MT Schienenwahl

Medical Electronics - Medizinelektronik

Prof. Dr.-Ing. Georg Fischer,
Dr. Phys. Jens Kirchner
Lehrstuhl für Technische Elektronik

Making Bits Fly

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Content

1. Lecturer/Lecture

Lecturers
CV

Prof. Dr.-Ing. Georg Fischer (born 1965)

1986-1992	Study at RWTH Aachen University Electrical Engineering - Communications, RF/Microwave, Acoustics, Antennas, Field theory/Electrodynamics
1993-1996	Research Assistant at University of Paderborn Adaptive Antennas and Microwave Circuit Technology at 12 GHz Doctoral Thesis: *Ein Empfangssystem für den Satellitenrundfunk mit Adaption der Richtcharakteristik und der Polarisation*
1996-2008	Employment at Lucent, later Alcatel-Lucent, Bell Labs Research (now NOKIA) Research/predevelopment Basestation Technology
2000	Bell Labs DMTS (Distinguished Member of Technical Staff)
2001	Bell Labs CMTS (Consulting Member of Technical Staff)
2007	Nomination for Bell Labs Fellow
2001-2007	Assistant Lecturer at FAU, LHFT
April 2008	Appointment as Full Professor at FAU Erlangen-Nürnberg as "Professur für Technische Elektronik"
	Research areas: Communication Technology, Medical Electronics, Metabolism Sensors,, AAL, Smart Textiles, Wireless Audio/PMSE, Trasceiver Technology, Analog-Digital partitioning of Electronic Systems
	Stuko IuK Vors

Lecturers
CV

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Dr. rer. nat. Jens Kirchner

Biography

Jens Kirchner studied Physics at Friedrich-Alexander University Erlangen-Nürnberg (FAU) and at University of St. Andrews, Scotland, between 1999 and 2004. In 2008, he received his doctoral degree from FAU in 2004, with his thesis about stochastic modelling of cardiological time series. Between 2008 and 2015, he worked for Biotronik SE & Co. KG in Erlangen and Berlin in research and development of implantable sensors. He joined the Institute for Electronics Engineering in 2015, where he leads the Medical Electronics group.

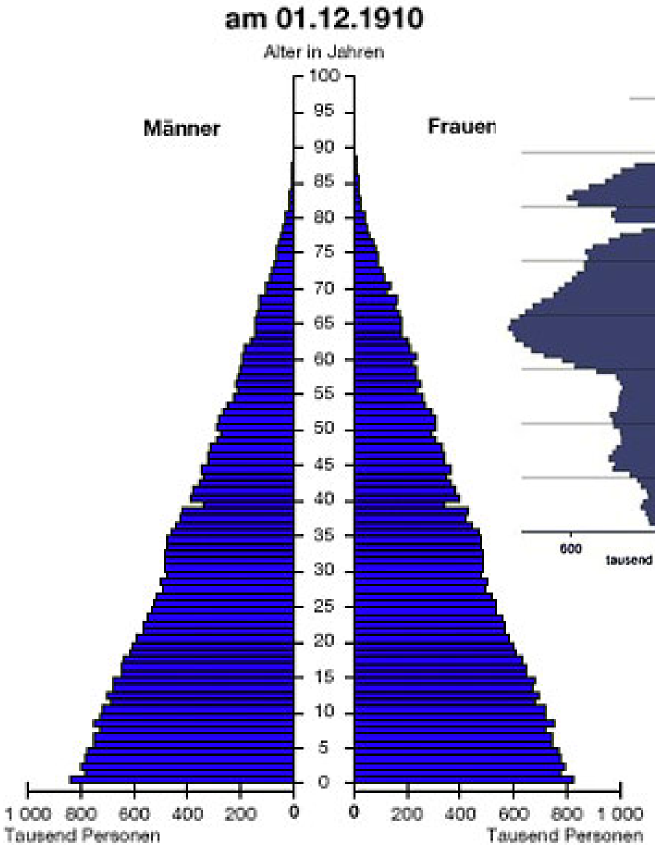
Areas of Interest

- Implantable sensors
- Monitoring of chronic diseases
- Analysis and modelling of cardiological measurement data

Lecture
Goal

Gain

- Substantial knowledge on principles for the circuit design of medical electronic devices
- Ability to analyse circuit diagrams of medical electronic devices
- Ability to separate medical electronic devices into its sub functions
- Ability to analyse energy budget of medical sensors and circuits with body near electronics
- Basic ability to design electronic circuits to comply with obligations by MPG
- Substantial knowledge on circuit design for standard medical devices, e.g. ECG, EEG, EMG
- Substantial knowledge on wireless Body Area Networks (BAN)
- Substantial knowledge on circuit design rules for micro/mm-wave medical sensors
- Substantial knowledge on circuits including microsystem (MEMS) components for health assistance systems



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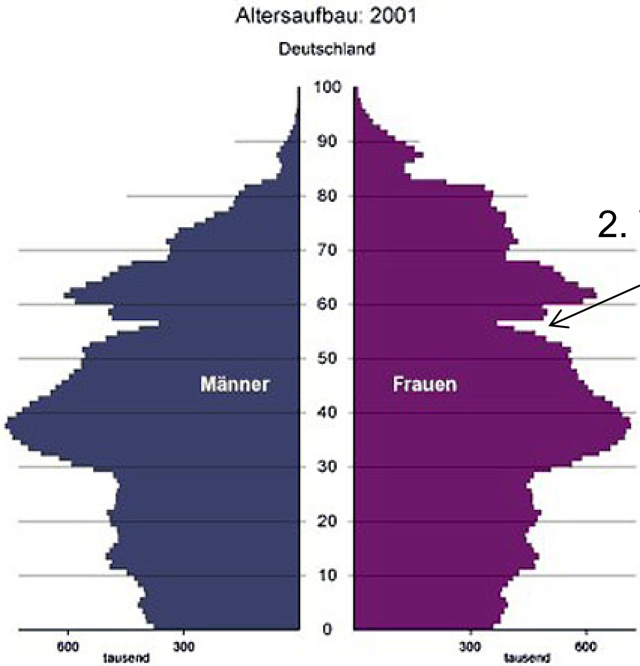
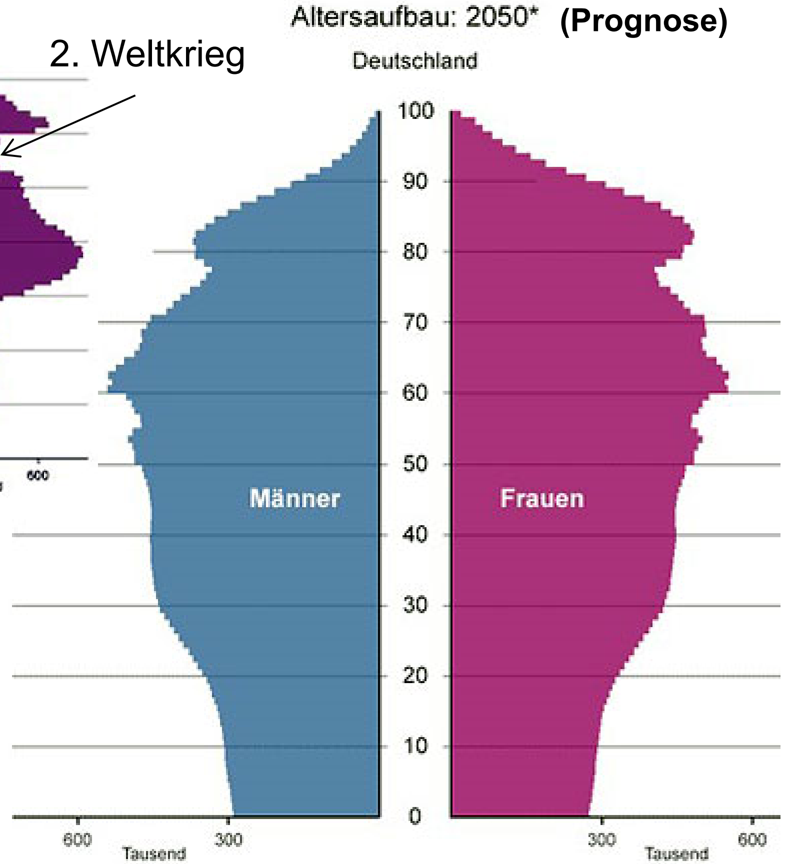


2. Weltkrieg



(Prognose)

➡ The age pyramid is upside down!

2. Cooperations and activities

Cooperations and activities
Overview

Research
- BioRadar for detecting Breathing and heart beat
- Spectroscopic sensors 5…120 GHz
- Body Area Networks, Wireless connectivity for Telemedicine
- Biosignal acquisition
- Implant communication, e.g. Stent Antennas
- Energy Harvesting (Inside/outside body)
- Inertial sensors, Pulse Oxmetry, Pulse wave

Teaching
- Seminar on Medical Electronics and AAL
- New Curriculum BS/MS Medical Engineering/Medical Electronics
- New lecture Medical Electronics 2V+2Ü within Medizintechnik Master
- StuKo Medizintechnik active member
- Member of ZIMT

Projects
- BMBF Spitzencluster Medical Valley
- EU ENIAC MAS Mobile Assistenten
- Industry cooperations (Corscience, Siemens, FhG)
- Care giver cooperations (Diakonie Neuendettelsau, Netscouts)
- Sensors for Bbrown dialysis machine

3. Regulations and safety

Regulations and safety
Example

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Medical wall-mount power supplies provide up to 15W

Steve Taranovich, Senior Technical Editor -- EDN, April 11, 2012

Power Sources Unlimited Inc has announced the TR15RAM Series of AC/DC medical-grade wall-mount switching power supplies. The series provides up to 15W of continuous output power and meets EN60601-1/UL60601 3rd Edition and EN55011, FCC Class B emissions limits.

The TR15RAM Series also meets Energy Star 2.0 Efficiency Level V with efficiency ratings up to 82%, as well as the requirements of global energy efficiency standards such as EISA2007, CEC, and the European ErP Directive.

Specifications include a universal AC input of 90 to 264 VAC (47 to 63 Hz) and output voltages ranging from 5 to 24 VDC.

Other features include interchangeable AC plugs, continuous short circuit protection, overvoltage protection, and a wide variety of DC output plugs, cable lengths, and types.

Units are priced under $19 in OEM quantities with delivery from stock to 5-7 weeks ARO.

Power Sources Unlimited

Source: EDN, April 2012

Regulations and safety
MPG

Medizinprodukte werden an Hand von Klassifizierungsregeln in vier Klassen (I, IIa, IIb, III) eingeteilt

Die Regeln sind risikobasiert orientiert an der Anwendungsdauer, der Invasivität und der Energieversorgung (aktiv, nicht aktiv) des Medizinprodukts

Klasse I

Stethoskop
Quelle: www.elvita.pl

Kompressionsbinde
Quelle: www.bmp-aachen.de

Klasse IIa

Operationshandschuhe
Quelle: www.hartmann.de

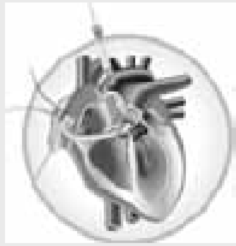
Infusionsset
Quelle: www.medstore.at

Klasse IIb

Defibrillator
Quelle: www.medisave.co.uk

Beatmungsgerät
Quelle: www.Draeger.com

Klasse III



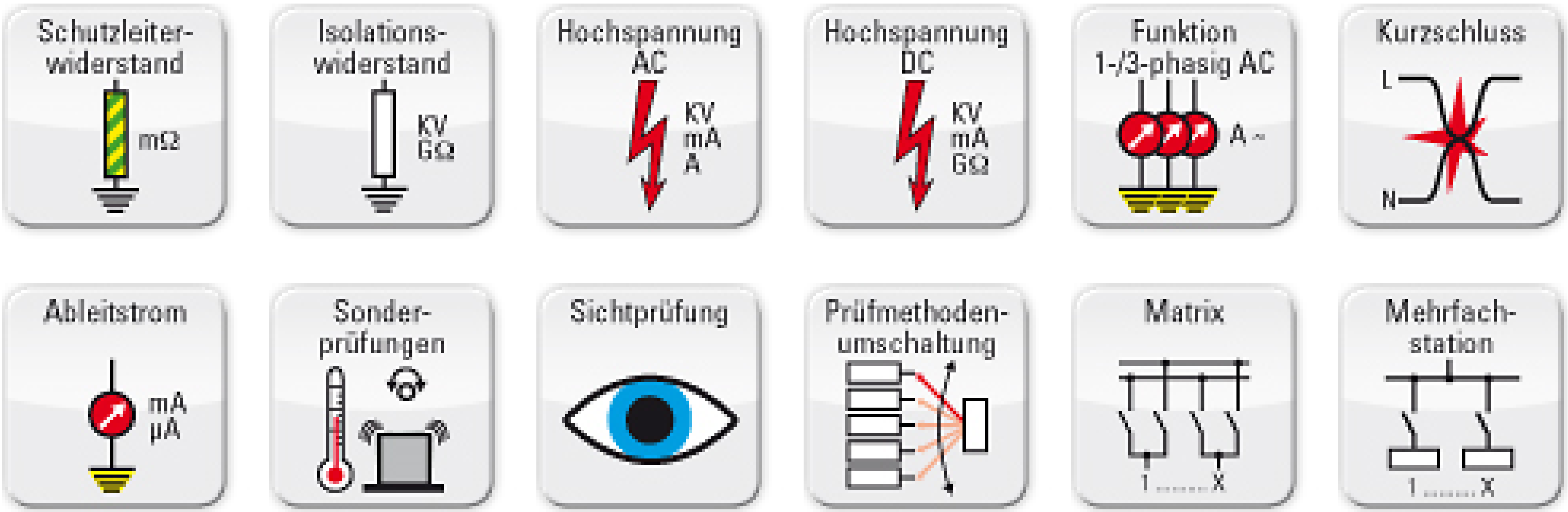
Ventricular Assist Devices
Quelle: Impella.com

Herzklappe
Quelle: www.zdf.de

Philips Lehrstuhl für Medizinische Informationstechnik | Helmholtz-Institut

Source: Dr. Marian Walter, RWTH, Entwicklung und Risikomanagement von sicheren Geräten für die Medizintechnik

Regulations and safety
Tests



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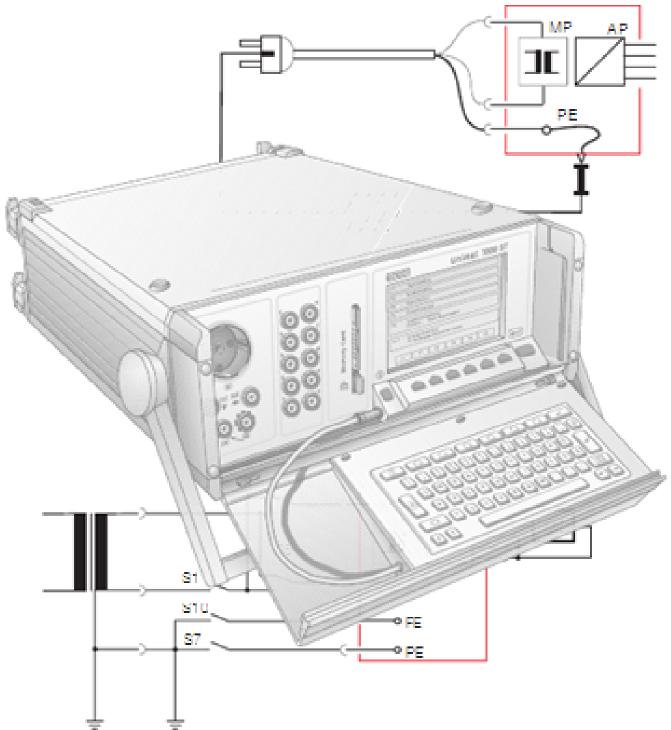
Example for test equipment



