



Maxwell

Issue 19.2
February 2016

Nuna8

With Nuna8 our dream became reality

Exchange in Switzerland

Study Abroad

Audiosampling

Part 2

Studieverzameling

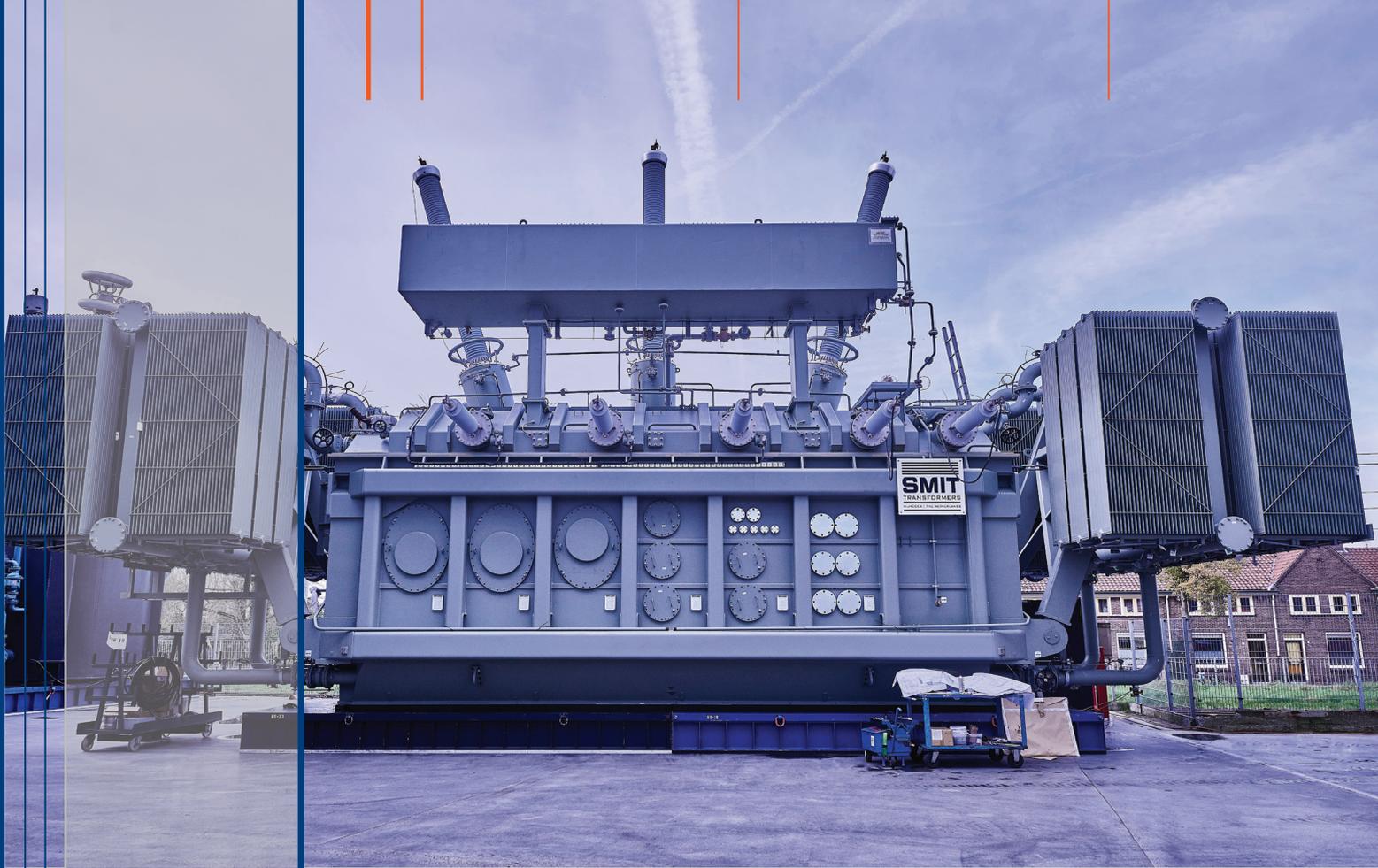
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Partners in Power



From the Board

President

Dear reader,

It's always hard to believe how fast time passes. At this point we are about half-way the academic year. We've had the Christmas break, we've celebrated new year's eve and we are about to have our next break. In fact, at the time of reading this break has already passed as well.

So what has happened up to this point? We already had two lustrum weeks full of lustrum activities, an ETV party, a ton of lunch lectures, some excursions and much more. In short, the ETV is full of energy. First years students are starting to feel comfortable around the Board Room and show up at many activities. Older students are busy studying and trying to get their bachelor's or master's degree by the end of the year.

I am happy to see so many people study very actively. All my fellow students from my year are now really putting all their energy in studying. It seems like the third year is the year where you realize it's about time to become really serious.

As a study association we can of course only support that kind of behavior. Because let us not forget, the reason we exist is education. This is also something we have seen in the survey we conducted the beginning of this year. Lots of students are very appreciative of the ETV's involvement in education evaluation and such. They would even like to see more of that, as well as things like study groups or a way of facilitating students helping each other.

In short, there is enough for us to think about and to work on during the second half of this year. Apart from that, we also have some really cool events coming up. The Lustrum Gala for example, which will take place the 18th of March in Germany and the Lustrum Rally.

I really would like to see as many people as possible at all coming events and I truly look forward to the second half of this year!

Cheers,

Daniël Kappelle



Commissioner of Education

Education changes constantly. In this way the master curriculum changed this year. In the last edition I wrote about the MIMs(master information meeting). Last quarter was a MIM and the attendance was mediocre but the "problem" courses were made clear by the students. However, further evaluation was delayed. We are now brainstorming about how we can improve the master evaluation cycle and get everybody's opinion and get more students involved. Besides that, I am working on the new minor guide for bachelor students. In this guide, students who attended certain minors write about their experiences. By this we hope to inform second year bachelor students on what they could choose as their minor and provide them with some extra information.

Jan de Jong





Colofon

Year 19, edition 2, February 2016
1000 copies

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Advertisements

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Page 17 - TNO
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Back cover - Pinewood

Printing

Quantes, Rijswijk

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Subscriptions

Non-members can receive the Maxwell four times a year, against a contribution of €10,- per year.

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Editorial

For most students every year is vastly different from the one before. Each year they meet new people, study new subjects (or at least they're supposed to) and enjoy unique and new experiences. All of these aspects and more create make every year special. This academic year the ETV is providing us all with a unique shared experience between all Electrical Engineering students of the TU Delft: the 22nd Lustrum. The release of this maxwell marks the halfway point of the Lustrum and a perfect moment to look back as well as forward to everything the ETV is doing to celebrate still being a healthy organisation after 110 years. This results in four times as many celebratory weeks, a symposium, a gala and a huge stunt! At the ETV however, we are well aware that Electrical Engineering students usually like some consistency in their lives and because of that the Maxwell-committee is proud to announce that... we're doing nothing special with the Maxwell this year and you will be able to enjoy in the same manner as you do every year!

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Pascal Lagerweij

In the second semester of the academic year 2014/2015 I went to study in the École polytechnique fédérale de Lausanne in Lausanne, Switzerland, also known as the EPFL. I went here during my master Electrical Engineering and did an academic exchange, or Erasmus exchange as most people know it by. Technically this is not the case because Switzerland is kicked out of the Erasmus program as a result of a referendum in Switzerland where they closed their borders for foreigners a bit more but that is only technical speaking. The EPFL is situated in the canton of Vaud which is in the French speaking part of Switzerland. To be precise it is located in Ecublens, next to Lausanne, where the campus is spread out next to le Lac Léman, or lake of Geneva in English. To give you a rough orientation of where it is Lausanne is on the most northern part of the lake of Geneva.

From Lausanne you can look to the south side of the lake which is France and you can see the French Alps. From a viewing point in Lausanne you can actually see the Mont Blanc so the highest point in Europe.

The EPFL is the second best university in Switzerland after ETH Zürich and is ranked as number 14 in the Times' higher education world university rankings in the category Engineering and Technology (2015-2016). As a reference, ETH is number 8 and TU Delft is number 19. Because of this the general people who go to study at this kind of university is not the kind which goes on a Erasmus exchange in their bachelor and parties only for half a yearlong (I am speaking in stereotypes now but I assume you get the point). For me the biggest chance was not the level of education, as it doesn't differ so much from the level at the TU Delft, but the



semester approach instead of our usual quarters. Where as normally I am kind of a lazy student and I start generally quite late with studying for my exams this is not doable if you have a semester of 14 weeks of classes, some weeks off and then exams for the full amount of credit of a semester (30 if you approach it as a normal 60 ECTS/year). Most people who do their master in EPFL have a semester project of 10 credits and do courses of 20 credits next to that. If we want to take this to our university you would have to put the semester project in the free electives because of the setup of our master degree here in Delft (technically if you get your ISP approved with the project in your specialization part this is of course not true). Because I wanted to use my free electives for an internship I decided to take only courses which was when I look back to it quite a struggle.

This was caused by the fact that even though the courses were known when I knew I would go so in around October 2014. The schedule of the classes wasn't known until the mid/end of December. Because I took courses in Electrical Engineering, Communication Sciences and Mathematics the initial courses I had picked quite overlapping schedules. To give you an idea 1 ECTS credits means in general 1 hour/week





of classes so doing 30 ECTS means having 30 hours of classes. Which is a lot so there is bound to be overlap. As I normally in the first week of my quarter just sit at 5 courses and pick the 3 I wanted to use the same approach there. This resulted in my final course list being way different than the one I submitted to the TU Delft and my ap-

plication beforehand. This is not really an issue if you pick courses of a good enough standard they will be approved here in the TU Delft anyway. Which won't be a problem if u go to the EPFL. This was a small example of things you have to do when u go to study in another country for a while next to this I had to take care of a student visa, get hous-

ing and all the other logistics which all in all was a really great experience in my opinion because I like to arrange stuff like that, if you want to know more about this feel free to email me your questions, in general of specific for Switzerland (or even Lausanne. Next to that Lausanne is quite flat because it is next to the lake but it is really close to the Alps so skiing/snowboarding or hiking opportunity's lay just around the corner just be aware that Switzerland is a really, but I mean really, expensive country so be prepared for that if you are going.

I can recommend everybody who has the time and is doubting to do something like this to actually do it, from internship or studying in a foreign country. It is a great experience which you won't regret at all. ■

My name is Pascal Lagerweij, at the time of writing this, I am 24 years old and am currently enrolled in the master program of Electrical Engineering, track Signals and Systems. I started studying at the TU Delft in the bachelor Elektrotechniek in the academic year

2010/2011. During the year 2012/2013 I have been in the board of the ETV and as a result of that I finished my bachelor in the end of 2013/2014. In September 2014 I enrolled for my current master program Electrical Engineering.



