other half to do a tour through EWI. This group was then split up into even smaller ones, to prevent having 50 or more people on the roof at the same time. After a visit to the roof, the tour also brought us to the high voltage laboratory (including a demo), the 'studieverzameling' and the Tellegenhal.
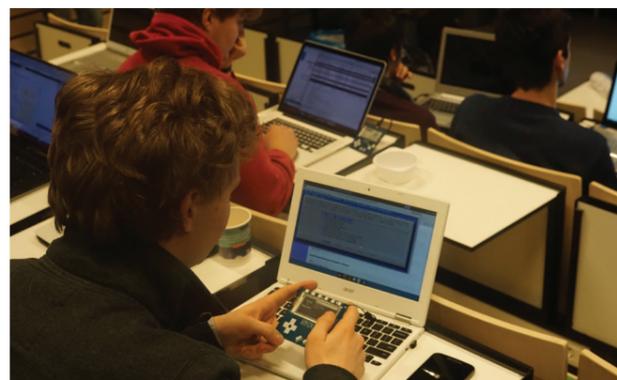
After the tour it was time for both groups to switch places, and thus for us to have the lecture. This lecture was about the use of electrical devices inside the human body with the goal of curing, mostly mental illnesses. The day was concluded with drinks in the /Pub, where everyone had the opportunity to ask some last questions to everyone involved.

Thomas Pouwels

EESTEC Hackathon

Resulting from the longstanding partnership from the ETV and the international Electrical Engineering group EESTEC, a workshop was organized on the 26th of February to expand the "hacking skills" of EESTEC members. "Hacking" in this context is primarily making changes until a desired result is achieved. Especially in this event, lots of hacking was needed-because of the short time to finish your program.

The goal was to make a program for a so called "SHA badge", a small board capable of interpreting Python, flashing some LEDs, displaying images on a display, read capacitive touch sensors, interacting with SD-card, etc. All in all, there were a lot of features to play around with. Some of the resulting programs included snake, "juffen", and even something simple as cookie clicker.

Getting to expand your hacking skills is not the only aspect of the hackathon. As this was an international event, international members also participated in the challenge. The international participants had the opportunity to integrate and learn from the Delft students and the other way around.

Looking at the amount of knowledge gained by the participant, I'd say that the event is definitely worth a follow-up.

Philip Groet

wAkCie Ice skating trip

The cold and dark days give a person the desire to go skating. This is simply part of our nature as inhabitants of the Netherlands. To satisfy this desire the wAkCie organized a day trip to the ice skating hall "De Uithof", located in Den Haag.
The trip started for most with a typical train ride with the NS arriving a few minutes late at our destination. The moment we arrived, we rented skates and bought the tickets and went to the track. Carefully, all participants stepped on the ice, for most it was the first time they skated in years! Some instantly felt at home on the ice and were soon making their way around the ice track like Olympic athletes. Others needed some more time to get used to the slippery frozen floor. After two very entertaining hours there was, as a surprise, hot chocolate for everybody! This gave all participants a moment to catch their breath. After everyone had finished their chocolate, all the participants went their own way, either going home or hurry back on the ice. Some even stayed till closing.

In short, it was a very successful day, and everyone had a blast. As the President of the wAkCie had said: "It is our task to bring people together in this cold and dark period", and so the wAkCie did.

Jasper-Jan Lut

ETV CoDe Cantus

One of the loudest yearly activities in Leiden is the Cantus. Together with the members of the study association, Corpus Delicti (CoDe), we sing along (loudly) with some classics. The event was organized in a big room in Augustinus. Upon entering, integration between the ETV and CoDe members did not go really well, but the Cantus board quickly changed that by alternating guys and girls. When everyone was in, everyone got their booklet and a bucket of beer on the table. The Cantus started with singing the study association songs for both associations. After that, many more songs followed, like Pianoman, 'Het regent zonnestralen' and Angels.

Of course, after drinking a fair amount of beer, a toilet break was necessary. This was not without consequences because the ones going to the toilet had to chug an extra glass of beer in the 'Australian style'. This meant holding the glass with your hand upside down and drinking it in one go.