Technisches Handbuch

Unimet 1000 ST

- **Meßtechnik**
- **Schnittstellenbeschreibung**

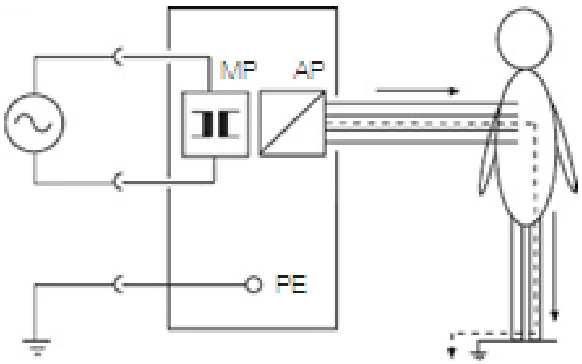
Source: Bender, TGH 1315/02.99, Scribd

Regulations and safety

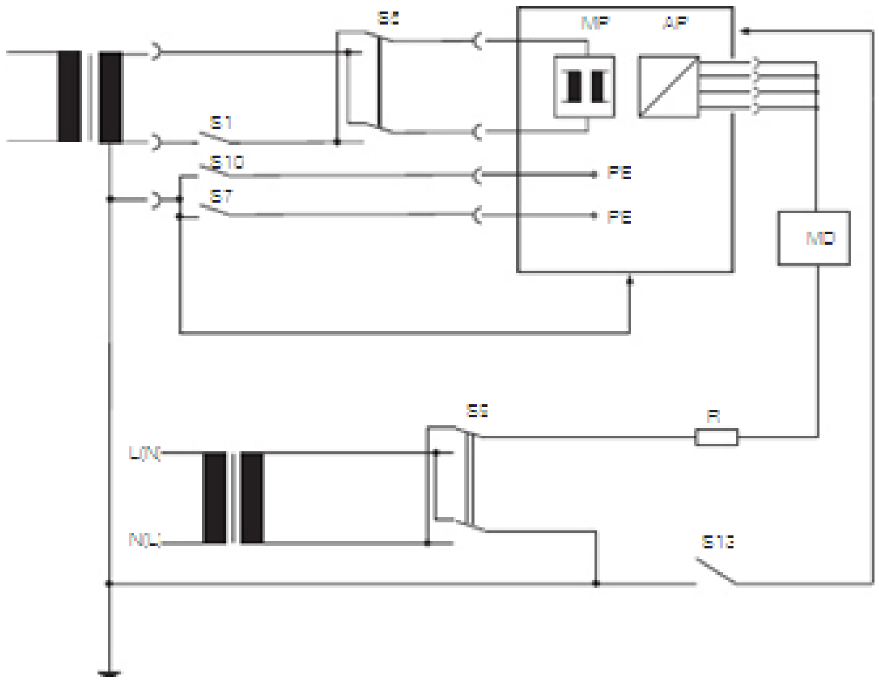
Test equipment

Requirement

- Patientenableitstrom,
  leakage current through patient



Prinzipschaltbild Patientenableitstrom



Meßanordnung zur Simulation der Normalbedingung und Erster-Fehler-Bedingungen bei der Patientenableitstrommessung. In diesem Fall wird der Patientenableitstrom durch eine externe Spannung am Anwendungsteil verursacht.

Strom, der vom Anwendungsteil über den Patienten zur Erde fließt (ausgenommen Patientennutzstrom) oder Strom, der durch eine unbeabsichtigte Fremdspannung am Patienten verursacht wird und über diesen und ein isoliertes (erdfreies Anwendungsteil Typ F zur Erde fließt)

Source: Bender, TGH 1315/02.99, Scribd

Regulations and safety
Circuit solutions for Isolation

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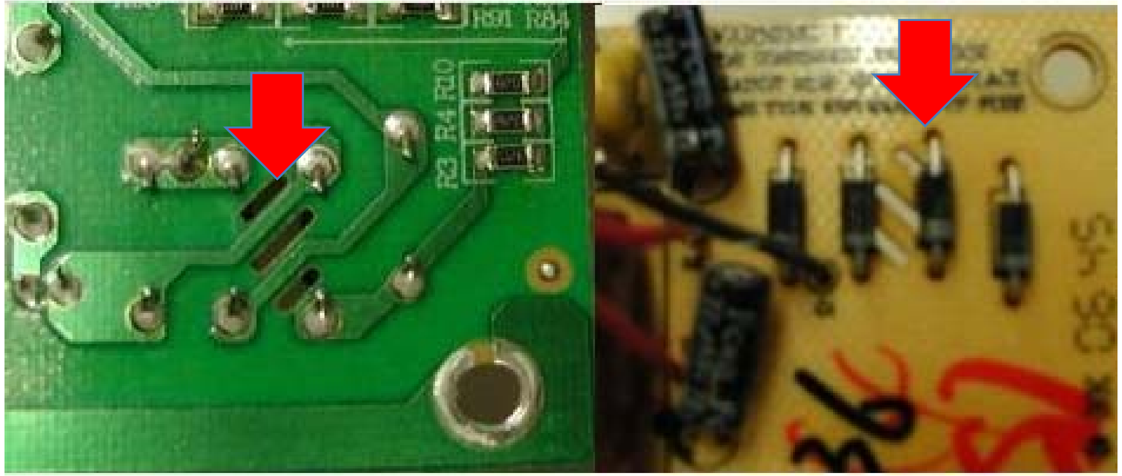
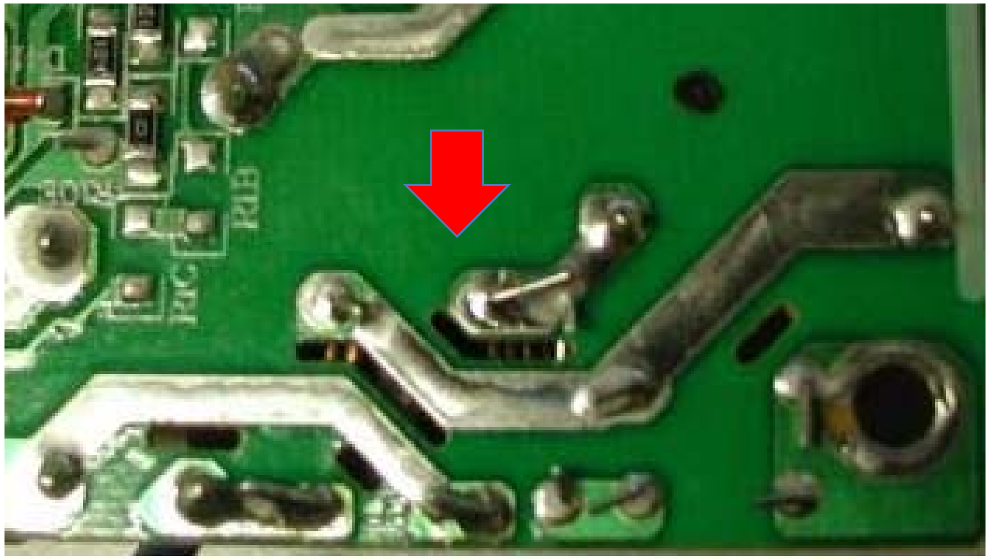
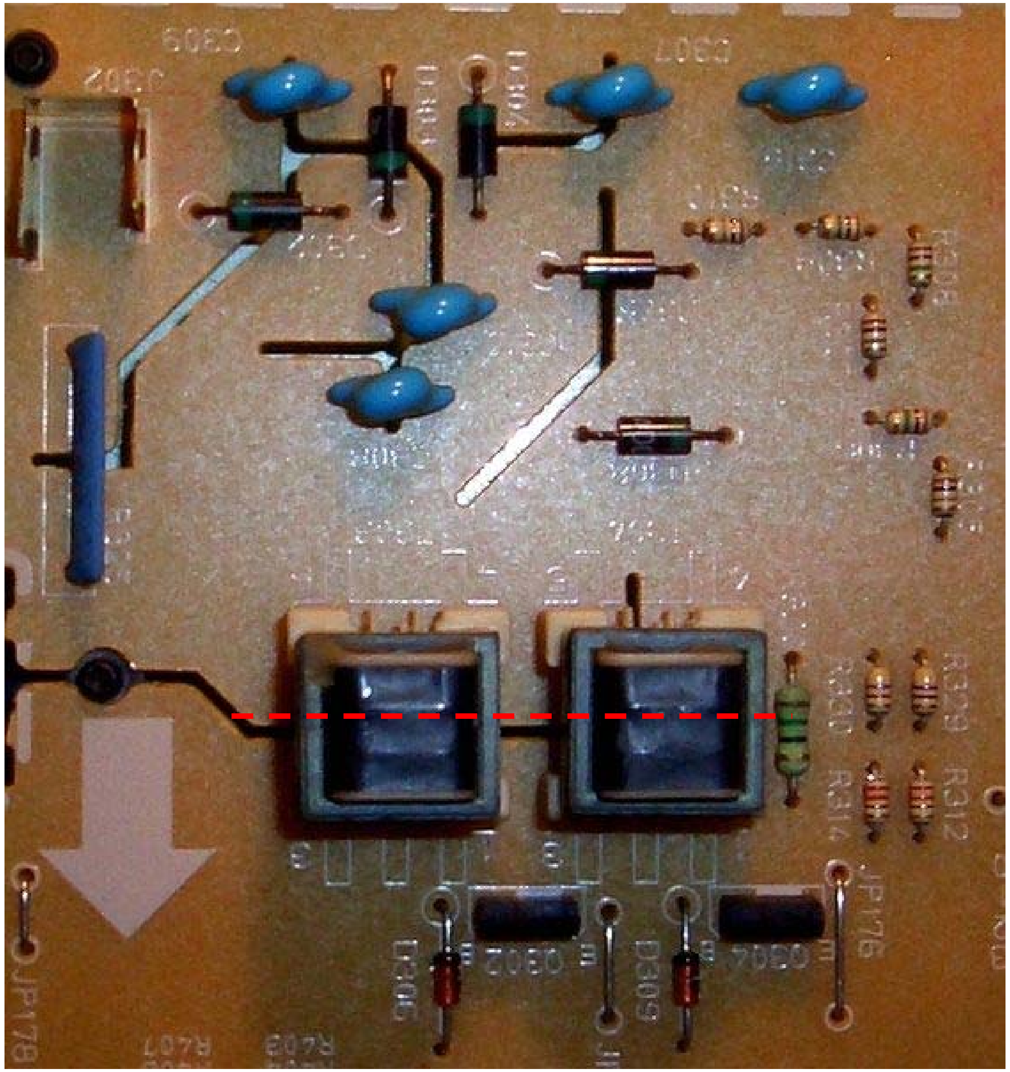




Cut-outs in the PCB!

Regulations and safety

Circuit solutions for Isolation



Isolation

- Separation of circuit sections by cuts/slits *(Schlitze)* in PCB

Isolation barrier by transformers

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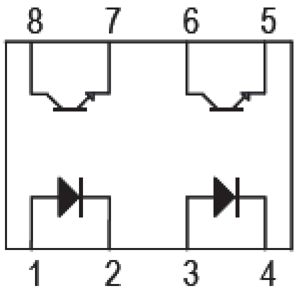
Optocoupler

- TX: LED emits light
- RX: Phototransistor receives light
- Can work for digital and analogue signals

ACPL-827 pin layout



- Pin 1, 3 Anode
- Pin 2, 4 Cathode
- Pin 5, 7 Emitter
- Pin 6, 8 Collector

Description

The ACPL-827 is a DC-input dual channel full-pitch phototransistor optocoupler which contains two light emitting diode optically coupled to two separate transistor. It is packaged in a 8-pin DIP package.

Likewise, the ACPL-847 is a DC-input quad channel full-pitch phototransistor optocoupler which contains four light emitting diode optically coupled to four separate transistor. It is packaged in a 16-pin DIP package

For both types, it is also available in wide-lead spacing option and lead bend SMD option with input-output isolation voltage at 5000 Vrms. Response time, tr, is typically 4 µs and minimum CTR is 50% at input current of 5 mA

Source: Avago

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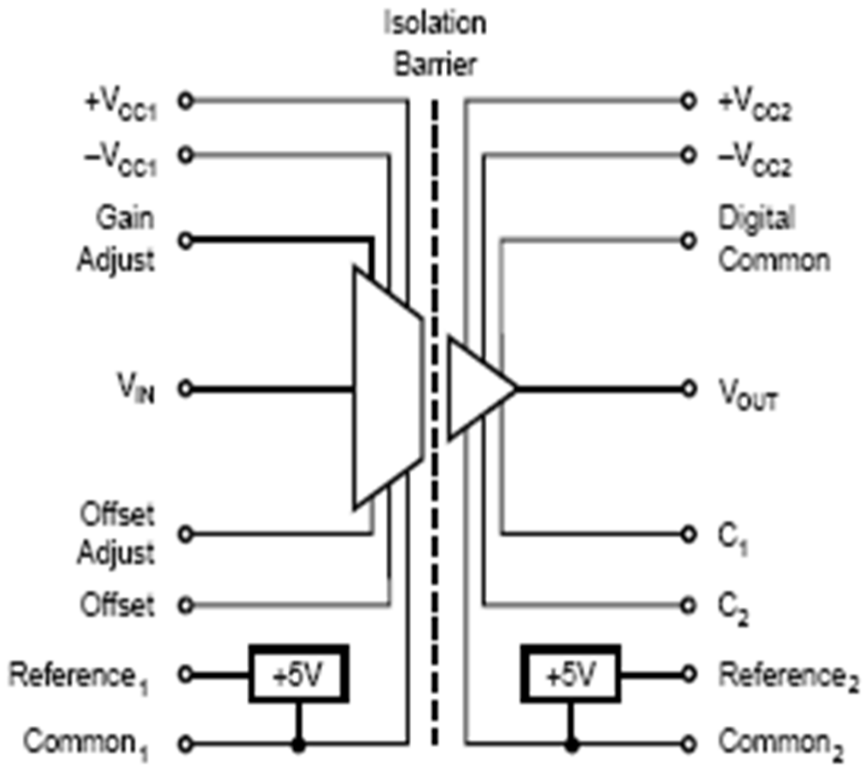
Isolation amplifier

- Galvanic separation of two circuits
- Main Requirement: maximize breakdown voltage
- Working principle capacitive coupling

Example ISO 106

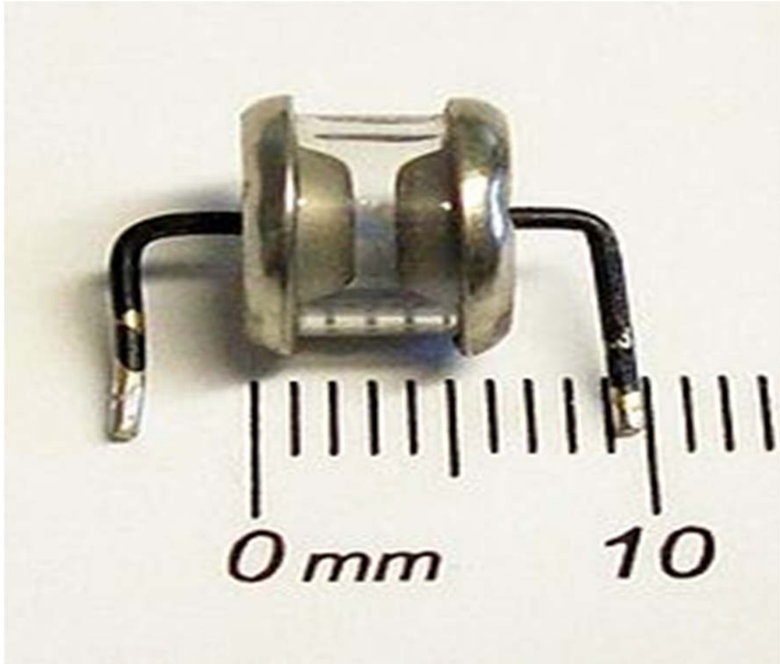
FEATURES

- **14-BIT LINEARITY**
- **INDUSTRY'S FIRST HERMETIC**
- **ISOLATION AMPLIFIERS AT LOW COST**
- **EASY-TO-USE COMPLETE CIRCUIT**
- **RUGGED BARRIER, HV CERAMIC CAPACITORS**
- **100% TESTED FOR HIGH VOLTAGE**
- **BREAKDOWN**
  ISO102: 4000Vrms/10s, 1500Vrms/1min
  ISO106: 8000Vpk/10s, 3500Vrms/1min
- **ULTRA HIGH IMR: 125dB min at 60Hz,**
- **WIDE INPUT RANGE: –10V to +10V**
- **WIDE BANDWIDTH: 70kHz**
- **VOLTAGE REFERENCE OUTPUT: 5VDC**



Ignition Spark Gap
(Zündfunkenstrecke)

- Shortens high voltages
- Overvoltage protection OVP *(Überspannungsschutz)*
- Ignition voltage *(Zündspannung)* moderately high typ. 200V
- Falls down to burrning voltage *(Brennspannung)*, typ. 20V
- Defibrillator provides high voltage, may destroy ECG input
- Protect ECG circuit by shorting inputs
- Also has parasitic capacitance, results in parasitic low pass filter, corner frequency must be checked!