Advertorial Ricardo

Waar is mijn trein?

Treindetectie op het Nederlandse spoor

Stephan van 't Hof
Junior consultant bij Ricardo Rail

Met dagelijks zo'n 5500 reizigerstreinen en 350 goederentreinen is het Nederlandse spoor het drukste spoornet van de Europese Unie. Een trein heeft geen stuur en de machinist bepaalt niet hoe de wissels liggen, dus al deze treinen worden centraal gestuurd. Om botsingen te voorkomen, moeten we met zeer grote zekerheid kunnen vaststellen waar de treinen zich bevinden. Hoe weten we in Nederland waar de treinen zijn?

Natuurlijk pakken we dat elektrisch aan. Het spoor is opgedeeld in blokken, stukjes spoor van ongeveer 1,5 tot 1,8 kilometer lang. Als een trein zich in dit blok bevindt, is het blok bezet en mogen er geen andere treinen in rijden. Dit is zichtbaar: de seinen voor dit blok gaan op rood. Bovendien gaat het sein van het blok ervoor op geel, zodat een aankomende trein op tijd kan remmen. De machinist wordt met bellen gewaarschuwd: als de machinist zijn snelheid moet aanpassen klinkt er een bel ("ting") en als de machinist de lagere snelheid bereikt heeft tringt de bel drie keer kort ("tring tring tring"). Misschien heb je dat wel eens gehoord over de intercom van de trein, tijdens een oproepbericht van de machinist.

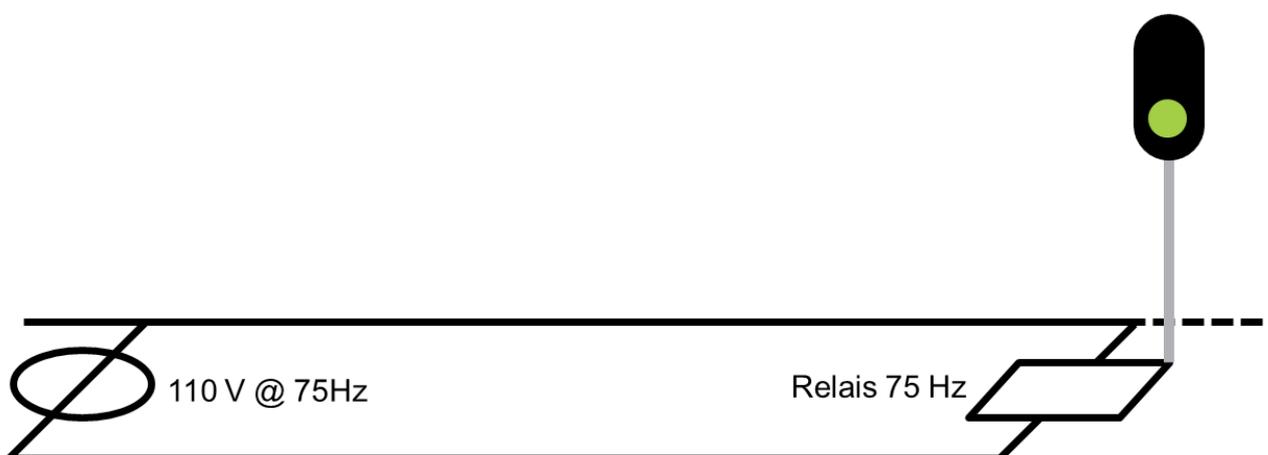
Door de twee spoorstaven van een blok wordt een wisselstroom van 75

Hz gestuurd. Aan de ene kant van het blok staat de stroombron, aan de andere kant van het blok - zo'n 1,5 kilometer verderop - staat een relais waar de stroom doorheen loopt. Dit is een zogenaamd spoorrelais, welke precies op 75 Hz werkt en bovendien de fase van de stroom vergelijkt met die van de stroombron. Als de frequentie en de fase kloppen en de stroom is groot genoeg, dan is het blok vrij en staan de seinen op groen.

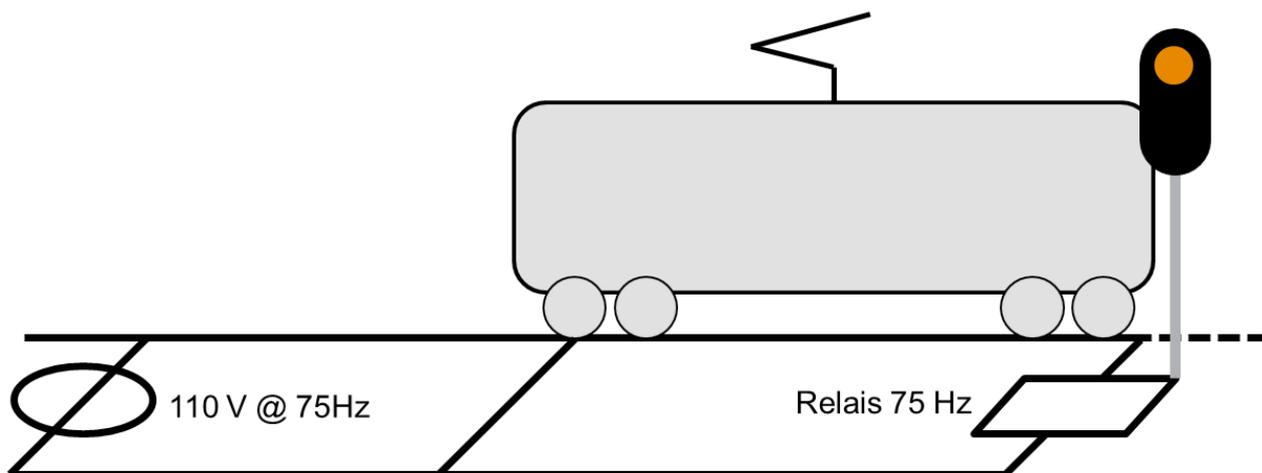
Wanneer een trein het blok binnenrijdt, sluit deze de spoorstaven kort met zijn wielen en assen. De stroom van de stroombron loopt dan door de trein en niet meer door het spoorrelais. Daardoor valt het relais af en wordt het sein rood. Bovendien wordt dit doorgegeven aan de centrale, zodat zij kunnen bijhouden waar de treinen zijn.



Dit systeem stamt uit de jaren zestig en doet zijn werk nog steeds goed. Het heeft wel enkele gevolgen. Zo moet de trein de spoorstaven goed kortsluiten. In de Nederlandse wet, de Regeling indienststelling spoorvoertuigen artikel 7, vijfde lid, staat "De kortsluitwaarde van een wielstel van een locomotief en van een treinstel, gemeten van wielband tot wielband, met inbegrip van de overgangsweerstanden tussen de wielbanden en de koppen van de spoorstaven, bedraagt minder dan 0,20 Ω ." Je leest het goed, in de Nederlandse wet wordt



Figuur 1: spoor zonder trein, de stroom loopt door het relais en het sein is groen



Figuur 2: spoor met trein, de stroom loopt door de wielen van de trein en het sein is rood

een eis gesteld aan de elektrische weerstand van een trein. Bovendien gaat het om de weerstand tussen trein en spoor. Als het spoor dus vies of roestig is, kan deze te hoog worden! Daarom moet elk stuk spoor elke dag bereiden worden door minstens een trein. Elke dag worden treinen heen en weer gestuurd door wissels en zijsporen om de sporen schoon te rijden, het zogeheten roestrijden. Overigens gebeurt dit vrijwel nooit met passagierstreinen. Een ander gevolg van dit systeem is dat een trein geen 75 Hz-stroom mag genereren. Als een trein dit zou doen, zou deze stroom het spoorrelais kunnen activeren, waardoor het lijkt alsof er geen trein aanwezig is. Daarom moet een treinenfabrikant zijn trein laten meten voordat deze het Nederlandse spoor op mag. Dan worden alle bedrijfstoestanden van de trein getest en wordt gemeten hoe veel 75 Hz-stroom de trein genereert.

Je weet nu hoe treindetectie in Nederland werkt. Alle Europese landen hebben hun eigen systeem om te detecteren waar de treinen zich bevinden. Dat is natuurlijk onhandig voor inter-

nationaal treinverkeer. De ICE ondersteunt bijvoorbeeld meer dan tien beveiligingssystemen. De Europese Unie wil hier iets aan doen en heeft een Europees treinbeveiligingssysteem ontwikkeld: ERTMS. Op dit moment wordt dit systeem in de hele EU uitgerold. In Nederland is het systeem al actief op sporen tussen Amsterdam en Utrecht, tussen Lelystad en Zwolle, op de HSL (hoge snelheidslijn tussen Schiphol en Rotterdam) en de Betuweroute (van de Rotterdamse haven naar Duitsland).

Bij Ricardo Rail werk ik mee aan dit soort projecten. Zo doe ik metingen aan de tractie installaties van nieuwe treinen, om te controleren of ze geen 75 Hz-stroom genereren. Ook doe ik proefritten op sporen met ERTMS, om te testen of het nieuwe beveiligingssysteem werkt zoals verwacht. Verder ontwikkel ik nieuwe meetmethoden, zodat data voor onze klanten sneller of vaker beschikbaar is. Ons kantoor is in Utrecht, boven het centraal station. Daardoor ben ik vanuit Amsterdam binnen een half uur op kantoor. Bovendien kan ik in mijn pauzes een rondje

door het centrum van Utrecht lopen of winkelen. Mijn groep collega's is een gezonde mix van senioren om van te leren en junioren om mee te borrelen.



Figuur 3: Stephen met een spoorrelais

Binnenkort organiseren wij in samenwerking met de ETV een casedag op ons kantoor in Utrecht. Tijdens de casedag mag je in kleine groepjes een case op treingebied oplossen, zoals over de onderwerpen uit dit artikel. Na de cases gaan we borrelen en kan je met mij en mijn collega's praten. Schrijf je in bij de ETV-balie! ■



Nuna8

With Nuna8 our dream became reality

Auteur: Bas van Wee
Fotograaf: Hans-Peter van Velthoven

It is Sunday morning the 18th of October in Darwin, Australia. After working more than a year to this moment it was finally here. The first few cars have already past the start line, in a few moments our own build solar car Nuna8 will start her 3000km journey towards Adelaide. Together with Thijs and Bart we guide Nuna towards the start line. Our biggest competitors are already gone. When will we overtake them? Will something terrible happen during the start? A lot of questions pass my mind while the final seconds slowly tick away. Finally they announce Nuna8 to approach the start line. 3-2-1-GO!!! Nuna accelerates without a hitch. But there is no time to celebrate. Thijs, Bart and I start running like we have never done before! We have to get to our convoy vehicle we call Support and start following Nuna as quick as possible. If something happens we have to be there to fix it!