After the music stopped, there was still time to visit some other places in Leiden, like the row of the Hifi and even the Next. Finally, the night ended, and we returned to Delft, looking forward to the Cantus next year.

Tom Salden

EESTEC

Erik Hagenaars

EESTEC is a great part of the ETV, but a lot of members do not know what it is. It is best explained by this quote. "EES-TEC is a student organisation where electrical engineering and computer science students all around Europe gather, connect and exchange ideas through many activities. EESTEC supports its members development in their personal, academic and professional life. We have different international teams and projects, where we work together in order to support our Committees in many aspects. Also throughout the year, local rounds of our technical competition, work-shops with different EECS topics, and cultural exchanges are held by our Committees all around Europe. Our members who participate at this event, discover new cultures, learn new things about EECS topics and develop those skills, and get the chance to improve their soft skills by joining training sessions which are delivered by our trainers." – Gizem, Vice Chairwoman of Internal Affairs

Workshops and events

If you are a member of the ETV, then you are by default a member of EESTEC, and this is great news! EESTEC members can participate in numerous skilled work-shops and exchange programs through-out Europe. Some of the events are very informative while others focus more on the social parts.

One of the best things about these events is that most of them are free! During a lot of workshops and events, food, shelter and some parties are provided for you. The only cost is the transportation. This is where the ETV comes to aid. The ETV will give up to €100,- per year for one event on transportation costs!

What to expect during an event?

An event can be exciting and scary at the same time. Most of the time, you'll be the only one from Delft attending an event, just like other participants. This makes bonding with the other participants easy and great friendships have resulted from this. Every start of an event will have extra social activities to get to know each other better.

Most first days will include city rallies, pub crawl and local traditions. One of the tra-ditions during an event is an International Night where all the participants will bring a beverage and food from their own coun-try. Ask the EESTEC veterans about raki-ja or soplica and watch their reaction for fun. In conclusion, an event is a must have on your bucket list!

Our events

Since Delft is one of the Local Commit-tees in EESTEC we regularly organize events as well. Our most recent event was called UnTIEing the future. For one whole week, 12 participants attended the event. Staying at the Delft Hostel near the Grote Markt, we had an amazing week full of workshops, debates, symposia and social events. As social events we went to Rot-terdam, Amsterdam and had multiple ac-tivities in Delft.

Among international events, the commit-tee also organizes local events for ETV members only. You might have heard of our Hackathon or our social drink in the /Pub. Our current goal is getting EESTEC more on the radar of our members and we'll hope you will join us! For more info, our contact links are found below.

https://eestec.net/
https://www.facebook.com/eestecdelft/
https://chat.whatsapp.com/J6vTMLm-LAIe0K70gLJ9meI

WELCOME TO THE WORLD OF HUISMAN

HUISMAN INNOVATION TOWER

Head in the cloud,
feet on the ground

Kom bij ons werken

Voor ons Pinewood Security Operations Center (SOC) zijn wij altijd op zoek naar enthousiaste en ambitieuze studenten met een grote passie voor techniek en security. Vanuit het SOC monitoren wij de IT infrastructuur van grote organisaties. Je werkt met de meest geavanceerde tools om de dreigingen in de kaart te brengen. Daarnaast maak je gebruik van de actuele Threat Intelligence informatie en ga je proactief op zoek naar cyberdreigingen. Op basis van jouw analyses breng je advies uit naar de klant. Met behulp van de Pinewood Academy wordt je opgeleid tot security consultant en stemmen wij de functie af op jouw capaciteiten en jouw toekomstplannen. Wij bieden een carrière binnen een hands-on en praktijkgerichte organisatie waarbij veel ruimte is voor persoonlijke groei.

Zoek jij een goede baan binnen de cyber security en wil je meewerken aan de verdere groei van onze dynamische en professionele organisatie, kijk dan snel op www.pinewood.nl en wie weet word jij onze nieuwe collega.

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