4. Biosignal Acquisition

Biosignal acquisition
Frequencies

Frequency Ranges

- Breathing 0.2 Hz ....
- CT Scanner Rotation 0.5...3 Hz
- Heartbeat 1 Hz, obvious....
- EEG 1...60 Hz and higher *(new signatures are being studied…)*
- Train Power 16 2/3 Hz
- Pulsing of TETRA frames 1/ 56.67 ms=18 Hz
- Pulsing of TETRA bursts 1/ 14.167 ms = 71 Hz
- Mains Power Supply 50...60 Hz
- EMG, mainly up to 100 Hz
- Pulsing of GSM Frame 1 / 4.615 ms=220 Hz
- Pulsing of GSM Bursts 1.7 kHz
- Power Control in UMTS, 1.5 kHz (15 slots in a frame of 10 ms)
- ECG monitoring 0.5…500 Hz / ECG diagnostic 0.5…2 KHz
- VLF (Very Low Frequencies - Längstwelle) 3...30 kHz
- LF (low Frequency – Langwelle) 30...300 kHz
- MW (medium wave – Mittelwelle) 300 kHz-1.5 MHz
- KW (Short wave - Kurzwelle) 3...30 MHz
- UKW (Ultra short waves) 30...300 MHz
- 4G LTE Modem 700 MHz
- GSM Modem 900 MHz/1800 MHz
- UMTS Modem 2 GHz

See also:
http://www.sciencedirect.com/science/article/pii/S0924424710002657)

Biosignal acquisition
TETRA

Digital Radio BOS (TETRA) will assist you in assisting....

Interference by other radio signals

- Mobile phones, Broadcast stations, Man Made Noise
- Pulsed Communication Signals:
  Digitaler Behördenfunk / Digitaler Polizeifunk, GSM

A real case - Newspaper:

The introduction of a **TETRA** network (called C2000) for the emergency services in The Netherlands ran into severe problems. Initially there was fear about the radiation safety for the officers. A study by TNO concluded that there is no scientific evidence for adverse health effects.
However, now the ambulance and police services after much delay finally began to roll out they found that the handsets interfere with medical equipment. TNO tested the handsets against 90 different types of medical equipment. They found 13 severe problems, 25 intermediate, 11 light. In 9 cases the medical equipment had to be shut down completely and powered up again to get it back to Normal working. Severe problems were found a.o. with pacemakers and equipment to stop cardiac arrest. The temporary solution is that the police officers and paramedics may Only use their TETRA handset in the listen mode, while in or nearby hospitals or ambulances. If they need to peak, they have to find the nearest fixed line phone …

Source: De Volkskrant, NL

Voltage Ranges

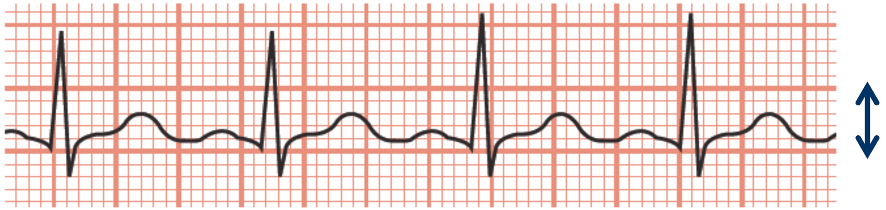
- GSM phone: receiver Sensitivity 2 μV (equal to -100 dBm @ 50Ω), transmitter 10 V (equal to 2 W @ 50Ω)
- Biosignals: EEG 5...250 μV, ECG 1...3 mV, EMG 5..10 mV
- Digital Logic: 2.7, 3.3 or 5 V, Sub threshold logic 200 mV
- Analog OPV: +/-5 V, +/-12 V, +/-15 V
- Batteries: AAA 1.5 V, Block 9V, Camera 12V
- Vehicle Battery: Car 12 V, Lorry 24 V, old Beetle -6V, in future 48V
- Small Voltages: < 60V
- Telecom voltages e.g. Basestation: -48V
- Mains Plug: 110...240 V, three phases 380 V
- High Voltage power lines: 110, 220, 380 kV
- Defibrillator: 5kV
- CRT TV: b/w 10 kV, colour 22 kV (Cathode ray tube electron acceleration)

Biosignal acquisition
ECG

ECG

- ElectroCardioGram
- Measurement of voltage - potential difference
- ECG plot shows voltage over time
- Part of patient monitor

Source: CardioPerfect PC-Ruhe-EKG , Praxisdienst



1mV equals
1cm with printing

Source: One Time Electrodes, Praxisdienst

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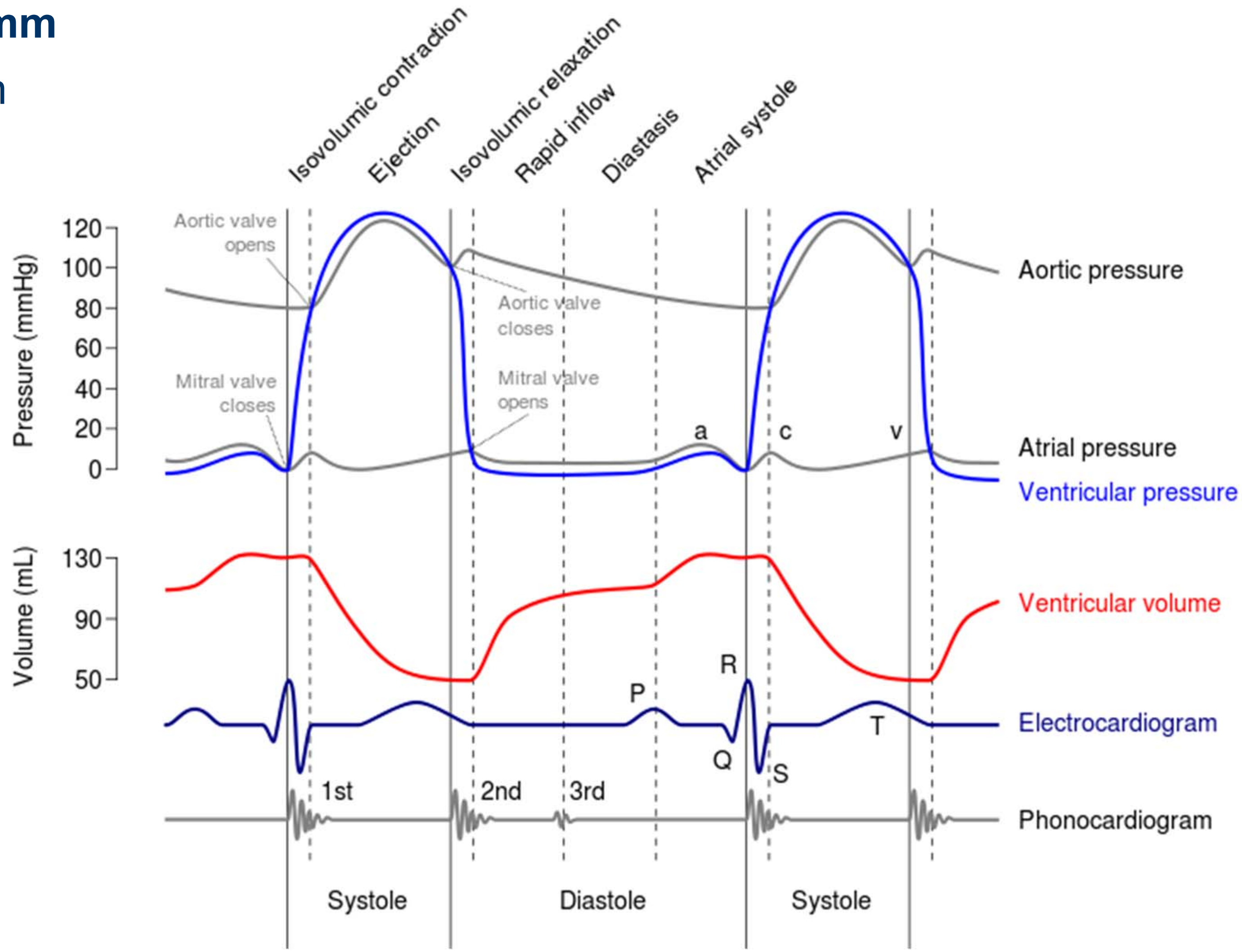
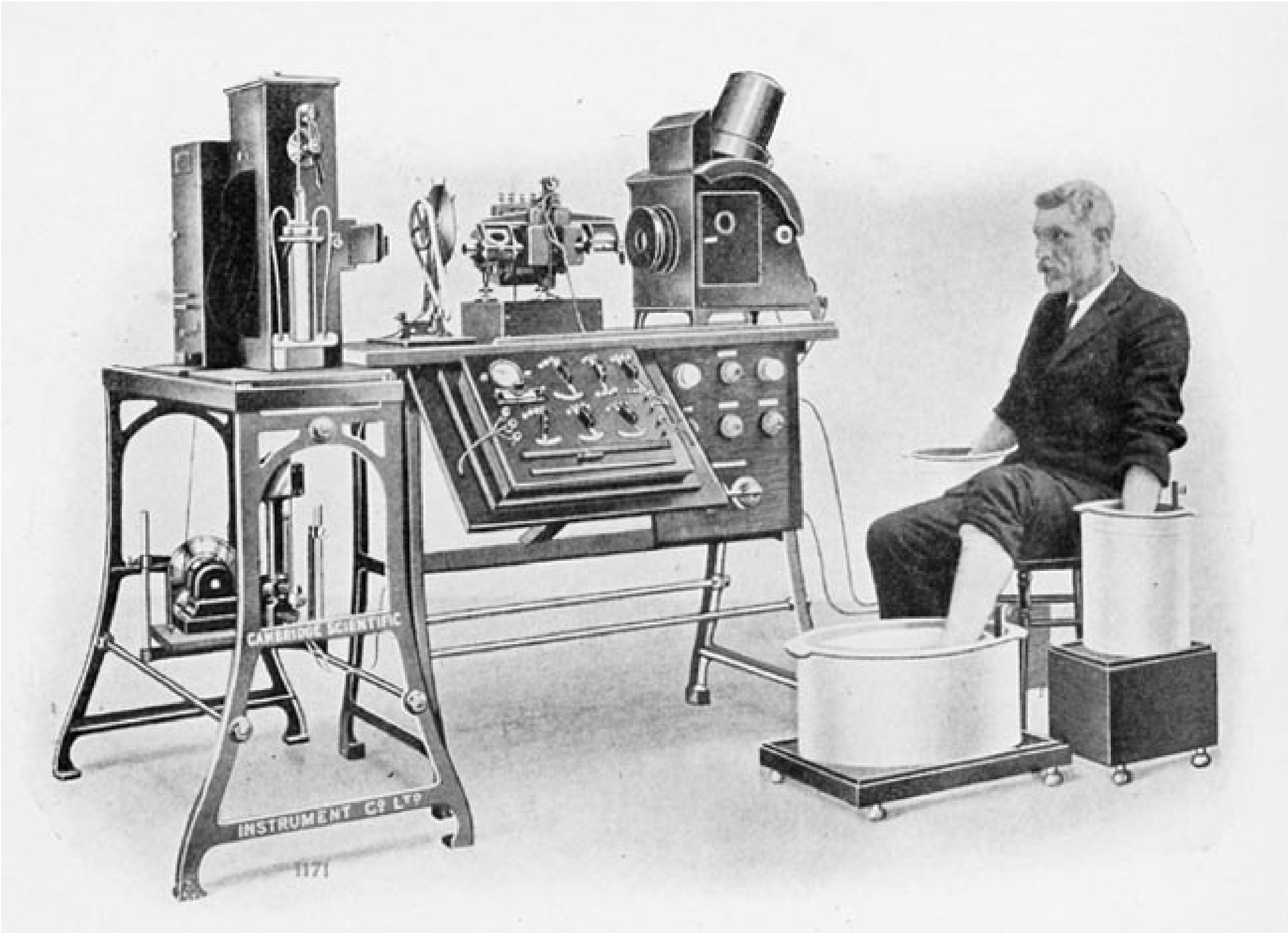
Wiggers Diagramm

- Cardiac rhythm



Source: *[DanielChangMD]*



Photograph of a Complete Electrocardiograph, Showing the Manner in which the Electrodes are Attached to the Patient, In this Case the Hands and One Foot Being Immersed in Jars of Salt Solution