It all started one and a half year ago. I, Bas van Wee, and fourteen other students had been selected to design and build the latest solar vehicle for the Nuon Solar Team. Together with Renzo and Casper we were mainly focusing on the electrical design of Nuna8. In 2013 Nuna7 had won the Bridgestone World Solar Challenge (WSC) and retrieved the trophy back to Delft after four years. So our goal was clear, keep the trophy in Delft by winning the WSC by building an even better solar car

than we had before.

To do so, we went back to the drawing board and questioned everything about previous Nuna editions. What were the pros and the cons of those concepts? But also the regulations of the WSC where changed with respect to the electronics of the car. Safety has taken a much larger role, the term "Safe State" was a hot topic for Nuna8. Despite the change in regulations Nuna8 turned out to be one of the most reliable and electric efficient solar cars ever build.

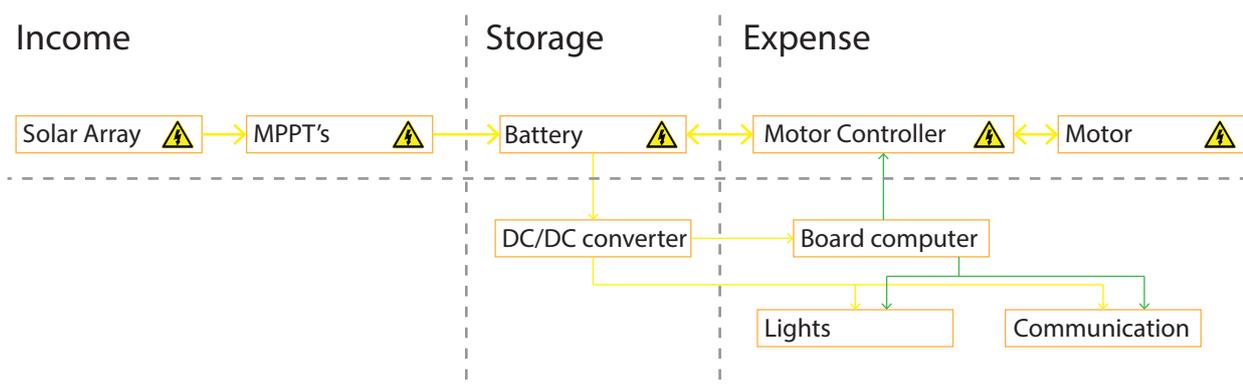
The basic electronics of a solar car are relatively simple. All the energy to drive Nuna is collected by the solar array. Every photon needs to be collected and converted in electricity with the highest efficiency. This energy can then be stored in a battery or flow directly to the motor. In the end all the electrical energy is converted to kinetic energy to bring the car in motion by the motor. These three main parts must be as efficient as possible. First the solar array, the solar array of Nuna consists out of 6.000m² silicon solar cells. The total measurements of this area is predetermined by the regulations. The solar cells used on Nuna8 are SunPower IBC (Integrated Back Contact) solar cells which has an efficiency up to 24%. A total of 391 cells are placed in several modules to form the full array. These encapsulated modules have a top sheet which has a micro pyramid structure to minimize

reflections. By decreasing the thickness of all these layers and optimizing the pyramid structure the largest amount of energy will be converted by the solar cells. These modules are then connected to several MPPT's (Maximum Power Point Trackers) to form the main energy source of Nuna.

The battery regulates the energy flow through the car. At the start of the WSC we were allowed to start with a full battery, so having a large battery gives you some major advantage. But according to the regulations, Nuna can only take 20kg of Li-Ion battery cells. The challenge is to find battery cells with the highest Wh/kg ratio. Nuna uses standard Panasonic NCR18650 cells, which gives Nuna a battery capacity of 5kWh.

Last but not least the motor with motor controller. This part does not only consumes power to speedup Nuna, but can also be used for breaking. If doing so, the kinetic energy is converted back to electrical energy and can be stored in the battery. The motor in Nuna is a Mitsuba Brushless DC in-wheel motor specially designed for solar races and it has an efficiency over 95%.

Nuna has also a wide variety of low power components. For example the board computer, this board computer (MobiBoxx) comes from the company Technolution. This board computer has two main functions, collecting all the data from Nuna and sending motor



commands to the motor controller. The MobiBoxx communicates with all different parts of the car through the CAN-bus protocol. When collecting data the MobiBoxx reads out the CAN-bus, for example data from the BMS (Battery Management System). But it can also control the motor. If you pull the throttle lever on the steering wheel the MobiBoxx will send the drive commands to the motor controller. Eventually all the data will be sent to the chase vehicle through Wi-Fi.

All those separate components will be placed on a test vehicle called Benny. This is an aluminum frame to test all the electrical and mechanical components before placing it on a carbon fiber body. Now here is where the magic happens. All those separate parts are not that complex and work most of the time completely fine, but when putting it together as one system it can change everything. Up to the first test day the main question was, do we have throttle? Most of the time we could answer the question with yes, but did you ever expect that speeding up could sometimes change the input from the solar array?

To be honest, we didn't. At that moment the troubleshooting skills from

the electrical engineers had been put to the test. After a regular test day and some research we decided to take a closer look outside of the vehicle. A separate test setup was build consist out of a power supply connected to a MPPT, the battery pack and a DC load. After switching on the MPPT, a constant current flows in to the battery pack. But when switching on the load, the output current of the MPPT is limited and starts oscillating. At least we could reproduce the problem in a controlled environment. Now the investigation starts, first the battery pack was switched to the old pack from Nuna7. After starting up everything worked fine, changing currents from the load or the power supply didn't effect anything. When switching back to the Nuna8 battery pack immediately the problems reoccurred again. We suggested that the battery pack influences the behavior of the MPPT, but why?

As already mentioned, all the different electronic parts communicate through CAN-bus. If we connect a laptop to the test setup the CAN-bus can be monitored. When comparing the battery pack of Nuna8 with the battery pack of Nuna7 one of the CAN-ID's which was active at the battery pack of Nuna8 was

not active at the pack of Nuna7. This CAN-ID belongs to the current sensor which is located in the battery pack. After disconnecting the current sensor the battery pack of Nuna8 worked fine! When looking some things up in a datasheet you'll find out that the output of the MPPT's can be controlled by putting a value on a certain CAN-ID called 'X' for now. Accidentally the current sensor was sending data on that same CAN-ID 'X'. So when the battery current changes, the maximum output from the MPPT's changed. This was one of the many difficulties we faced changing from a single component to a full system.

Unfortunately Nuna will never be finished. But at a certain point Nuna8 is race worthy. The main purpose of the test rides changes from testing Nuna to prepare the race-crew. Nuna doesn't cross the Australian outback on her own. She is protected by a small convoy which includes Support with all her spare parts. By speeding up the repairs of Nuna we can probably win some time during the race. When first changing a motor controller, it took over 15 minutes. But after swapping the controller for the third time it had already been decreased to 5 minutes from

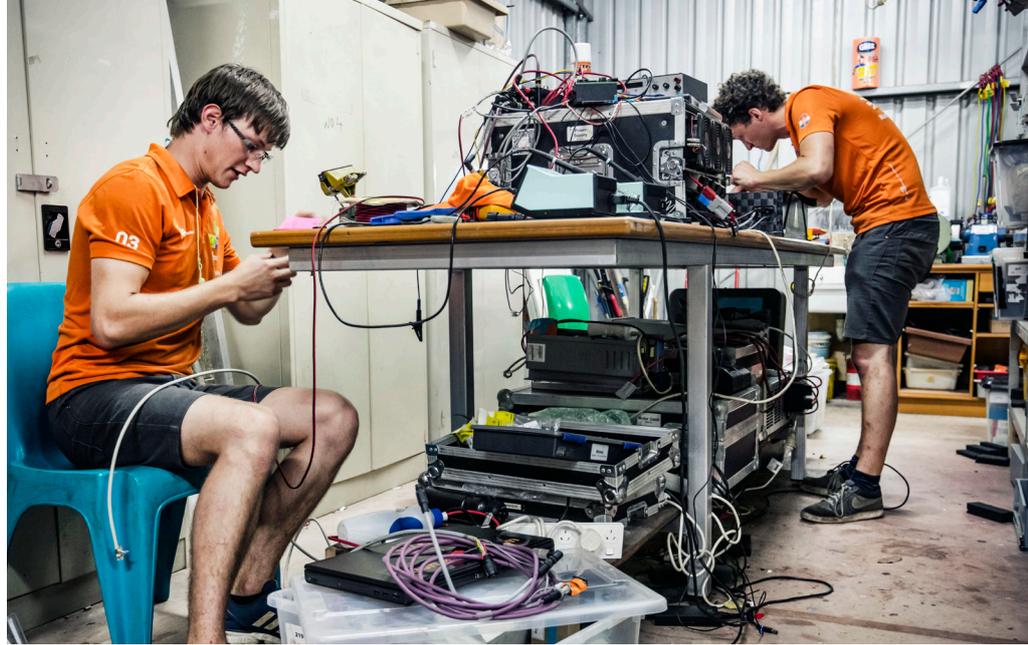


standing still to changing the controller and drive away.

Then the moment is finally there, the start of the WSC. The final checks are done, the wheel covers are placed on Nuna and every system works. We have to wait until the seventeen teams for us drive away from the start. During the qualifications a few days ago we managed to gain the 18th starting position. Finally Nuna is heading towards the start line to start her 3000km journey through the Australian outback. After the start we run towards Support and try to catch up with Nuna. Through the radio we hear a smooth communication guiding Nuna along roadworks, slow driving vehicles and competitors. We pass several competitors before we see Nuna standing still at a cross section. Where she stands directly next to another solar car. When the light jumps to green both cars starts to accelerate. But the other team stops accelerating at 70km/h while Nuna accelerates further till the speed limit of 90km/h. Another smooth overtaking!

After driving a bit more than 300km we arrive at the first control stop in Katherine. At the control stop Nuna has to stand still for exactly 30 minutes. While standing still Nuna is only allowed to charge its battery, so if something is broken we are not allowed to fix it. At this stop we hear that we already overtook 13 other teams. At 17:00 everyone has to stop, we were able to finish second on the first day with only a few minutes between the top five teams. At that moment we were extremely happy with the results and still not aware of the fact what would happen the next three days.

At the second day before the third control stop in Katherine we overtook Michigan and Twente overtook us. From now onwards the distance between



Twente closely followed by Delft and the rest of the field slowly increased. But what happened between us and Twente was something nobody had ever expected. For the next 1500km we drove less than ten minutes and most of the time less than a minute behind the first place. The second day we still could not believe what had happened and expected they had a more empty battery. With even a control stop where we drove away at exactly the same time could not help us to gain the first place. After the third day, where we still did not overtook them, we knew we had to do something.