AgCl electrolyte

Biosignal acquisition
Capacitive ECG – for the back

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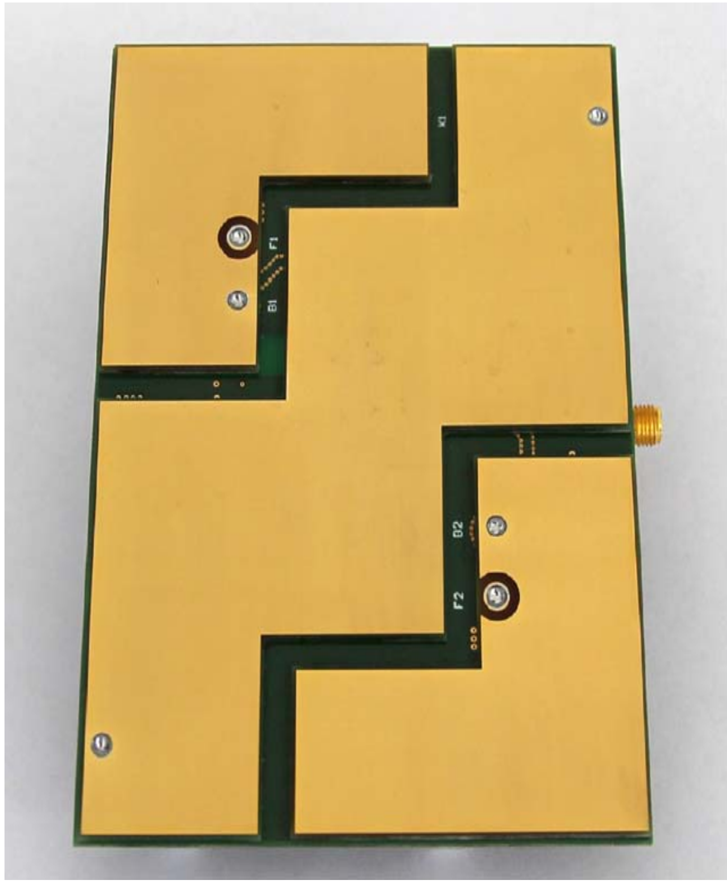
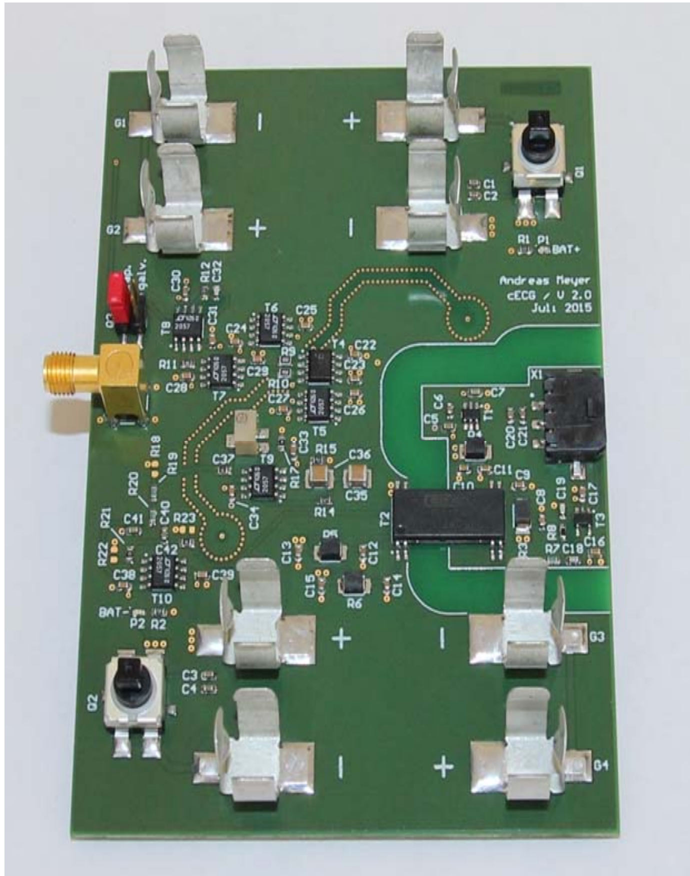
cECG for the back

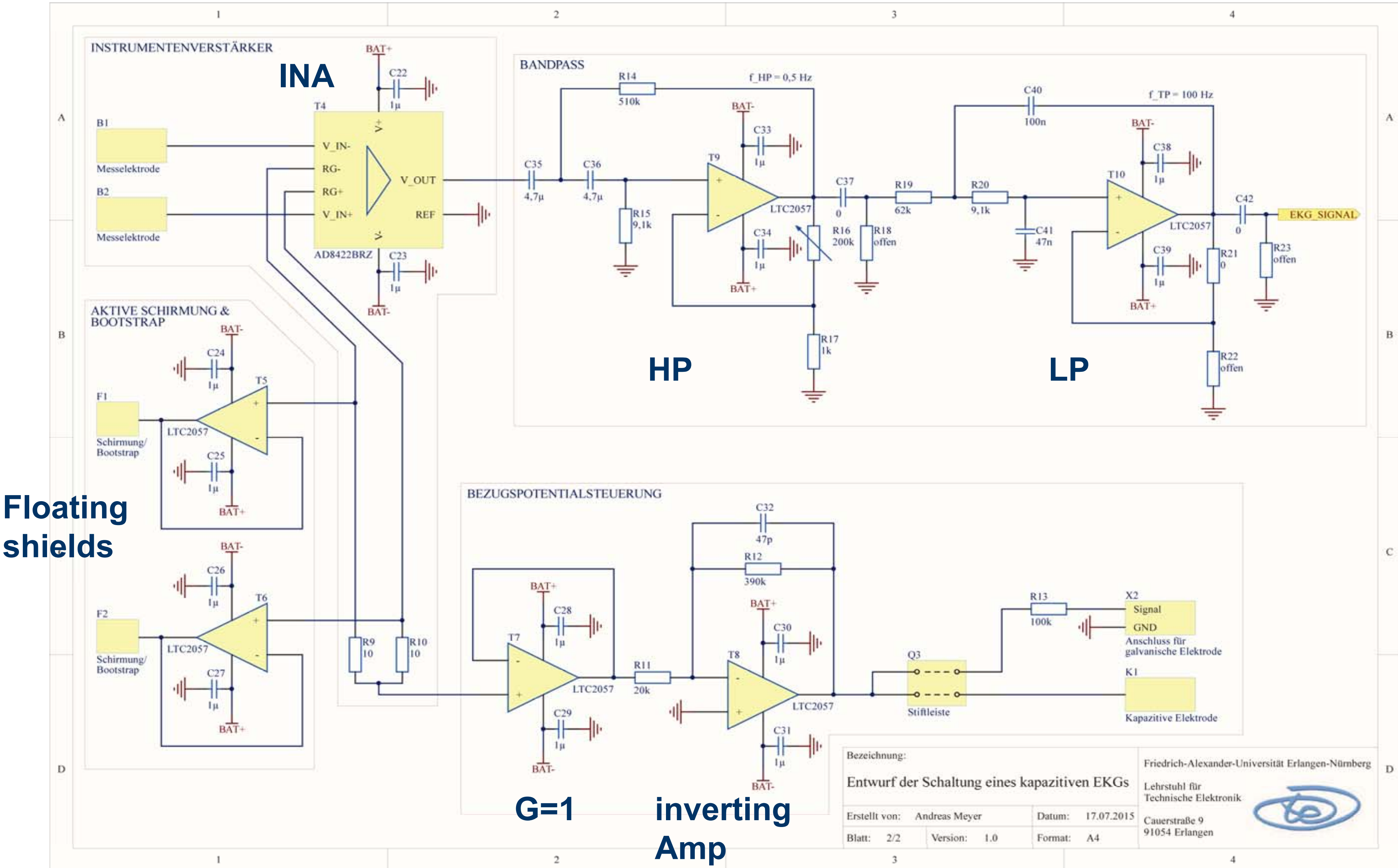
- Capacitive coupling through back plaster or clothing
- Very weak signals, vulnerable to interference and artefacts





Source: Andreas Meyer

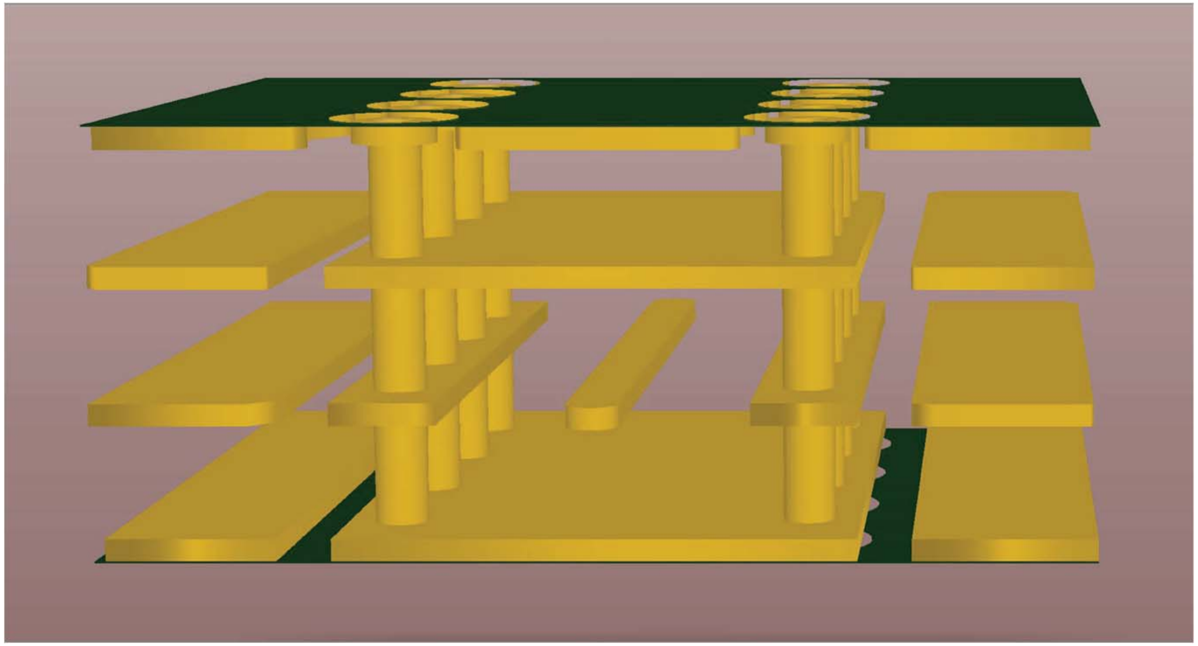
4. Circuits for biosignal acquisition
4.7 cECG – for the back



Source: Andreas Meyer

Floating shield for every input line

- Input capacitance reduced by floating shield
- Shield should reduce radio interference but comes at the price of increased input capacitance
- Parasitic capacitance by shield (like coax line) has no effect as there is no voltage
- As there is no voltage, there is no charged stored, so capacitance has no effect
- However input capacitance of INA still in place…
- Active shields feed noise into inputs, but very low and thus negligible



$$Q = C \cdot U$$

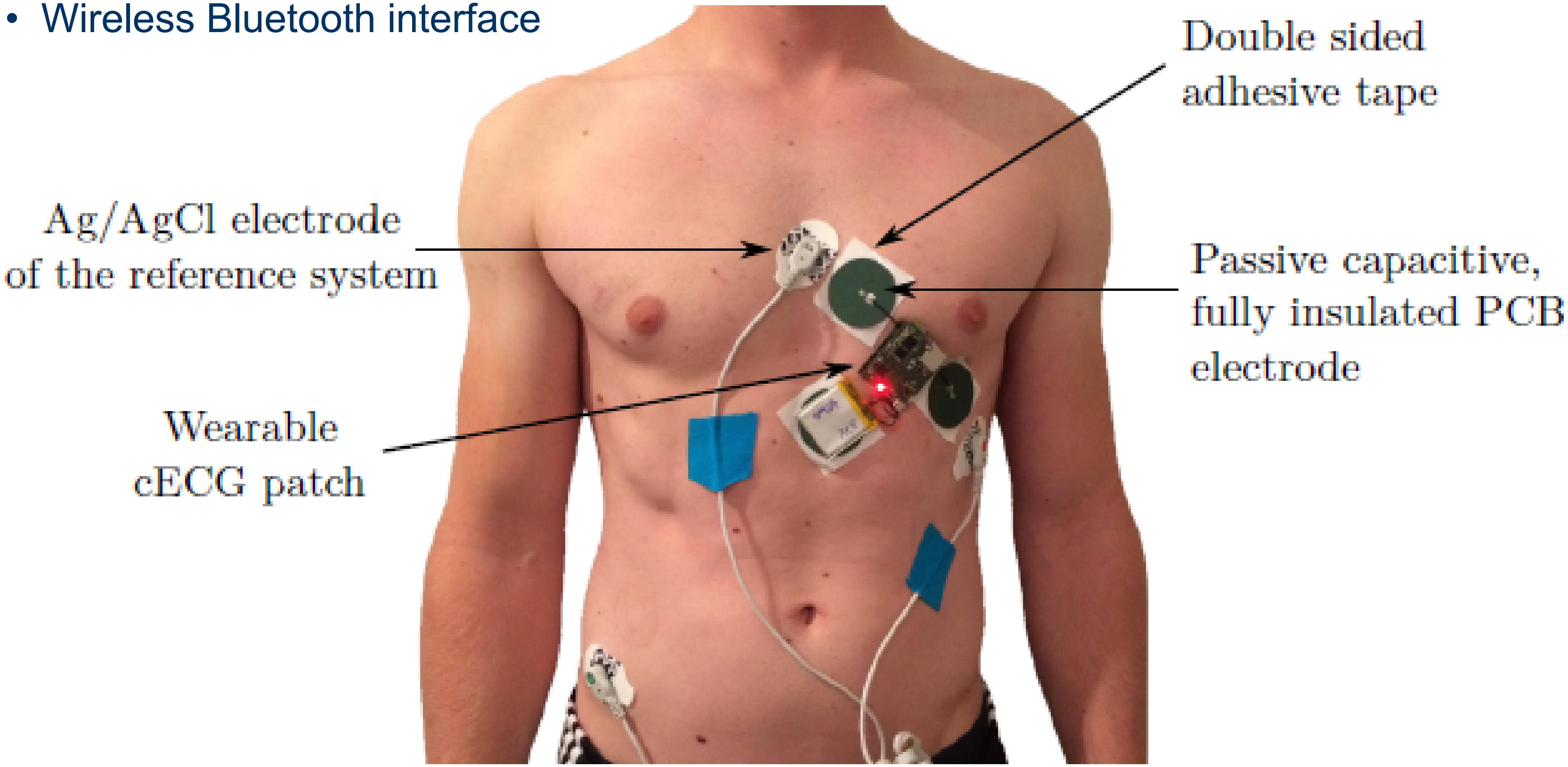
$$U = 0 \;\Rightarrow\; Q = U$$

$$\Rightarrow\; C \; has \; no \; effect$$

Source: Andreas Meyer

New Approaches

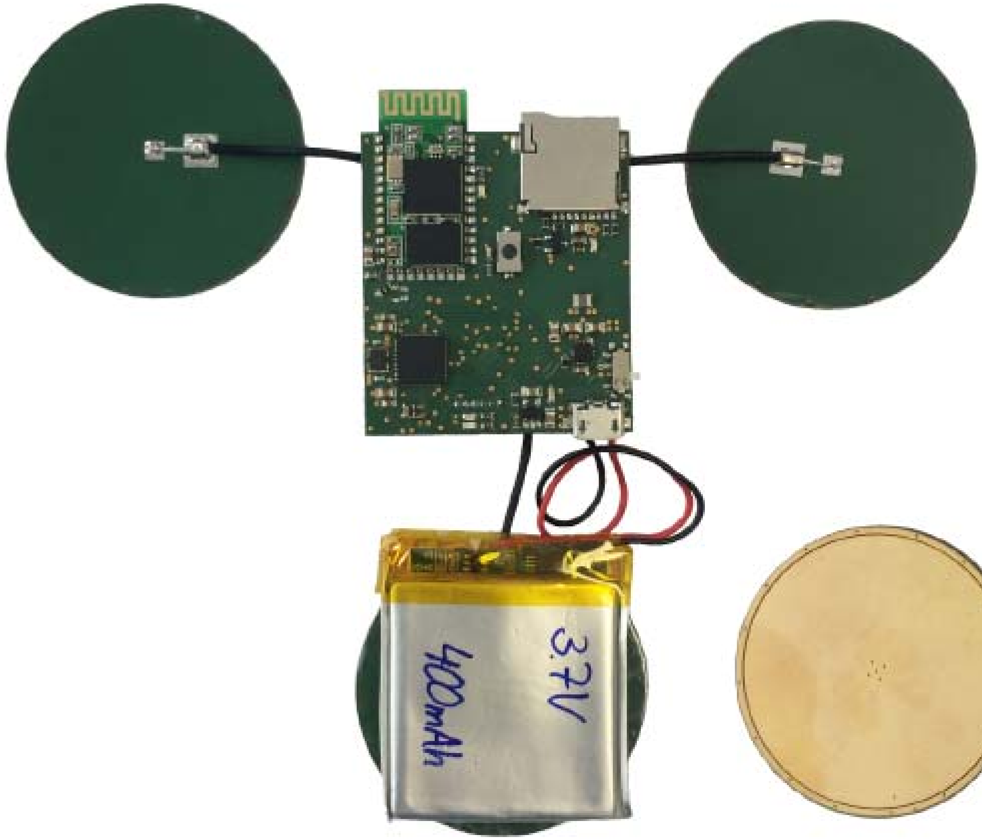
- Flexible PCB arrangement
- Carefull shielding
- Shielded electrodes
- Baseline Drift compensation
- Wireless Bluetooth interface



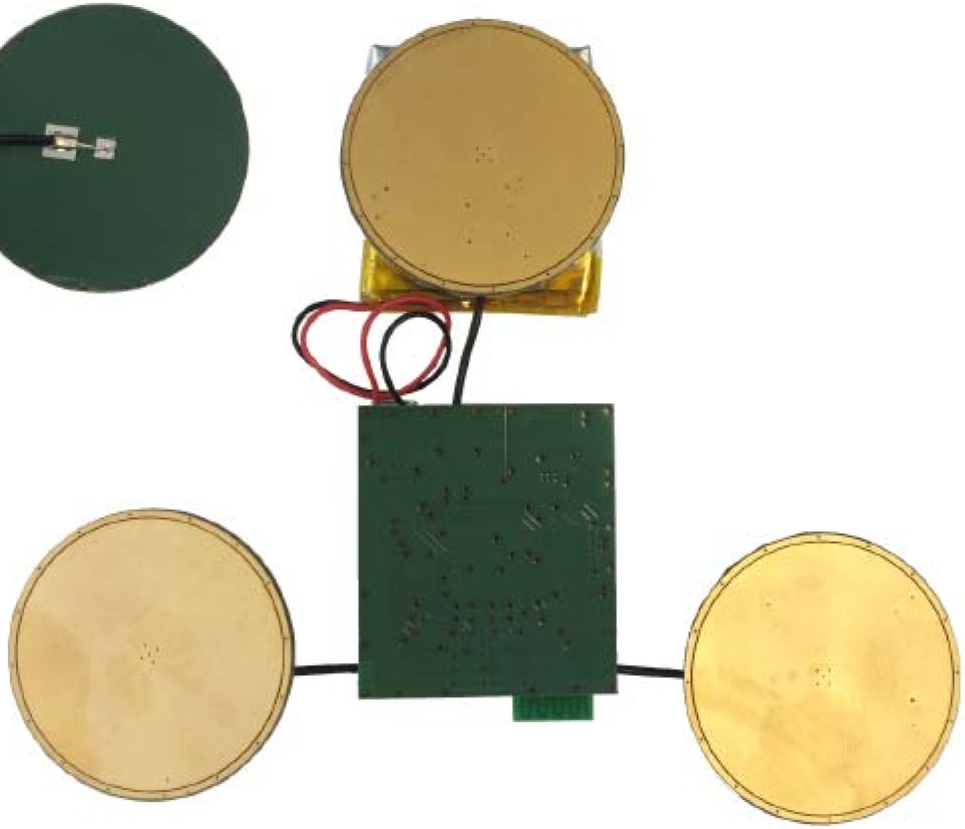
Source: Nils Roth

Biosignal acquisition
cECG refined through 2mm

Photo



(a) Top-view



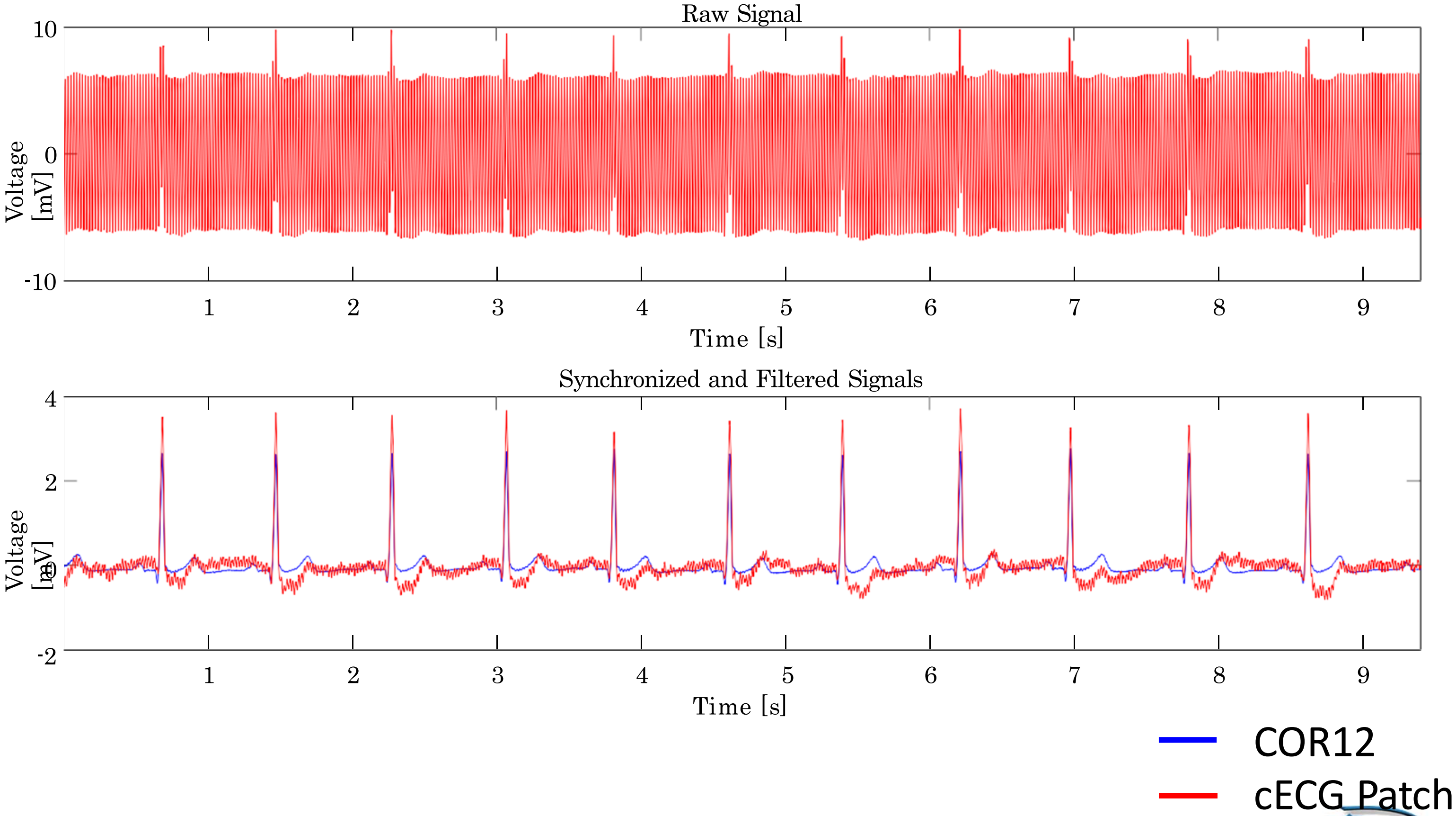
(b) Bottom-view (rotated)

Source: Nils Roth

Biosignal acquisition
cECG refined through 2mm

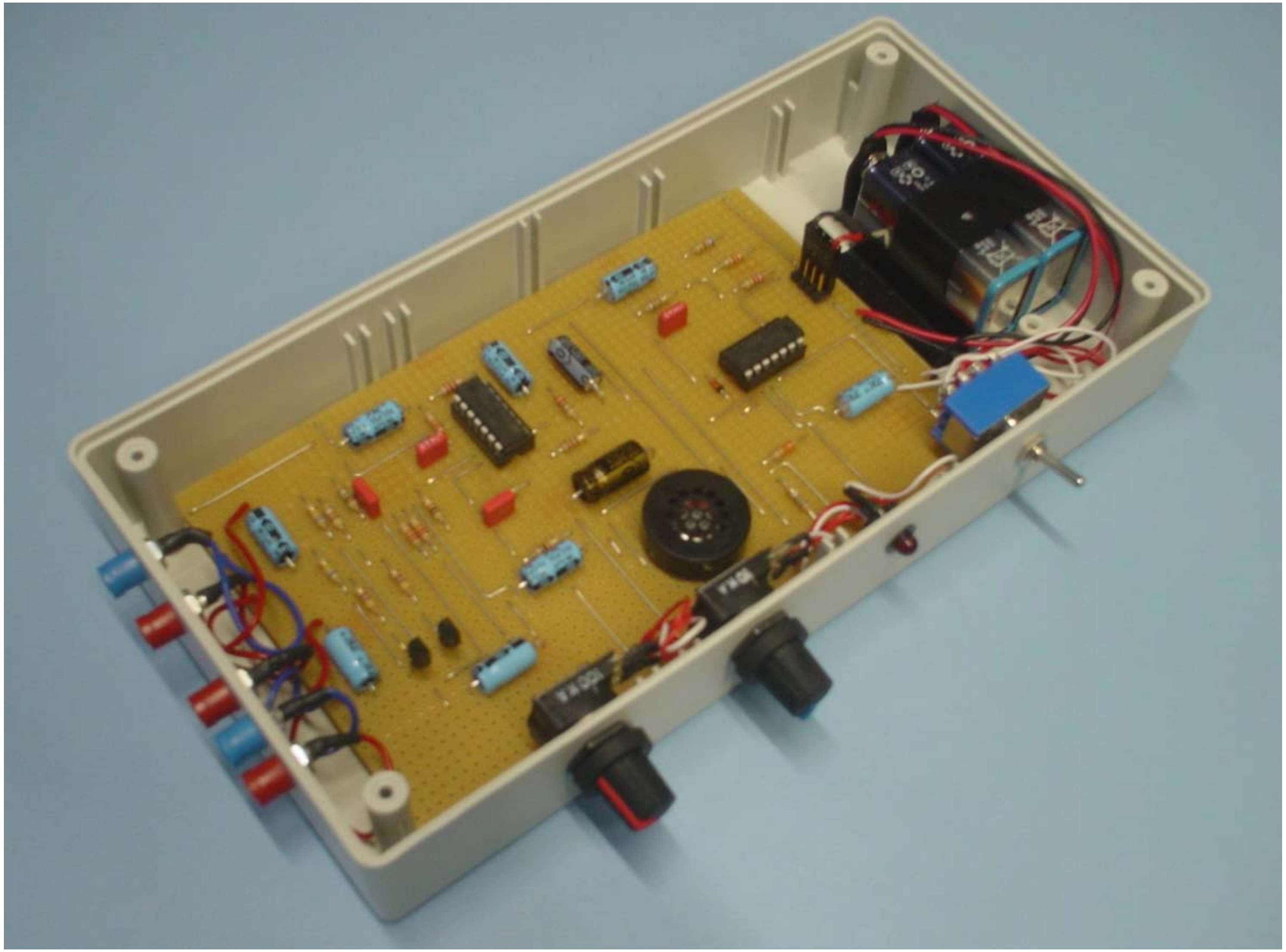
Advanced Circuit Technology

- ECG signal measured through three layers of clothes (~2100µm)
- High common-mode noise due to asymmetric contact capacities
- After digital filtering still usable signal