On the fourth day we made the decision, after clocking their speed and doing some calculations we had saved enough energy to overtake Twente. After we gained the first place we decided to increase the gap to a minimum of five minutes. From now on there was only one goal, keep the first place, we only had to drive 150km on the final day.

And then it is suddenly the worst day of your life. You crawl out of your tent and what you see is a fully clouded sky. The battery is nearly empty and at that moment we weren't even able to reach the finish line. While trying to collect some indirect sunlight the battery slowly charged. The first calcula-

tions had shown that we could make the finish line while driving 50km/h. At 8:05 Nuna starts its journey towards the finish line. Slowly the air began to clear and the speed of Nuna increases bit by bit. At a certain moment we lost sight of Nuna, what happened? So we increased our speed and tried to catch up with the convoy. A few minutes later we see Nuna driving 105km/h. How can we drive so fast? When we approached Adelaide, traffic lights started to slow everything down and large amounts of traffic surrounds Nuna with only 10km to go. Because of the busy traffic and all the traffic lights we again lost sight of Nuna. We were all extremely nervous hoping that nothing would happen, please don't flatten out the battery. Than at a certain moment you see Nuna standing still in the middle of the road, you don't get it, what is happening? We had to turn left and saw a small group of orange shirts standing in the grass next to Nuna. Than in flash the extremely focused engineers in Support switched to a jumping, partying, screaming and crying group of idiots realizing that Nuna8 has won the World Solar Challenge! It was hard working, stressful and had a lot of drawbacks, but winning the World Solar Challenge with Nuna8 is priceless! ■

Studieverzameling

De blauwe tram

Han Geijp

De Studieverzameling heeft in haar lange bestaan, maar vooral de laatste tien jaren meer structuur gekregen. Echter kunnen wij nog niet op onze lauweren gaan rusten, integendeel. Het aantal vrijwilligers, meest specialisten uit een werkzaam TU-leven, weten het geheel steeds verder te optimaliseren. Meestal op maandagen treft men deze mensen aan in de kelders van de laagbouw. Hun expertise, opgedaan in het verleden, is bijzonder waardevol. Zij zijn in staat het erfgoed weer handen en voeten te geven, zodat de student van nu en morgen meer inzicht kan krijgen in het turbulente leven van Elektrotechniek, Wiskunde en Informatica.



Belangwekkende verzamelingen worden ontsloten, uit de vergetelheid onttrokken en bruikbaar gemaakt voor tentoonstellingen, onderwijs en onderzoek. Zo zijn er tal van objecten gebruikt voor filmopnamen en ter illustratie voor diverse boeken en tijdschriften, zoals Maxwell, Delta, Breen, etc. Onlangs nog werd medewerking verleend bij de samenstelling van edities als "Histechica 40 jaar" en "Spanning en Sensatie". deze laatste uitgave

was in het kader van 110 jaar Delftse Elektrische Energietechniek. Zo zijn wij altijd in beeld als er iets te vieren valt en het verleden de aandacht vraagt. Het 20e lustrum van ETV was ook zo'n moment.

"Goed dat jullie dat nog hebben" is een veel gehoorde opmerking. Er zijn unieke verzamelingen in de EWI-kelder van de laagbouw ondergebracht. Bijzondere mensen hebben door hun gedrevenheid ons unieke zaken nagelat-

en. Een voorbeeld hiervan zijn de navigatiesystemen uit de nalatenschap van Kees de Wilde († 2009), waaraan hij 35 jaar in de EWI-kelder heeft kunnen werken. Ook bevindt zich er een enorme verzameling elektrodenbuizen,

De NZH-motorwagens A 106 en A 327, in gezelschap van de Budapestse B 412. Dit materieel is voor het nageslacht behouden, dankzij de inzet van vrijwilligers: hobbyisten, die o.a. met steun van sponsoren zich het restauratievak hebben eigen gemaakt. Er is respectievelijk 32, 25 en 10 jaar aan deze trams gewerkt.



ruim 20.000 in getal, afkomstig van verschillende verzamelaars en inmiddels in kaart gebracht. Verder wordt de nodige aandacht besteed aan de ontwikkelingen van ondermeer de telefonie, computers, rekenmachines, hoogspanning, microgolf en IC-technologie.

Op verzoek van het ETV-bestuur dat traditiegetrouw, wanneer ons gastenboek is vol geschreven, voor een nieuw exemplaar zorg draagt, zou ik als tegenprestatie iets schrijven over één opvallend onderdeel, die bij ons is ondergebracht, namelijk de collectie van de Stichting Historisch Genootschap "De Blauwe Tram" (www.blauwetram.nl).

Het betreft een collectie bijeengebracht en afkomstig van het grootste trambedrijf dat Nederland ooit heeft gekend: de Noord-Zuid Hollandse Tramweg Maatschappij (NZH). Omdat dit bedrijf, nadat het van stoom in 1881, naar elektrisch vanaf 1911 was omgevormd, kreeg het onze aandacht. Al vroeg in het bestaan van onze faculteit aan de Mekelweg deed men in het Machinelab al beproevingen met trammotoren van de NZH. Deze motoren afkomstig van de allereerste gelede tramstellen (1932) van Nederland (serie A 601/602-619/620) en gebouwd bij de Koninklijke Fabriek van Rijtuigen en Spoorwagens J.J. Beijnes te Haarlem. In het najaar van 1961 viel in Voorburg definitief het doek voor dit eens zo populaire trambedrijf en daarmee ook voor dat bijzondere tramtype. Maar we hebben nog één motor veilig kunnen stellen en deze is te bewonderen in onze studieverzameling.

Het omvangrijke netwerk van lokale en interlokale tramlijnen in de regio's Haarlem, Leiden en Waterland werd destijds bereiden door opmerkelijk robuuste Blauwe Trams en waren geliefd bij het publiek. Dat blijkt wel uit een bord dat op een van de laatste tramrijtuigen was bevestigd: "Die rot bus wordt nooit zo knus". De gebruikelijke kleur van trams



in de stad was destijds crème. Maar die Blauwe was een indrukwekkende tram vond ik al als kleine jongen. Niet wetende dat juist de Blauwe Tram een rol zou gaan spelen in mijn verdere leven. Ook niet dat precies op die plek, waar de Blauwe de Bezuidenhoutseweg overstak, nabij het Haagse Centraal Station, ik deelgenoot zou worden van het veilig stellen van de allerlaatste Blauwe Tramrails, waarmee wij in 1983 de landelijke pers haalde. De leden zaagden een gedeelte van de rails in stukken en brachten het met een certificaat van echtheid aan de man. Dat werd dan ook ons eerste verkoopartikel: het geld lag letterlijk op straat. Ook van de NZH-collectie wordt veelvuldig gebruik gemaakt voor publicaties en tentoonstellingen. Een van de belangrijkste activiteiten van de

stichting in de afgelopen decennia was de restauratie van het in 1923 te Budapest gebouwde Blauwe Tramrijtuig B 412. Dit rijtuig ontsprong als enige van in totaal zeventig "Budapesters" de slopershamer, omdat het gedurende zestien jaar dienst had gedaan als zomerhuis. Het unieke, maar in zeer slechte staat verkerende rijtuig werd overgebracht naar Voorburg, waar het in bijna 10 jaar tijd is teruggebracht in zijn originele staat en inmiddels is te bewonderen bij het NZH Vervoer Museum in Haarlem.

Vaak komen er na verloop van tijd nostalgische gevoelens naar boven die er voor zorgen om iets uit je jeugd terug te halen naar het heden. Dat gaat nu eenmaal wanneer er dingen verdwijnen die je vroeger mooi, indrukwekkend of vertrouwd vond. Al is het maar



De NZH-motorwagens A 106 en A 327, in gezelschap van de Budapest B 412. Dit materieel is voor het nageslacht behouden, dankzij de inzet van vrijwilligers: hobbyisten, die o.a. met steun van sponsoren zich het restauratievak hebben eigen gemaakt. Er is respectievelijk 32, 25 en 10 jaar aan deze trams gewerkt.

een aandenken, een emaille bordje, een asbakje of meer...

Zo is het ook Georg Groenveld (voorzitter) vergaan. Hij voelde zich ook aangetrokken door de nostalgie van de Blauwe Tram. Dat werd nog aangewakkerd als mede-oprichter van het Railtheater Voorburg, waar dia's en films aan een groeiend legioen bewonderaars werden vertoond. Hij wist onderdak voor de oude Budapest, de B 412 te bewerkstelligen en vormde een restauratieteam van liefhebbers. Ook het opsporen van attributen van dit trambedrijf, kwam eveneens in een stroomversnelling. Zo is er langzamerhand een "mobiel" museum ontstaan, "een reizend circus" met optredens in plaatsen waar destijds de Blauwe Tram heeft gereden. En de bezoekers zijn steeds enthousiast en talrijk.

Gelukkig zijn er meer mensen die verdwenen zaken willen terughalen naar deze tijd of in ieder geval willen bewar-

en. Ze belanden hoe dan ook in een tweestromenland, balancerend tussen weggooiden en behouden. Dit laatste uit eerbied en bewondering voor wat met veel denkwerk, inspanning en zeeën van tijd is ontwikkeld en ooit is toegepast. Je moet maar de euvele moed hebben om een oude afgedankte tram, die verworden is tot noodwoning of vakantiehuis, waarbij het interieur geheel is verdwenen, veilig te stellen en op te knappen. Daar is doorzettingsvermogen voor nodig. Tegen de stroom in soms. "Je moet wel gek zijn om er aan te beginnen" werd vaak tegen de initiatiefnemers gezegd, bij de aanvang van zo'n object. Desondanks ging men zeer gemotiveerd aan de slag.

Het waren niet eens allemaal vakmensen. Neen...heel gewoon vrijwilligers met uiteenlopende beroepen. Het waren "netwerkers" die in hun kenniskring spullen bijeen brachten voor hun doelstelling. Het eindresultaat mag dan ook gezien worden en men wil dit graag met anderen delen. Kijk maar eens op Youtube naar opnamen het afgelopen jaar van de Blauwe Tram in Katwijk.

Drie Blauwe Tramrijtuigen zijn in 2011 op de foto gezet tijdens het evenement "Retourtje Leiden" in het Haags Openbaar Vervoer Museum.