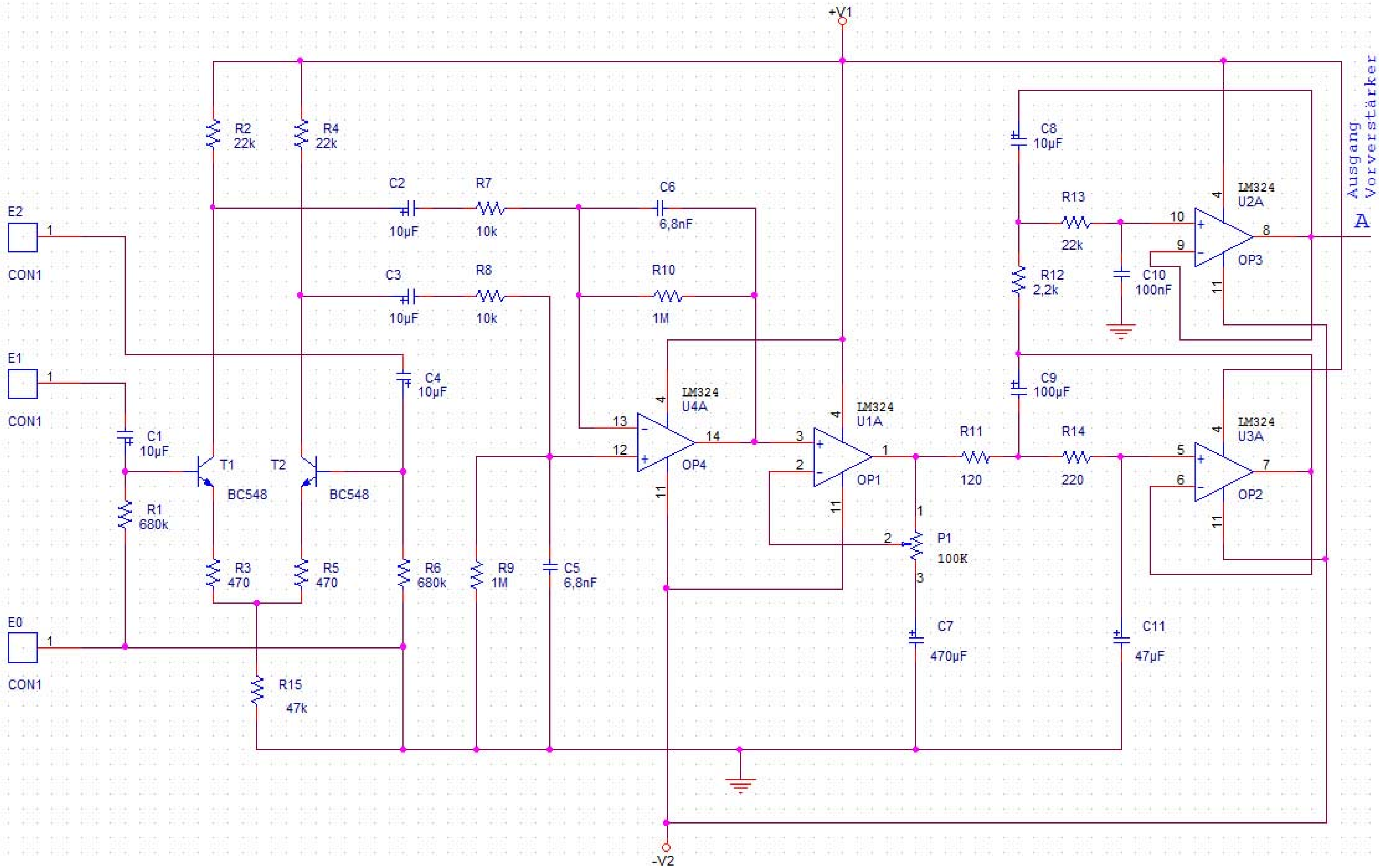
Source: Nils Roth

Biosignal acquisition
4.12 EMG



Source: Christian Schuster

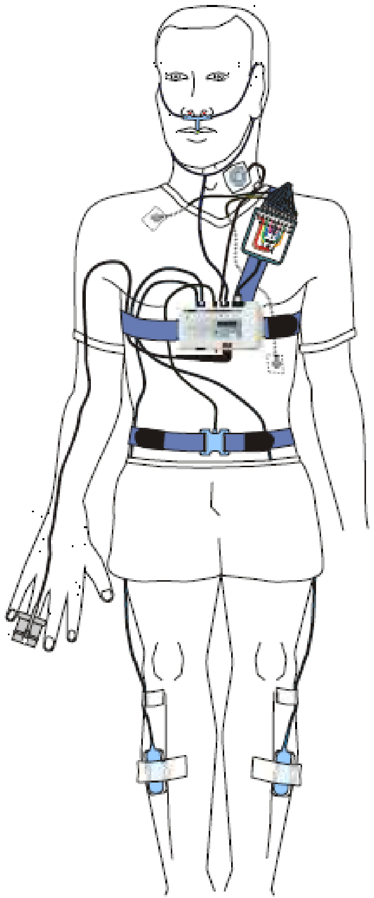
Biosignal acquisition
4.12 EMG

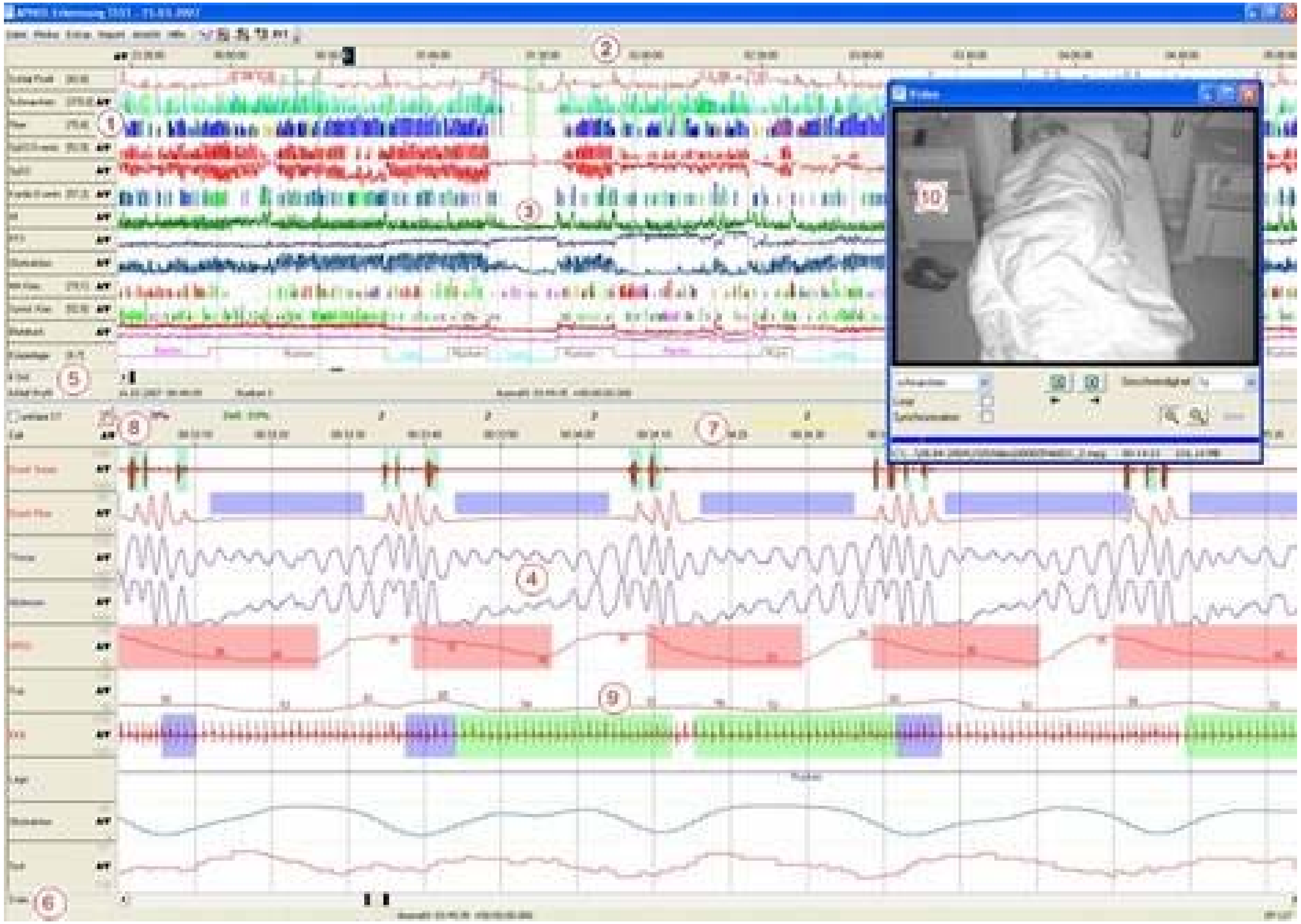


Source: Christian Schuster

Biosignal acquisition

EOG – Sleep lab, Analysis software

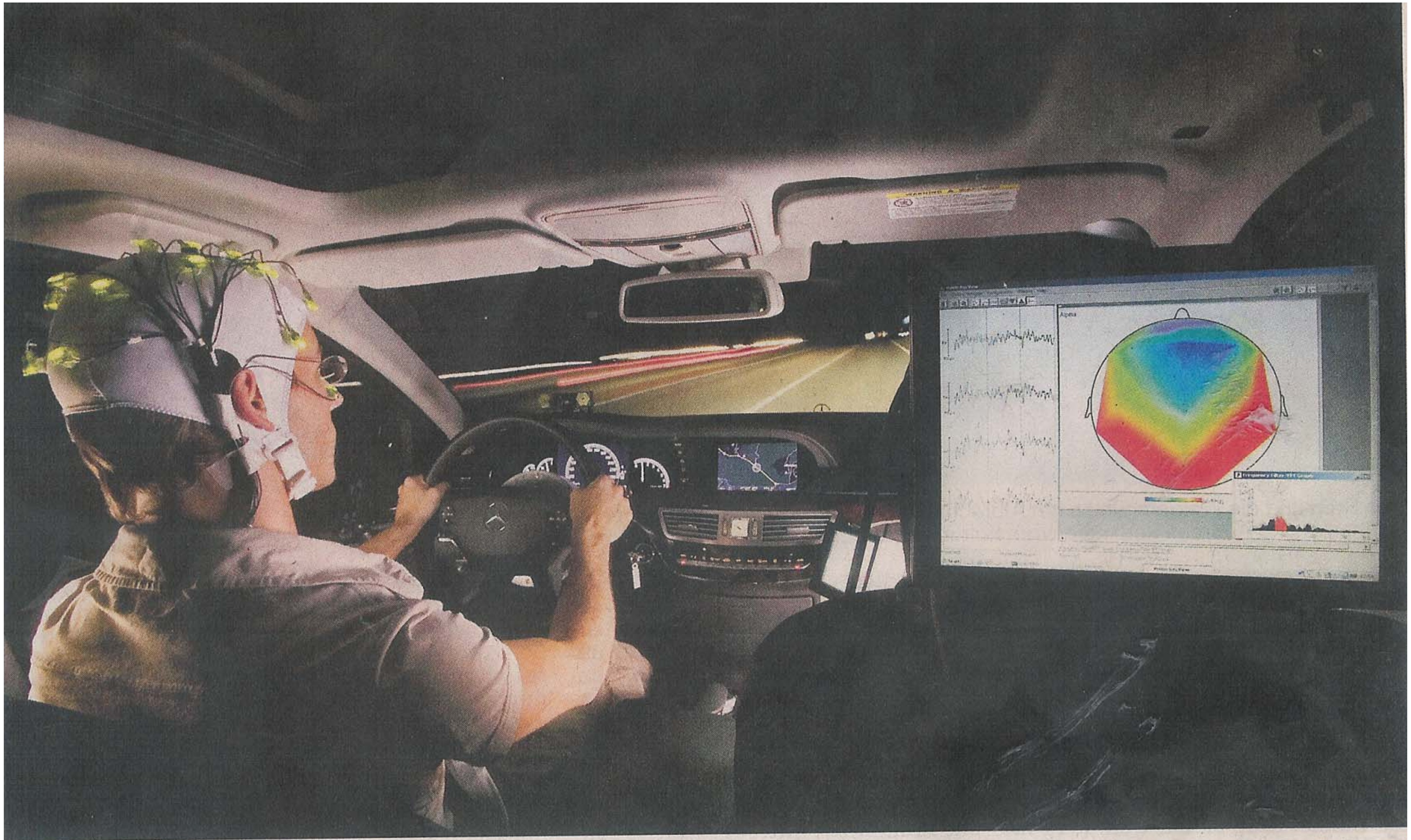




Source: Somnomedics

Biosignal acquisition
Working in automotive industry?

EEG for car safety



Der Fahrer ist verkabelt: Mercedes testet hier ein neues Assistenzsystem, das müde Autofahrer vor dem gefährlichen Sekundenschlaf warnen soll.
Foto: Daimler/dpa/tmn

5. Health Assistance Systems

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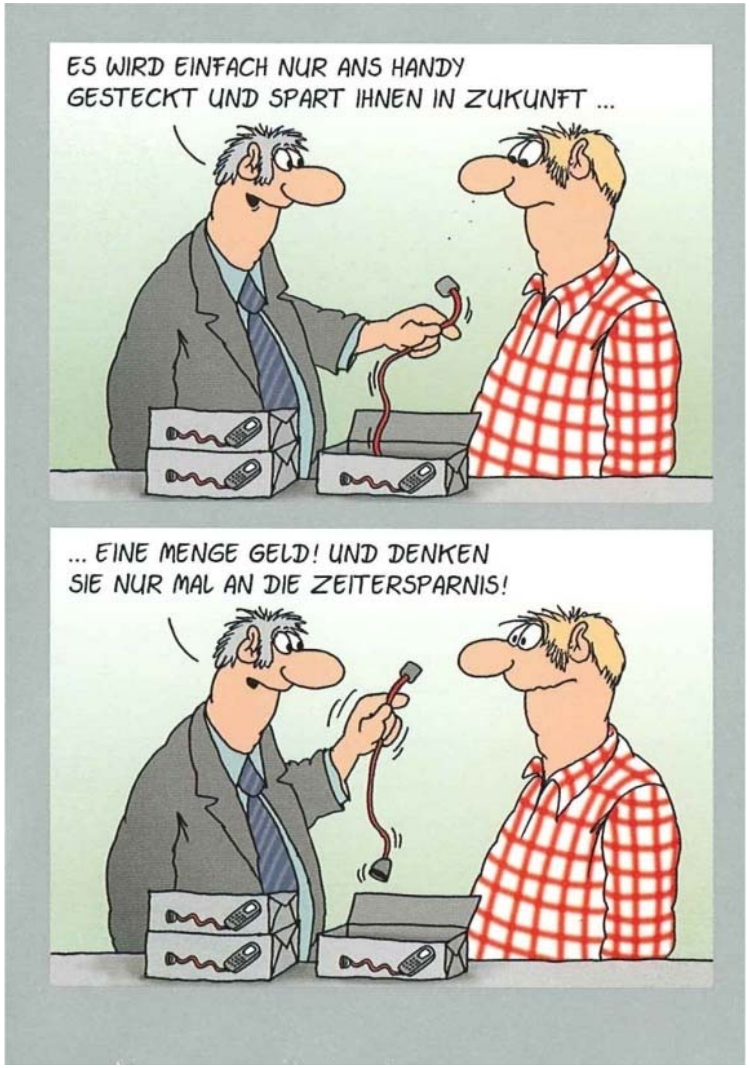
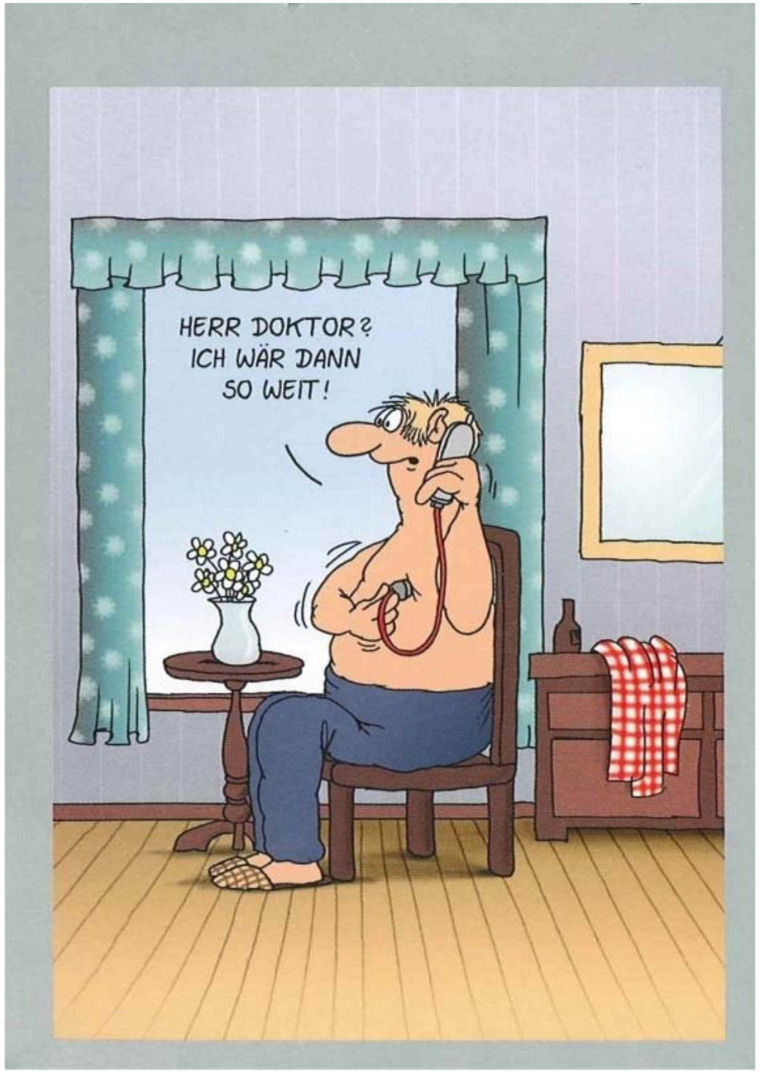
Health Assistance Systems

Examples – The future?