Gedreven personen die verdwenen zaken hebben weten terug te halen en dit bovendien uitdragen. Ik denk daarbij aan onze webmaster Otto Dijkstra, die als redacteur verbonden is aan het landelijke blad RailMagazine. Of ons medebestuurder Raymond Naber, die zijn hele gezin betreft bij zijn hobby en leiding geeft aan het restauratieteam van de werkgroep Scheveningen van de Tramweg-Stichting. Niet minder belangrijk zijn de instellingen die waar nodig de helpende hand bieden, zoals vroeger de liftenfabriek Starlift, de TU



Delft en niet in de laatste plaats de HTM. Maar zeker ook de achterban van diezelfde gedreven mannen, die zich terecht vaak afvraagt "wat ben je toch allemaal aan het doen?" of "moet je nu alweer weg?". Zonder deze support gaat het immers niet.

Zijn er nog tastbare herinneringen terug te vinden op plekken waar een halve eeuw geleden de Blauwe Tram heeft gereden? Een veel gestelde vraag. Het antwoord is: ja, in Leiden en in Haarlem. Gietijzeren muurankers van 9 kilo die vanaf 1911 en later aan de gevel van gebouwen zijn aangebracht voor het bevestigen van de bovenleiding. "Restanten van een roemrijk verleden, toen men elektrisch gebruik maakte van het openbaar vervoer" en geluk nog heel gewoon was.

Alweer enige jaren geleden is het bijna gelukt de Blauwe Tram te doen herleven met een railverbinding, de zgn. Rijn-Gouwelij, van Gouda via Leiden naar Katwijk en Noordwijk. Gemeentelijke politici hebben dit ambitieuze plan toen weggestemd. Een gemiste kans!



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Spaceflight minor

Orbits and bytes

Bart Kölling



In September of 2015 a new minor was launched. A minor that did not restrict itself to our small blue planet. The minor I am talking about is the Spaceflight Minor at the faculty of Aerospace Engineering. Like the rest of the TU Delft minors this minor takes place in the first semester of the academic year and has 30 EC of courses in it. In this article I will share my experiences with the Spaceflight Minor from the perspective of an Electrical Engineering Bachelor Student. Not everything I explain might be relevant in the next academic year because the minor could be altered (and improved) after this first run.

The main reason I chose to enroll in this minor is that I wanted to do something different than Electrical Engineering for a few months. It had to still offer a bit of a challenge regarding technical skills and it would be great if it was useful for later in my (academic) career.

The minor not only focusses on the engineering aspect of spacecraft, the history of the universe is also a subject in the minor. This is mainly a topic in the first quarter. In that quarter there were three courses: Space Exploration, Introduction to Spacecraft Technology and Earth observation. Aerospace Engineering Students did not take the

Introduction to Spacecraft Technology course, they had a separate course about Electronics. Lectures are not only given by teachers from the AE faculty, lecturers from other faculties and also from Leiden University are frequently seen in front of the class.

The Space Exploration course is the biggest in terms of time consumption and also has a set of diverse topics that are discussed in the course. It consists of a part called Astronomical Exploration, Planetary Exploration and Space Law. Other than that there were guest lectures discussing an ongoing mission to the Jupiter system. Astronomical Ex-

ploration and Planetary Exploration are courses in Astronomy, one discusses the origin, evolution and detection of galaxies and stars, the other discusses planets, within our solar system and exoplanets that orbit stars other than our sun.

Detecting stars and planets can be done with a variety of methods and a lot of them are discussed in the course. I can share with you as an example one of the most interesting ways to determine the distance to a star in my opinion. This method works when two stars are close to each other. One of the stars has to be a white dwarf, that means it has burned out and lost most of its mass and volume. This is what probably will happen to our own sun in about 5 billion years. The white dwarf leeches mass from its companion star and over time starts to reach the so called "Chandrasekhar limit". This is a mass for which a celestial body cannot support itself anymore if there is no internal fusion reaction to exert pressure outward. When the white dwarf reaches this limit it will implode and subsequently explode into a type 1A supernova. The reason this is so useful is that this always happens at the same mass of the white dwarf when it happens in such a binary system. The brightness with which we measure this supernova on Earth can then easily be used to determine the



An artist's impression of a type 1A Supernova

distance to that star.

When the minor is called Spaceflight you expect to also be taught a thing or two about rockets. The course **Introduction to Spaceflight** was an ideal start to understanding the science behind launching a vessel into orbit. The basics are actually quite simple. You need to know how much mass in fuel you can expel from your rocket, and at what speed you shoot it downward. This is incorporated in Tsiolkovsky's ideal rocket equation. With this you can calculate the difference in speed you can achieve with your rocket, also known as Delta-V. To do simple calculations with orbits around Earth, around the Sun or around a random celestial body this Delta-V is all you need! You are also taught something about the environment of space and the dangers that you might not think of. The vacuum of space is a major factor in this. For example, cold welding can create serious issues if it happens on accident. This is a phenomenon where two pieces of metal can fuse together in space when they come in contact, without them have been heated up at all.

Earth Observation was the last course in the first quarter. Here the geography, atmosphere and gravity field of our earth are examined, focusing on measurement taken with satellites. The ozone layer and its influences are discussed as an example. Radar is also a tool used a lot in the observation of our planet.

The first quarter has an emphasis on the theoretical side, this is a bit different in the second quarter. Here there were again three courses scheduled: The Spaceflight Assignment, Spacecraft Technology and Satellite Tracking and

$$\Delta v = v_e \ln \frac{m_0}{m_1}$$

Tsiolkovsky's ideal rocket equation



The main engines of the Space Shuttle. The pumps for each engine can empty a swimming

Communications.

The **Spaceflight Assignment** was not one assignment. Everyone could pick from a list of almost 20 subjects. The topics ranged from algorithms to detect craters from images to decoding and analyzing data sent by satellites orbiting the moons of Jupiter. There are projects where there is in fact a lot of Electrical Engineering knowledge needed, such as developing sun sensors. I myself chose a project where water rockets are modelled and simulated. Here Thermo-, Hydro- and Aerodynamics are in play. These subjects are not covered in the Electrical Engineering Bachelor so there was definitely a lot to learn.

In a way **Spacecraft Technology** is a continuation of the Introduction to Spaceflight course. Here the subsystems of space vehicles are discussed. Propulsion and orbital control were new topics for me, solar panels, power distribution and communications are subjects that were not new but there was still a lot to learn about their application in space. I learned for example that the Intel 358 chip, a very old processor, is still widely used in space. This is because a radiation hardened version is available and it has a very extensive flight heritage. A serious issue

for microelectronics in space is the radiation upsetting regular operation. This can cause data corruption or can even destroy electronics.

As a student in Electrical Engineering there are some advantages in the course **Satellite Tracking and Communications**. It was apparent other students had little experience with telecommunications themselves. This course featured for the most part practical work, there was a part where a communication between to radio transmitters had to be established and also a visit to the top of the EWI building was done to receive data from the Delfi-C3 satellite in orbit around earth.

In the end I found the whole minor very enjoyable. There were about 45 participants in this minor and some more students that followed it online. The topics of the courses kept me interested and I can recommend this minor for students interested in space and rocket science. You do have to do some work, it is not a case of free credits. With recent developments in commercial space travel and the ongoing preparations for a manned mission to Mars the space industry is more active than ever and you won't regret familiarizing yourself with the regions outside our tiny planet. ■

ECM

EESTEC Chairman Meeting

Kevin van der Mark

EESTEC, Electrical Engineering Students European association, the European association of which the ETV is a founding member, is a collaboration between more than 50 universities across Europe. Associations involved, so called Local Committees (LCs), organise educational workshops across Europe and all ETV members can participate for free!



Last November the ETV attended the EESTEC Chairpersons Meeting, ECM, in East Sarajevo. The goal of this week long meeting is to increase the cooperation between all the member associations. As representatives of LC Delft (ETV), our board members Mitchel Chandi and Erné Bronkhorst attended multiple working sessions and general meetings.

The week started with everyone getting to know each other and the basics of EESTEC. In short, EESTEC is an international organisation which has an international board coordinating and facilitating the cooperation between local associations like the ETV. Afterwards during the "LC Hangout" representatives shared knowledge on fundraising, recruiting members and promoting international events. Especially this last topic is very useful for the ETV since EESTEC is still not well known amongst our members. We got some nice ideas and hope to send more and more members out on these awesome international workshops!

The last few days of the week were ded-

icated to a general meeting. EESTEC only has two general meetings a year so the schedule was very busy. Besides reports from the board on the current status and plans for the next half of their mandate there were also some Rules of Procedures (HR) proposals. The most important one was a proposal to change the way the EESTEC board works. Last year the new board was elected on Congress in Madrid where they were immediately inaugurated in the board. The new board planned one week of handover with the old board and afterwards they were on their own. This caused a huge drop in efficiency and inhibited a proper knowledge transfer. The proposal was to separate the election date and the inauguration date, creating more room for a proper knowledge transfer between the board and their successors. The proposal got accepted and will ensure a more stable and efficient association.



Besides the serious sessions, there was of course also time for some socializing. The evenings were filled with parties where both board members and myself enjoyed the fine tastings of

eastern Europe. One night, so called "International Night", really tickled our tastebuds. This evening was all about sharing everyone's local delicacies. As Delft students, we of course treated our international friends to some fine Vlek Jonge Genever, liquorice and stroopwafel. Our eastern European friends chose a lesser known drink, namely home brewed 60%+ rakia.



All in all we had a very interesting and informative week. We learned some new approaches to our local problems and met a lot of new people. This exchange of knowledge and culture is what EESTEC is about. All workshops have no participation fee and all ETV members get a financial support for their travel costs. So what are you waiting for?

We encourage all ETV members to register on the website eestec.net and apply for an event! For more information about EESTEC please contact the ETV EESTEC Committee at eestec-etv@tudelft.nl. ■



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Rail**

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High bit rate audio sampling

Part 2

Monty Montgomery

Sampling fallacies and misconceptions

Sampling theory is often unintuitive without a signal processing background. It's not surprising most people, even brilliant PhD's in other fields, routinely misunderstand it. It's also not surprising many people don't even realize they have it wrong. I am assuming most of the readers have an electrical engineering background and are as such more educated in the sampling theorem than most, but let's make sure there is no confusion.

The most common misconception is that sampling is fundamentally rough and lossy. A sampled signal is often depicted as a jagged, hard-cornered stair-step facsimile of the original perfectly smooth waveform. If this is how you envision sampling working, you may believe that the faster the sampling rate (and more bits per sample), the finer the stair-step and the closer the approximation will be. The digital signal would sound closer and closer to the original analog signal as sampling rate approaches infinity. Similarly, many non-DSP people would look at figure 6 and figure 7 and say, "Ugh!" It might appear that a sampled signal represents higher frequency analog

waveforms badly. Or, that as audio frequency increases, the sampled quality falls and frequency response falls off, or becomes sensitive to input phase.

Looks are deceiving. These beliefs are, of course, incorrect. All signals with content entirely below the Nyquist frequency (half the sampling rate) are captured perfectly and completely by sampling; an infinite sampling rate is not required. Sampling doesn't affect frequency response or phase. The analog signal can be reconstructed losslessly, smoothly, and with the exact timing of the original analog signal.

So the math is ideal, but what of real world complications? The most notorious is the band-limiting requirement. Signals with content over the Nyquist frequency must be low-passed before sampling to avoid aliasing distortion; this analog low-pass is the infamous anti-aliasing filter. Anti-aliasing can't be ideal in practice, but modern techniques bring it very close \dots and with that we come to oversampling.

Oversampling

Sampling rates over 48 kHz are irrelevant to high fidelity audio data, but they are internally essential to several mod-

ern digital audio techniques. Oversampling is the most relevant example.

Oversampling is simple and clever. High sampling rates provide a great deal more space between the highest frequency audio we care about (20 kHz) and the Nyquist frequency (half the sampling rate). This allows for simpler, smoother, more reliable analog anti-aliasing filters, and thus higher fidelity. This extra space between 20 kHz and the Nyquist frequency is essentially just spectral padding for the analog filter as shown in figure 8.

That's only half the story. Because digital filters have few of the practical limitations of an analog filter, we can complete the anti-aliasing process with greater efficiency and precision digitally. The very high rate raw digital signal passes through a digital anti-aliasing filter, which has no trouble fitting a transition band into a tight space. After this further digital anti-aliasing, the extra padding samples are simply thrown away. Oversampled playback approximately works in reverse.

This means we can use low rate 44.1 kHz or 48 kHz audio with all the fidelity benefits of 192 kHz or higher sam-

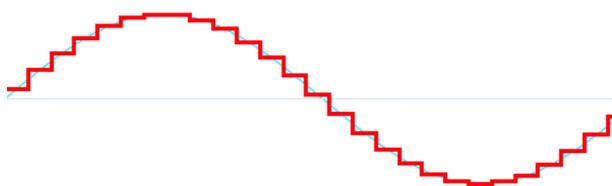


Figure 6: Sampled signals are often depicted as a rough stair-step (red) that seems a poor approximation of the original signal. However, the representation is mathematically exact and the signal recovers the exact smooth shape of the original (blue) when converted back to analog.

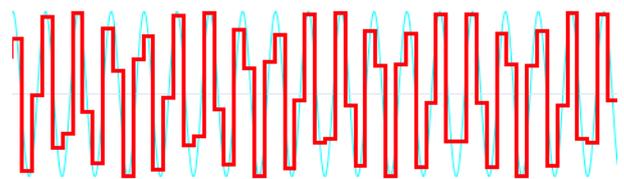


Figure 7: Representation of individual samples (Red) with the actual waveform (Blue)

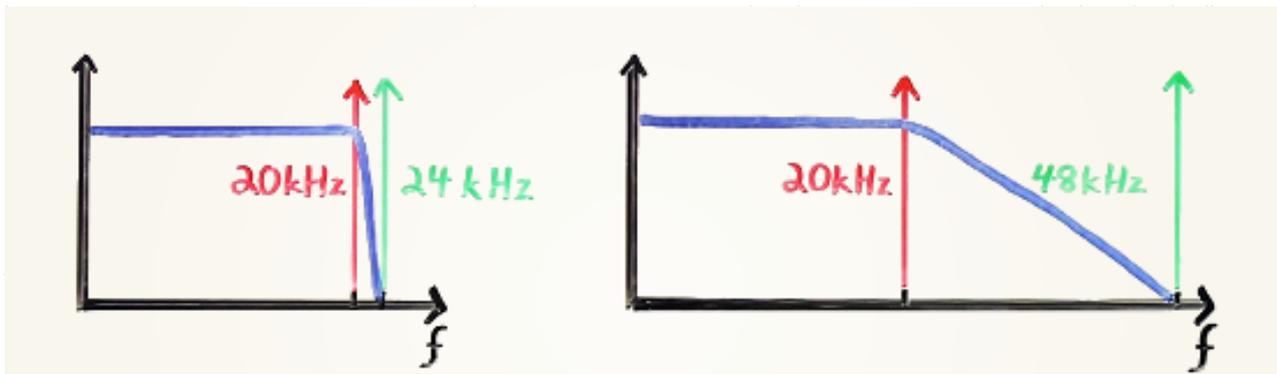


Figure 8: Whiteboard diagram illustrating the transition band width available for a 48 kHz ADC/DAC (left) and a 96 kHz ADC/DAC (right)

pling (smooth frequency response, low aliasing) and none of the drawbacks (ultrasonics that cause intermodulation distortion, wasted space). Nearly all of today's analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) oversample at very high rates. Few people realize this is happening because it's completely automatic and hidden.

ADCs and DACs didn't always transparently oversample. Thirty years ago, some recording consoles recorded at high sampling rates using only analog filters, and production and mastering simply used that high rate signal. The digital anti-aliasing and decimation steps (resampling to a lower rate for CDs or DAT) happened in the final stages of mastering. This may well be one of the early reasons 96 kHz and 192 kHz became associated with professional music production.

16 bit vs. 24 bit

OK, so 192 kHz music files make no sense. Covered, done. What about 16 bit vs. 24 bit audio?

It's true that 16 bit linear PCM audio does not quite cover the entire theoretical dynamic range of the human ear in ideal conditions. Also, there are (and always will be) reasons to use more than 16 bits in recording and production.

None of that is relevant to playback; here 24 bit audio is as useless as 192 kHz sampling. The good news is that at least 24 bit depth doesn't harm fidelity. It just doesn't help, and also wastes space.

Revisiting your ears

We've discussed the frequency range of the ear, but what about the dynamic range from the softest possible sound to the loudest possible sound?

One way to define absolute dynamic range would be to look again at the absolute threshold of hearing and threshold of pain curves. The distance between the highest point on the threshold of pain curve and the lowest point on the absolute threshold of hearing curve is about 140 decibels for a young, healthy listener. That wouldn't last long though; +130 dB is loud enough to damage hearing permanently in seconds to minutes. For reference purposes, a jackhammer at one meter is only about 100-110 dB.

The absolute threshold of hearing increases with age and hearing loss. Interestingly, the threshold of pain decreases with age rather than increasing. The hair cells of the cochlea themselves possess only a fraction of the ear's 140 dB range; musculature in the ear continuously adjust the amount of sound reaching the cochlea by shifting the

ossicles, much as the iris regulates the amount of light entering the eye. This mechanism stiffens with age, limiting the ear's dynamic range and reducing the effectiveness of its protection mechanisms.

Environmental noise

Few people realize how quiet the absolute threshold of hearing really is.

The very quietest perceptible sound is about -8 dB SPL. Using an A-weighted scale, the hum from a 100 watt incandescent light bulb one meter away is about 10 dB SPL, so about 18 dB louder. The bulb will be much louder on a dimmer.

20 dB SPL (or 28 dB louder than the quietest audible sound) is often quoted for an empty broadcasting/recording studio or sound isolation room. This is the baseline for an exceptionally quiet environment, and one reason you've probably never noticed hearing a light bulb.

The dynamic range of 16 bits

16 bit linear PCM has a dynamic range of 96 dB according to the most common definition, which calculates dynamic range as 6 bits per dB. Many believe that 16 bit audio cannot represent arbitrary sounds quieter than -96 dB. This is incorrect, as shown in figure 9.

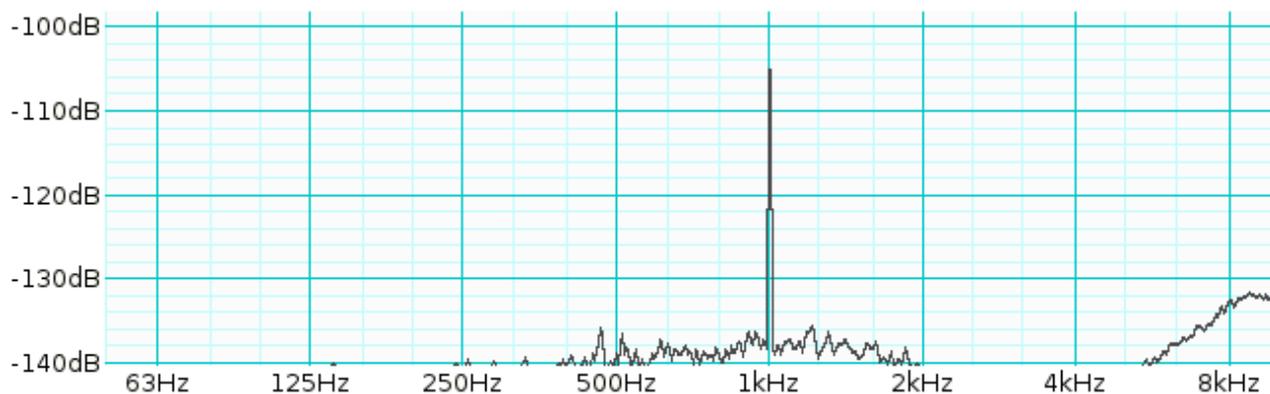


Figure 9: Spectral analysis of a -105 dB tone encoded as 16 bit / 48 kHz PCM. 16 bit PCM is clearly deeper than 96 dB, else a -105 dB tone could not be represented, nor would it be audible

To show this, I made two 16 bit audio files here; one contains a 1kHz tone at 0 dB (where 0dB is the loudest possible tone) and the other a 1kHz tone at -105dB. You can do this yourself at home with audio software or, again, find these files online.

How is it possible to encode this signal, encode it with no distortion, and encode it well above the noise floor, when its peak amplitude is one third of a bit?

Part of this puzzle is solved by proper dither, which renders quantization noise independent of the input signal. By implication, this means that dithered quantization introduces no distortion, just uncorrelated noise. That in turn implies that we can encode signals of arbitrary depth, even those with peak amplitudes much smaller than one bit. However, dither doesn't change the fact that once a signal sinks below the noise floor, it should effectively disappear. How is the -105 dB tone still clearly audible above a -96 dB noise floor?

The answer: Our -96 dB noise floor figure is effectively wrong; we're using an inappropriate definition of dynamic range. 6 bits per dB gives us the RMS noise of the entire broadband signal, but each hair cell in the ear is sensitive to only a narrow fraction of the total bandwidth. As each hair cell hears only

a fraction of the total noise floor energy, the noise floor at that hair cell will be much lower than the broadband figure of -96 dB.

Thus, 16 bit audio can go considerably deeper than 96 dB. With use of shaped dither, which moves quantization noise energy into frequencies where it's harder to hear, the effective dynamic range of 16 bit audio reaches 120 dB in practice, more than fifteen times deeper than the 96 dB claim.

120 dB is greater than the difference between a mosquito somewhere in the same room and a jackhammer a foot away... or the difference between a deserted 'soundproof' room and a sound loud enough to cause hearing damage in seconds.