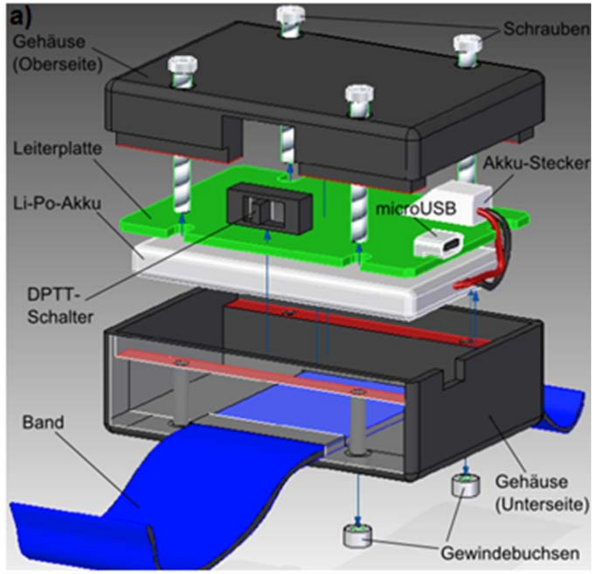


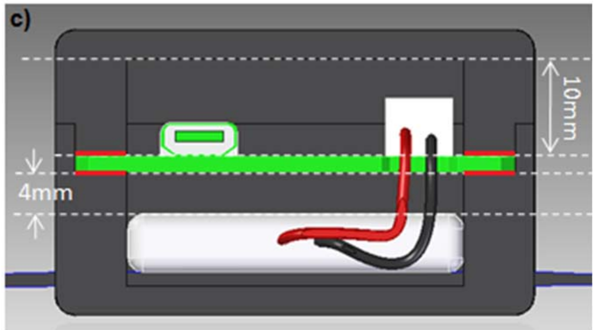


Source: Uli Stein

Health Assistance Systems

1.5 Examples – Activity Monitoring





Activity Sensor, Analysis of movements with Sports, Reha, COPD…

eesy-id

Source: eesy-id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THE RADIO DOCTOR—Maybe!
See Page 1406
IN THIS ISSUE:
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Dr. J. A. Fleming, F.R.S.
F. W. Dunmore and
F. H. Engel of
Bureau of Standards
Howard S. Pyle
Brainard Foote
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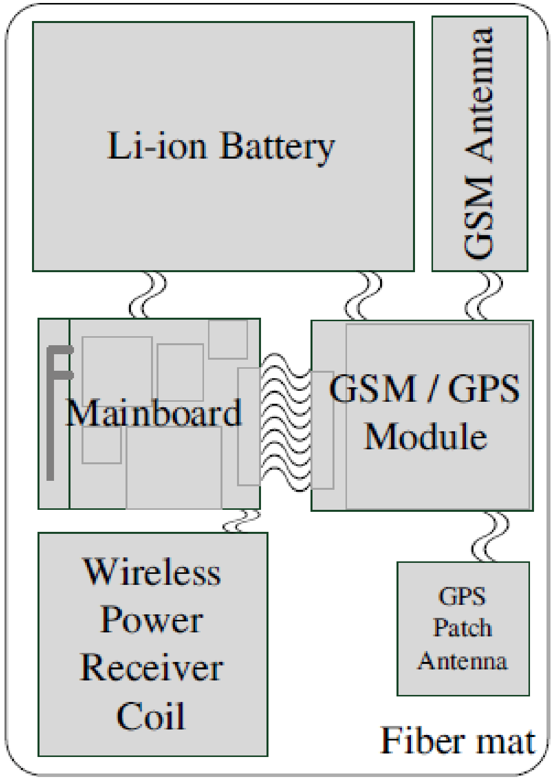
Since 1924?



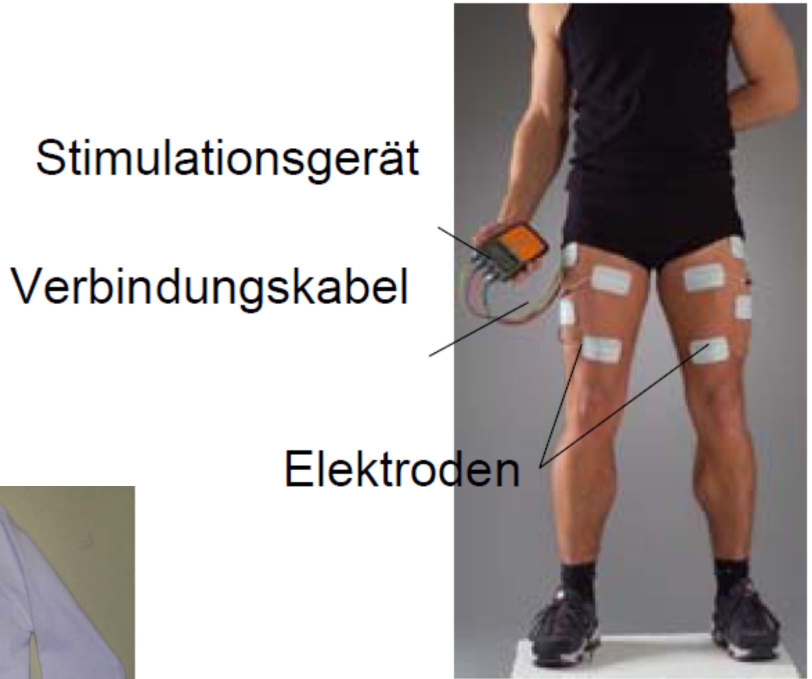
Features

- Flexible PCB, flat 8.5mm->5mm
- Highly precise analogue interfaces (Paracelsus)
- Java App interface, quick addition of more functions
- Extendable for more sensors
- Hermetically sealed, disinfection possible
- Wireless charging
- Wearing control
- Seamless localization indoor/outdoor

Health Assistance Systems
Examples – Smart Textiles

Source: EKG und EEG Elektroden TITV Greiz

Baby shirt for respiration and Heart beat detection, U Gent, KU Leuven



Cefar-Compex Scandinavia AB

Diagnostic: EMG Elektromyograghy
Therapy: FES functional electrical stimulation

STARRINGER
leder von sinnen

Anton Kathrein:
„Laptop und Lederhosen"

(Laptop and leather trousers)
– a reality

Source: Starringer,

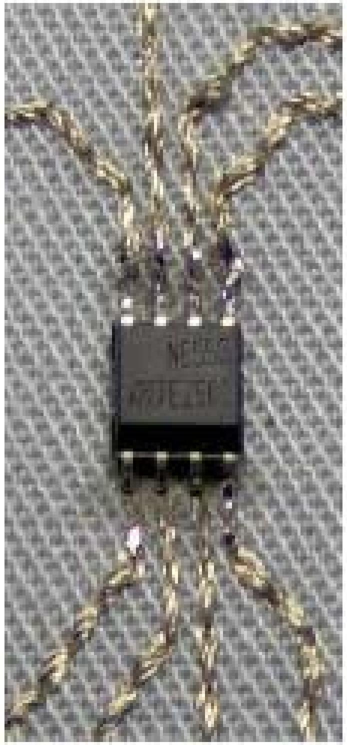
Consumer market

Source: Swany Swany Texsys G-Cell Bluetooth Gloves

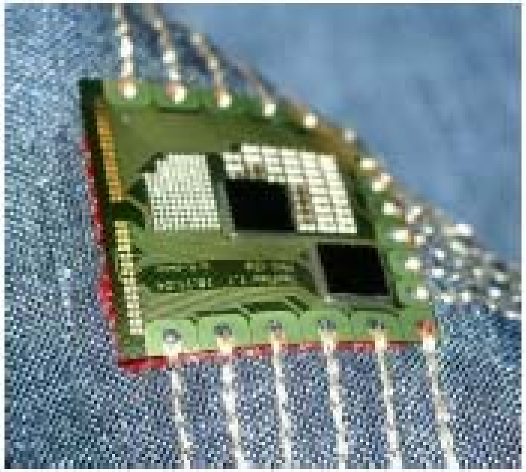
Source: TITV Greiz

Laptop und Lederhosen (Anton Kathrein)

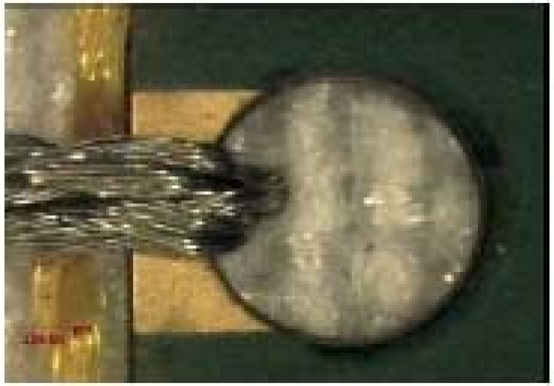
Circuit Technology



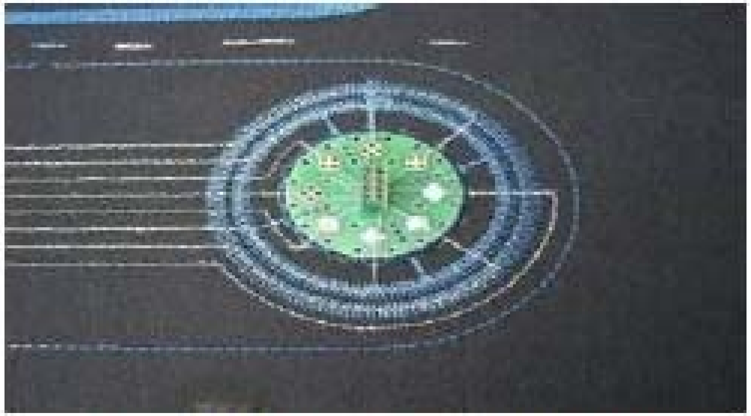
Gestickte Kontaktierung eines THT Bauteils



Gestickte Kontaktierung eines Flexsubstrates auf Gewebe



Gestickte Kontaktierung ohne vorbereites Loch



Gestickte Kontaktierung einer Leiterplatte

Source: TITV Greiz

6. Research: Energy for implants

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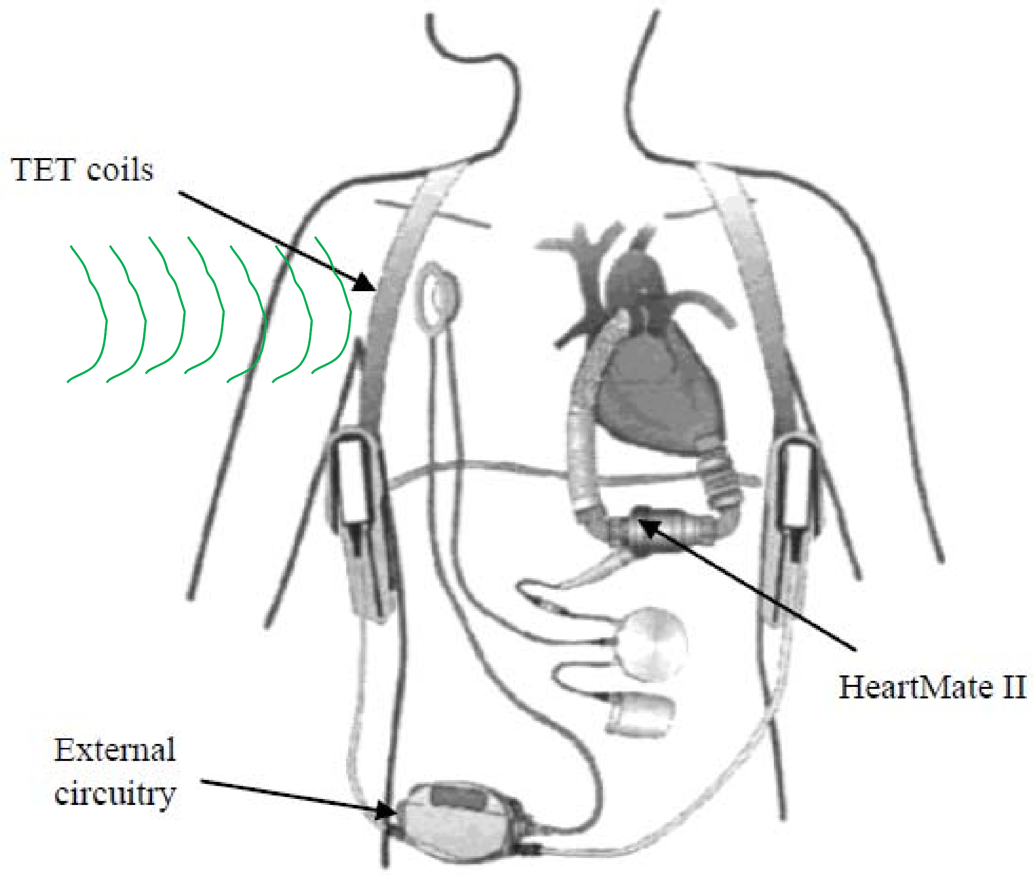
TET Transcutaneous Energy Transfer

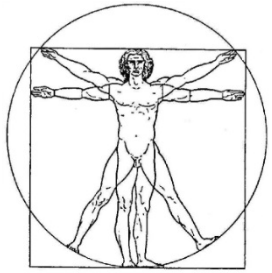
- E.g. Heart assist system

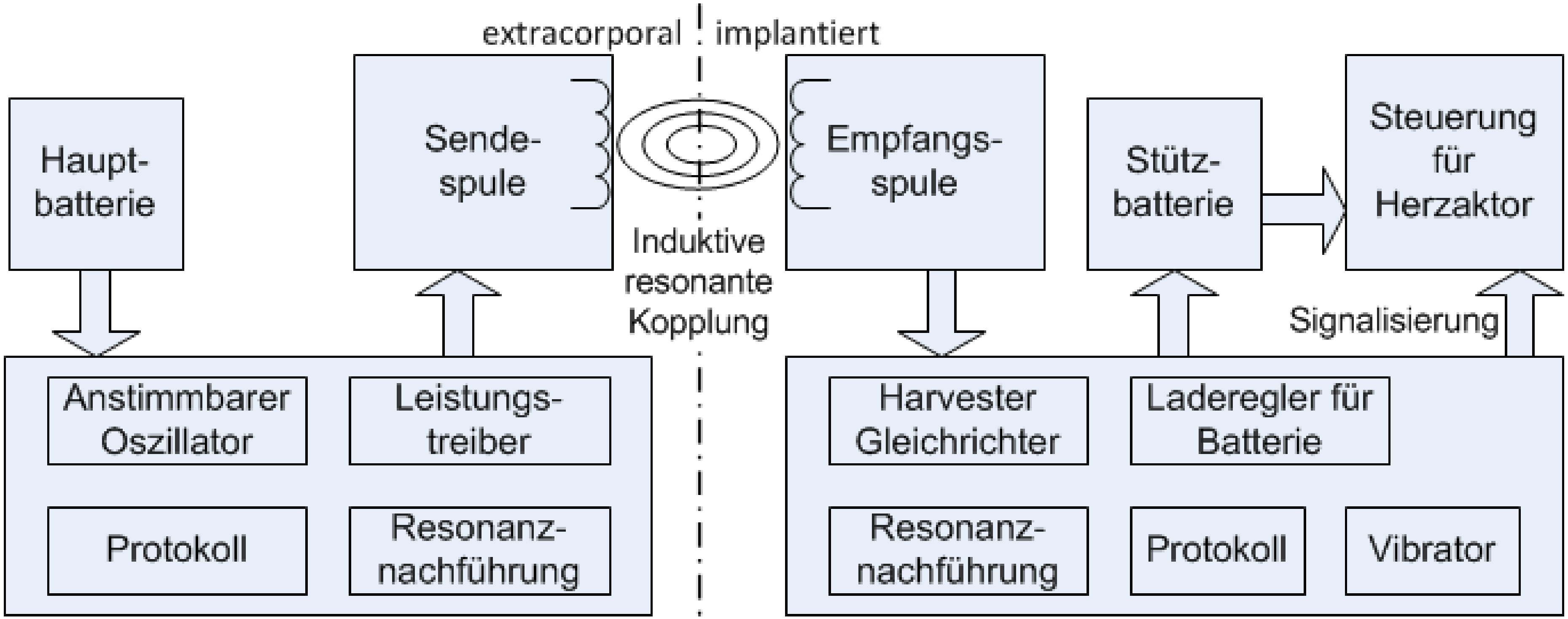


Berlin Heart incor system with transcutaneous cable

DFG Heart Actor project application

- High Power for heart assistance system
- Power of 15…20 W needed



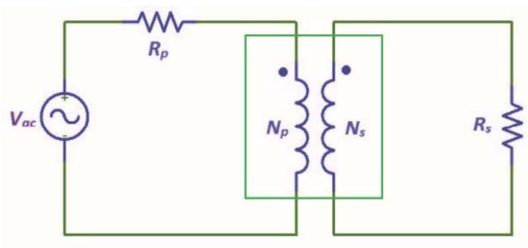


Wireless Research: Energy for implants Transfer

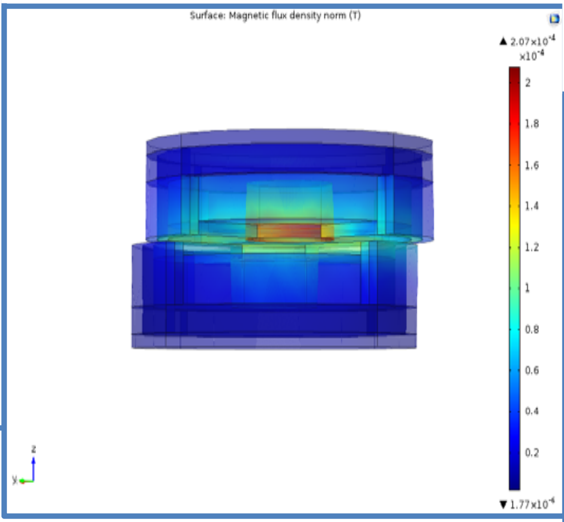
Wireless Power Transfer

Analysis steps supported by COMSOL multiphysics tool

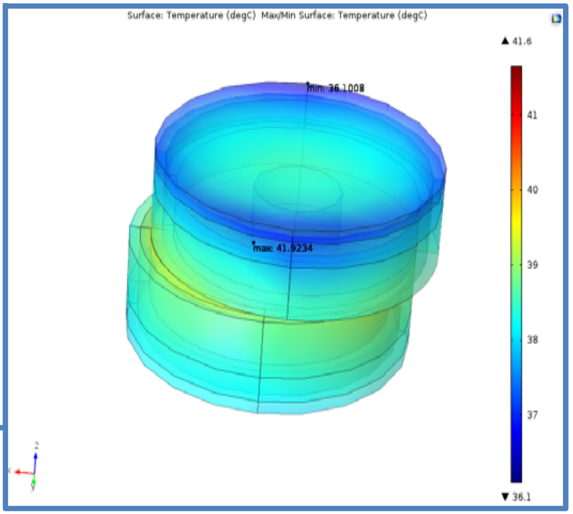
Starting from Electrical circuit (cir)