16 bits is enough to store all we can hear, and will be enough forever.

Signal-to-noise ratio

It's worth mentioning briefly that the ear's S/N ratio is smaller than its absolute dynamic range. Within a given critical band, typical S/N is estimated to only be about 30 dB. Relative S/N does not reach the full dynamic range even when considering widely spaced bands. This assures that linear 16 bit PCM offers higher resolution than is actually required.

It is also worth mentioning that increasing the bit depth of the audio representation from 16 to 24 bits does not increase the perceptible resolution or 'fineness' of the audio. It only increases the dynamic range, the range between the softest possible and the loudest possible sound, by lowering the noise floor. However, a 16 bit noise floor is already below what we can hear.

When does 24 bit matter

Professionals use 24 bit samples in recording and production for headroom, noise floor, and convenience reasons.

16 bits is enough to span the real hearing range with room to spare. It does not span the entire possible signal range of audio equipment. The primary reason to use 24 bits when recording is to prevent mistakes; rather than being careful to center 16 bit recording-- risking clipping if you guess too high and adding noise if you guess too low-- 24 bits allows an operator to set an approximate level and not worry too much about it. Missing the optimal gain setting by a few bits has no consequences, and effects that dynamically compress the recorded range have a deep floor to work with.

An engineer also requires more than 16 bits during mixing and mastering. Modern work flows may involve literal-

ly thousands of effects and operations. The quantization noise and noise floor of a 16 bit sample may be undetectable during playback, but multiplying that noise by a few thousand times eventually becomes noticeable. 24 bits keeps the accumulated noise at a very low level. Once the music is ready to distribute, there's no reason to keep more than 16 bits.

Listening tests

Understanding is where theory and reality meet. A matter is settled only when the two agree.

Empirical evidence from listening tests backs up the assertion that 44.1kHz/16 bit provides highest-possible fidelity playback. There are numerous controlled tests confirming this, but I'll plug a recent paper, Audibility of a CD-Standard A/D/A Loop Inserted into High-Resolution Audio Playback, done by folks at the Boston Audio Society.

Unfortunately, downloading the full paper requires an AES membership. However it's been discussed widely in articles and on forums, with the authors joining in.

This paper presented listeners with a choice between high-rate DVD-A/ SACD content, chosen by high-definition audio advocates to show off high-def's superiority, and that same content resampled on the spot down to 16-bit / 44.1kHz Compact Disc rate. The listeners were challenged to identify any difference whatsoever between the two using an ABX methodology. BAS conducted the test using high-end professional equipment in noise-isolat-

ed studio listening environments with both amateur and trained professional listeners.

In 554 trials, listeners chose correctly 49.8% of the time. In other words, they were guessing. Not one listener throughout the entire test was able to identify which was 16/44.1 and which was high rate, and the 16-bit signal wasn't even dithered!

Another recent study¹ investigated the possibility that ultrasonics were audible, as earlier studies had suggested. The test was constructed to maximize the possibility of detection by placing the intermodulation products where they'd be most audible. It found that the ultrasonic tones were not audible... but the intermodulation distortion products introduced by the loudspeakers could be.

This paper inspired a great deal of further research, much of it with mixed results. Some of the ambiguity is explained by finding that ultrasonics can induce more intermodulation distortion than expected in power amplifiers as well. For example, David Griesinger reproduced this experiment and found that his loudspeaker setup did not introduce audible intermodulation distortion from ultrasonics, but his stereo amplifier did.

Caveat Lector

It's important not to cherry-pick individual papers or 'expert commentary' out of context or from self-interested sources. Not all papers agree completely with these results (and a few disagree in large part), so it's easy to find minority opinions that appear to vindicate every

imaginable conclusion. Regardless, the papers and links above are representative of the vast weight and breadth of the experimental record. No peer-reviewed paper that has stood the test of time disagrees substantially with these results. Controversy exists only within the consumer and enthusiast audiophile communities.

If anything, the number of ambiguous, inconclusive, and outright invalid experimental results available through Google highlights how tricky it is to construct an accurate, objective test. The differences researchers look for are minute; they require rigorous statistical analysis to spot subconscious choices that escape test subjects' awareness. That we're likely trying to 'prove' something that doesn't exist makes it even more difficult. Proving a null hypothesis is akin to proving the halting problem; you can't. You can only collect evidence that lends overwhelming weight.

Despite this, papers that confirm the null hypothesis are especially strong evidence; confirming inaudibility is far more experimentally difficult than disputing it. Undiscovered mistakes in test methodologies and equipment nearly always produce false positive results (by accidentally introducing audible differences) rather than false negatives.

If professional researchers have such a hard time properly testing for minute, isolated audible differences, you can imagine how hard it is for amateurs.

To be continued in the last issue ■

¹ Karou and Shogo, Detection of Threshold for tones above 22 kHz (2001). Convention paper 5401 presented at the 110th Convention, May 12-15 2001, Amsterdam.

Advertorial Smit Trafo

Developments in Power Transformers

Timo Overboom

After receiving the PhD-degree, I was offered a position as electrical design engineer and technical specialist at Royal Smit Transformers. Having researched motion systems with micrometer positioning accuracy and magnetic levitation for several years, I entered the world of large power transformers. Suddenly, the value of quantities such as voltage, current and force increased by three orders of magnitude.

Royal Smit Transformers has been manufacturing large power transformers for more than 100 years and has one of the biggest individual factories in the world. Located near the city center of Nijmegen, it makes custom designs with maximum power ratings of 1200 MVA and voltage levels up to 800 kV. These transformers not only have high power ratings but are also big and heavy (see Fig.1). Royal Smit operates on a global level, exporting most of its products to Europe, USA, Middle East and some other parts of the world.

Transformers transfer electrical energy between circuits with different voltages by means of electromagnetic induction. Although this basic operating principle is well understood and has been exploited in the distribution and transportation of electrical energy for

over a century, the performance and design of transformers is continuously changing as a result of new standards, developments in material properties, different customer requirements, and a global competitive market. Detailed knowledge about the electrical, magnetic, thermal, acoustic, mechanical, and even chemical behavior is required to make a multi-disciplinary design which is reliable, efficient, and cost-effective. Also the manufacturing process has to be considered during the design stage since many parts are made and assembled by hand. Both the design and the manufacturing are precise and delicate processes because transformers are vital parts in the supply of electrical energy. To guarantee a long service life without any failures (usually more than 30 years), transformers should be able to withstand tremendous forces

in the event of a short-circuit and be insulated against overvoltages due to lightning impulses or switching surges. Also higher temperatures caused by overload conditions and magnetic overexcitation of the core due to overvoltage conditions, must be taken into consideration. After manufacturing, each transformer is tested in the high voltage laboratory of Royal Smit.

Ever since I started working at Royal Smit, I have been following an intensive training program to learn all aspects of power transformers. This program treats theoretical/empirical modeling, statistical analyses, and testing of transformers. At a later stage, I will also do an internship at the factory to completely understand how a transformer is actually built and how a design on paper is converted into a large physical object.

As part of the training, I am currently working on an analytical model to predict the flux distribution inside a five-limb core. Most three-phase transformers use a three-limb core made of electric steel with a high permeability to easily guide the magnetic flux (see Fig.2). The main limbs are each surrounded by a winding set, which comprises a primary and secondary winding, and in some cases also a tertiary. During no-load operation of the transformer, three-phase sinusoidal voltages with a fixed frequency (50 or



Figure 1: Picture of a 700 MVA power transformer.

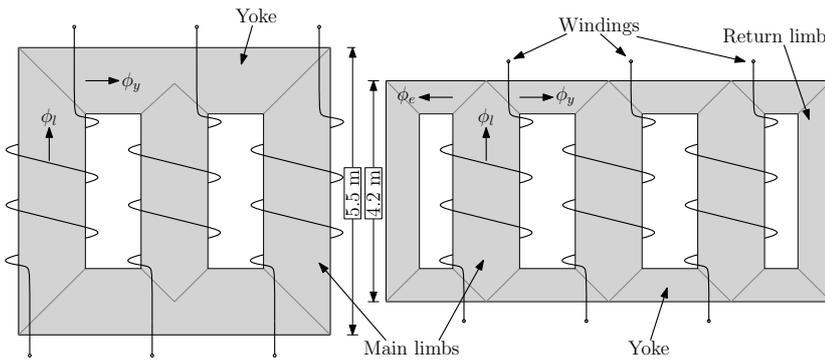


Figure 2: Geometry of a three-limb core (left) and a five-limb core (right).

60 Hz) are applied across the primary windings while the other windings are disconnected. According to Faraday's law of induction, the primary windings will link a sinusoidally varying magnetic flux, which has the same frequency as the three-phase voltages. The yokes of the core provide a low reluctance path between the main limbs and, therefore, carry the same flux. To maintain the same peak flux density throughout the core, the limbs and yokes have the same cross-sectional areas.

The total height of transformers is sometimes restricted due to limited

space at the site or transportation to the site (through tunnels for instances). In such cases, two return limbs are added to the core design, resulting in the five-limb configuration as shown in Fig.2. The return limbs provide an additional path for the magnetic flux, allowing a reduction of the cross-sectional area of the yokes and, hence, a smaller height of the core. However, due to the nonlinear magnetic characteristics of the core material, the fluxes confined inside the yokes and return limbs exhibit a non-sinusoidal variation in time, even though the main limbs carry a sinusoidally vary-

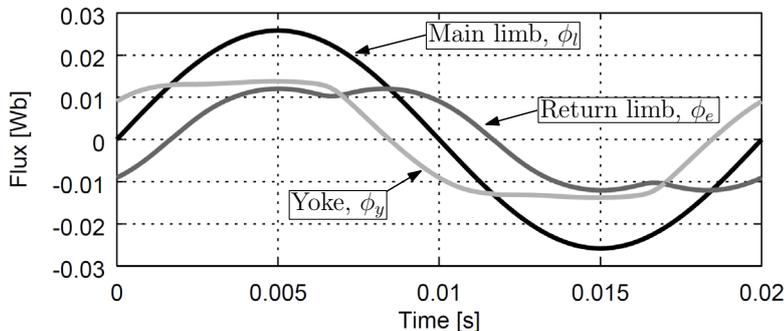


Figure 3: Flux inside the main limb, return limb, and yoke of a five-limb core.

ing flux. Aside from the fundamental frequency imposed by the three-phase voltages, the profiles of the flux within the yokes and return limbs also contain harmonics with higher frequencies (see Fig.3). These harmonics have a significant impact on the performance of the core in terms of the iron losses and audible noise.

The analytical model for the five-limb core is based on a magnetic equivalent circuit, where the magnetic flux is represented by a electrical current and the magnetic reluctance by a resistance. It is a challenge to include the nonlinear and anisotropic properties of the core material, simulate hysteresis, and model the joints in the core. Eventually, the model has to be verified with measurements on a full-size core.

I conduct my research within a group of highly skilled engineers who have different scientific backgrounds and work on other research topics. For instance, they work on the reduction of audible noise produced by a transformer, investigate the effects of geomagnetically induced currents (GICs), and try to improve the service life by reducing the water content in the paper insulation through proper drying and oil-impregnation methods. These are just a few examples but it shows that the technology related to power transformers is still progressing. Royal Smit Transformers will need more talented engineers in the future to cope with all its challenges. ■

Timo Overboom studied Electrical Engineering at Eindhoven University of Technology. In 2009 he graduated within the Electromechanics and Power

Electronics group on the design and optimization of a rotary actuator for a two degrees-of-freedom z-phi module. From March 2009 until May 2015 he worked

as a PhD-student at the same university. During this period, he researched a planar motor with magnetic suspension and wireless energy transfer.

ETV Activities

FeeCie Party

By Tom Salden



When first year students start off in Delft, a few dramatic changes stand out in comparison with the secondary school life. Of course, studying is much more intense and difficult than going to school, but maybe the biggest change is the male-to-female ratio. Especially in Delft, this is not beneficial for the males. Luckily, the ETV has found an excellent solution for this: organising a party in collaboration with another student association, Emile in Leiden. Particularly since the ratio male-female is (almost) opposite. And of course this does not only to first-years only.

Finally, on the day of the party, most of the ETV members assembled at the train station. The dress code was supposed to be the nineties, as the theme was 'Back to the Future'. Although many



of the gathered students added an original twist to the dress code, as most of them appeared in animal costumes and a few students, including me, dressed like the 1890's. After having some fun in the train, we arrived, and enjoyed the amazing party. The amount of people present was incredible, the two party halls in the building were filled completely and the atmosphere was great. The organisation clearly worked hard, with balloons, and other decoration everywhere. On top of that, many people had a great costume, ranging from fluorescent hair-bands, safety-vests and glittery shirts.

Even though the two groups of students kept separated a bit, quite some integrating did happen, and after a long night that felt too short, everyone can probably agree that it was an amazing party and that this tradition must continue!



SSD Christmaslunch

By Remco van der Plaats

On December 16th 2015 a yearly returning event was organized by the Sterkstroomdispuut der Electrotechnische Vereniging (SSD). During the lunch break a lunch was organized for students and staff members of the Electrical Sustainable Energy (Power Engineering) (ESE) department. Traditionally this is a lunch in the High Voltage Lab of our faculty. In this beautiful environment the SSD has each year the privilege to organize a lunch just before the Christmas break. With a Christmas tree in the middle of the Lab, tables around it and with Christmas decoration the High Voltage Lab was transformed into a perfect location for a Christmas lunch. With almost 70 participants many students and staff members enjoyed a lunch at one of the last moments before Christmas. During the lunch good food and hot Glühwein was served for all participants. The yearly Christmas lunch is a good moment to talk with your colleague students as well as with the professors and other staff members of the ESE department. During the lunch there were hot snacks and there was a wide variety of sandwiches and spreads as well as fruit. At two tables the food was served and like a buffet people could get what they want. After the lunch all students and staff members continued work for the last days of the year. During the lunch the new board was also announced. A year ago the board of 2015 started and from January 2016 a new board will continue their work of organizing activities for students and staff of the ESE department.

Lustrum Activities



Sint- en Kerstlunch

By Ralph van Schelven

December is weer voorbij, maar de herinneringen aan twee van de traditionele activiteiten van de ETV zitten nog vers in het geheugen. Ik heb het natuurlijk over de Sint- en de Kerstlunch. Deze twee heerlijke lunches in de /Pub maken het toch altijd wat makkelijker om de laatste koude maand voor de kerstvakantie te doorstaan. Buiten de normale dingen die je kan verwachten bij een lunch (broodjes, filet americain, kroketten) waren er in beide gevallen ook andere dingen aanwezig. Aangekomen bij de Sintlunch hebben alle ETV'ers die hun schoentje hebben gezet kunnen zien wat Sinterklaas voor hen heeft meegenomen. Zodra de pakjes waren bekeken vielen de aanwezi-

gen aan en aten de buikjes rond.

Bij de kerstlunch was er een hele speciale gast aanwezig: de enige echte Kerstman kwam een verhaal vertellen. Het verhaal ging over de geboorte van een meisje, de profetie die eraan voorafging en het levensverhaal van de inmiddels Oude Dame. Na het verhaal konden alle aanwezigen genieten van een heerlijke lunch, kerstsnoepjes en natuurlijk de traditionele Glühwein, gemaakt door het Bestuur.

Als aanwezige bij beide lunches kan ik zeggen dat de activiteiten ook dit jaar weer een groot succes waren. Voor mij is de koude decembermaand met al deze gezelligheid gemakkelijk voorbij gegaan.



TNO Excursion

By Roel de Rijk

On a Tuesday morning the week before Christmas break the ETV organised an excursion to TNO in The Hague where they specialise in radar technology, distributed sensor systems and intelligent imaging. After an explanation about security rules and the horrible message that we had to leave our phones in a locker we went to a small conference room. After a cup of coffee different employees of TNO gave a small presentation about their work and their department within TNO. One of these presentations was about a traineeship at TNO, this was very interesting because a traineeship means that you work at a department for a short time and then switch departments to get a better view of the company and your capabilities. After the presentations there was a lunch organised with the people that gave the presentations so we could ask them more questions. After the lunch we got a tour of the facility, and saw a few of the methods they use to measure and test radar systems like acoustic chambers and a tower on top of the building. At the end of the tour we got to a room that had a large basin in the middle to test sonar devices and do other under water measurements. At the edge of the basin another few presentations were given and the excursion ended with a small drink next to the basin. After all the excursion gave a good impression of the variety of things done within the TNO facility.

ETVoice

By Rik Wilmer

A lustrum year of the ETV has many nice aspects, divided into four weeks over the year. On the Monday evening of the second week - themed "give me a signal" - the ETVoice was organized. The meeting room of the ETV was transformed by a marvelous crew to a studio: blankets to de-echo the walls, recording equipment, and headphones; the ambiance was really great. Enthusiastic members of the ETV let their vocal chords ring to the enjoyment of all other ETV members, even those who were not present: the crew had set-up a livestream to YouTube. This way, almost thirty members could join the fun from home. Bad one-liners, pickup lines, live radio, golden voices, songs with impromptu made lyrics (and/or melody): everything could be heard that night. Songs as "I'm so electric" were turned into "I'm so electrip", hinting to and sung by one of many committees

of the ETV. Singing capabilities - or lack thereof - often led to shaking of heads or happy smiles. It is good to know we did one thing right: amuse all of our fellow ETV members.

Dinner brought pizza or spaghetti to the boardroom, which made a nice break in the evening. After the nice dinner, the ETVoice went on till closure of the faculty. This was an event not to be forgotten. And even better; this spectacular happening will make memories which can't be forgotten: recorded songs will be composed onto a lustrum-CD.

/Pubquiz

Door Koen Peelen

Het was 17 December, een hele mooie dag. Het was een lustrum dag, en niet zomaar een. Het was mijn verjaardag EN de dag van de /pubquiz. Hoe kan het mooier dan dit. Na een biertje te delen met mijn mede electro'ers adopteren wij een van het zeldzame

geslacht in ons team en gaan we zitten. Team #birthdayastrithans was compleet. Na een woeste en lastige eerste ronde hadden we helaas maar een paar punten gehaald maar dat mocht de stemming niet dempen. De tweede ronde ging van start en dit keer vochten we hard terug om het verlies goed te maken. Toen de uitslag kwam konden we tevreden zijn, best goed gescoort. De derde rondje zou ons uitslag geven. We ploegde ons door de vragen van uiterst hoog niveau, terwijl we onzin antwoorden rond schreeuwde om de vijand van slag te brengen. Het mocht niet baten, we wonnen niet. Gelukkig kwam er een gratis fust om ons verdriet te verdrinken samen met een prachtige presentatie over de Selfiechallenge, waar onze Wilmer (#Wilmmeerwilmer) ons verraste met vele fantastische selfies op meerdere locaties waardoor hij de normale en creative prijs won, wat een held. Overal was het een geslaagde avond en een prima besteding waar veel intergreert is. ■



Promotion flyer

3rd Period

Motibo - *Monday, February 8th 17:30* - /Pub

The third period will kick off with a drink in the /Pub to evaluate the last period and get ready for the next.

FRAME - *February 22nd - 26th*

Do you have what it takes to become that number 1 sales person? Apply for a 4-day crash course in sales and fundraising.

Biercantus - *Tuesday, February 23rd*

In cooperation with the study association CoDe (Leiden) a cantus will be organized with beer, ETV-members and (ETV-)songs.

EEMCS Recruitment Days 2016

The following activities will be organized for the Recruitment Days:

- CV workshop - *Monday, February 15th 16:00*
- CV check - *Thursday, February 18th 14:00*
- Meeting days - *March 29th - April 1st*

Lustrum week 3 - *week 3.6*

The theme of the third Lustrum week will be 'power'. A caseday, mini-symposium and a gala (March 18th) are organized. Need a suit (white tie)? We will organize an event where you can buy one.

Lunch lectures

In the third period the next lunch lecture will take place:

- ASML - *Thursday, February 11th*
- More will be planned





PINEWOOD
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08.02
08.03

challenge.pinewood.nl

hackers challenge

Ben je student aan de TU Delft en heb je bovengemiddelde security en hacking skills? Doe dan mee met de Pinewood hackerschallenge!

In deze challenge kun je bewijzen dat jij de beste skills hebt op het gebied van crypto, networking forensics, web security en pentesting. Je zult daarbij te maken krijgen met bijvoorbeeld bit-torrent, password hacking, wireshark, IPv6, SQL injection en ransomware.

Voor wie?

Deze uitdaging is geschikt voor alle studenten met enige IT kennis en affiniteit met security, waarbij vooral de nadruk ligt op kritisch, logisch en creatief nadenken.

Hoe werkt het?

- Registreer je op: challenge.pinewood.nl
- Vanaf 8 februari krijg je online toegang tot de verschillende challenges tot uiterlijk 8 maart 12:00.
- De score's van alle deelnemers zijn realtime te volgen.
- Zorg dat je de meeste punten haalt en sleep die prijzen in de wacht.

Waarom meedoen?

Op 10 maart vindt de prijsuitreiking plaats in het gebouw van EWI. Voor de beste hacker ligt er een Samsung Galaxy TAB S2 te wachten. Daarnaast zijn er nog vijf Raspberry PI 2 te verdelen.