Traveling to Magnetic fields (mf)



And then to Heat transfer in solids (ht)



COMSOL

Student licenses available at RRZE

7. Research: Bioradar

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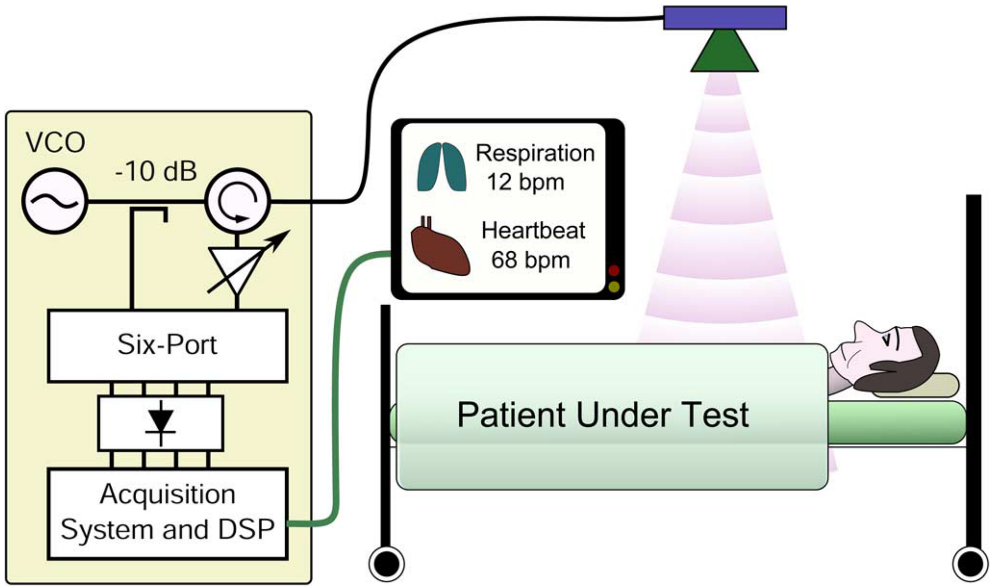
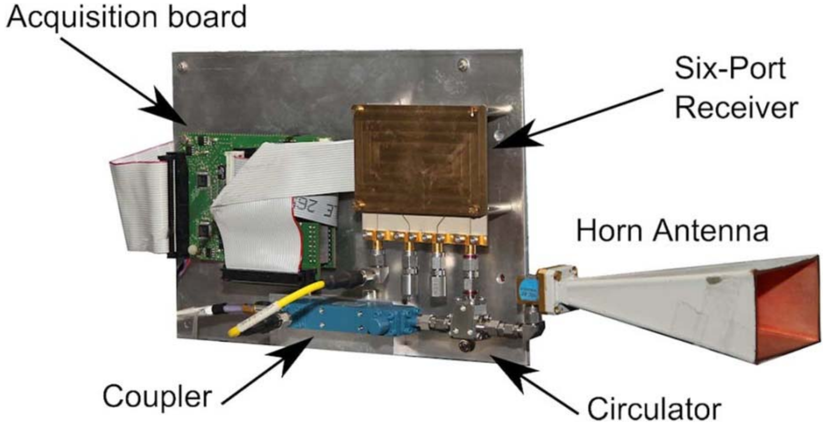
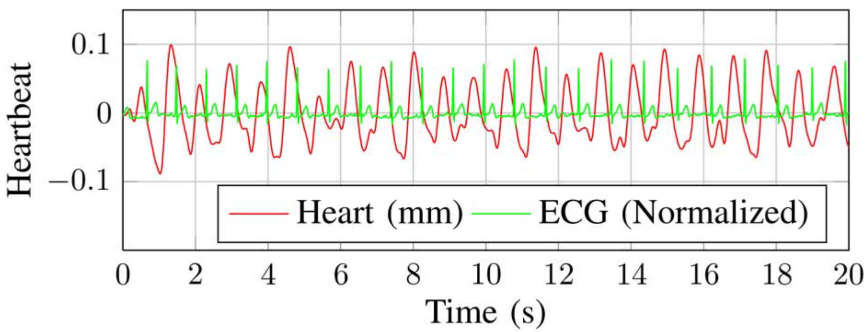
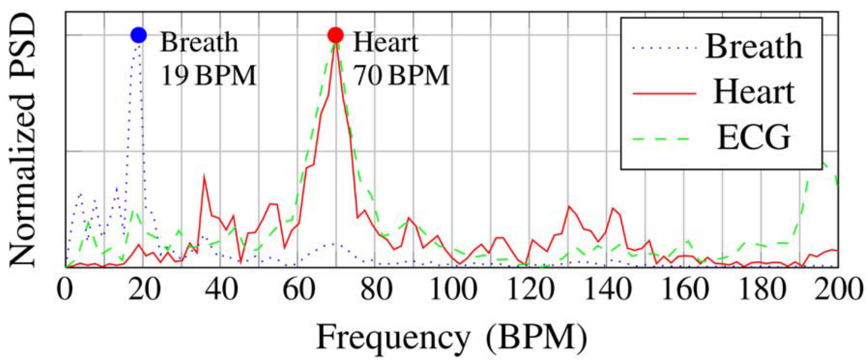
Research: Bioradar
Vital Interferometer





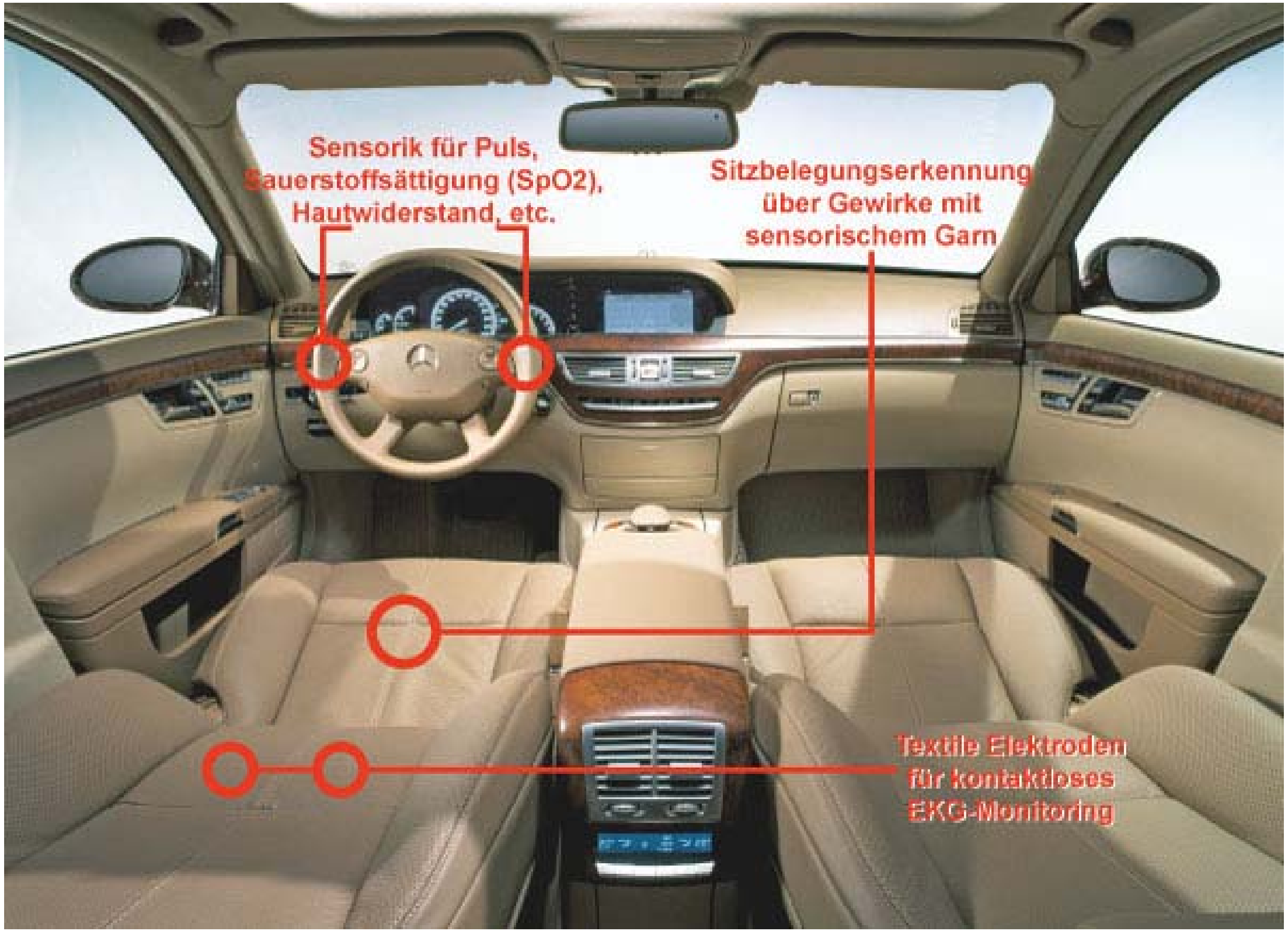




Research: Bioradar
Driver’s seat … driver’s sleep

Drivers physiological state / warnings before microsleep

- Medical electronics engineers working in automotive industry? YES!



Source: INSITEX project

8. Research: Molecular communications

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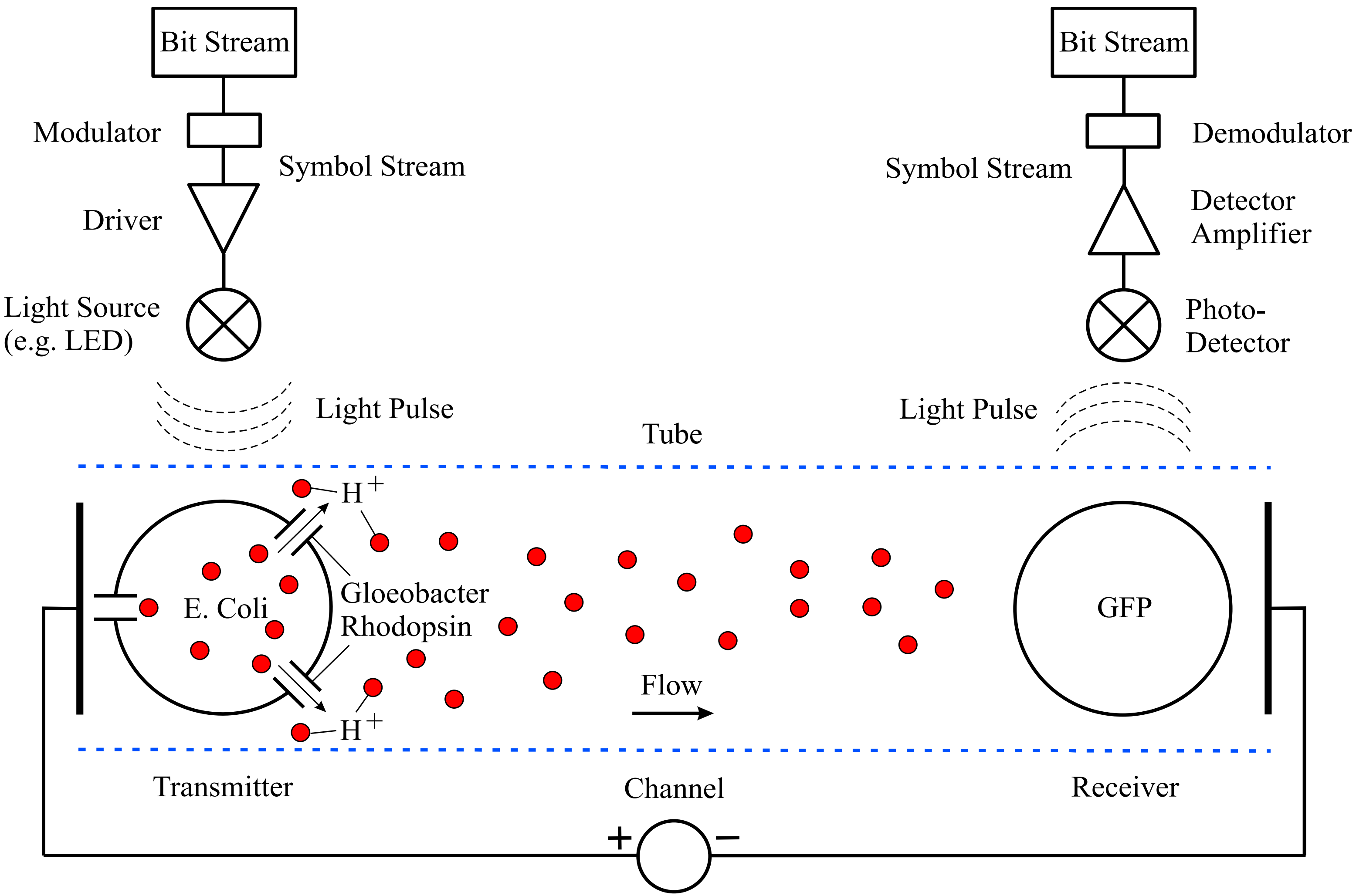
Research: Molecular communications
Testbed realization - protons

Opportunities

- New therapeutic and diagnostic opportunities in Medical Engineering



Research: Molecular communications
Testbed realization - protons

Testbed

- Protons used as information molecules

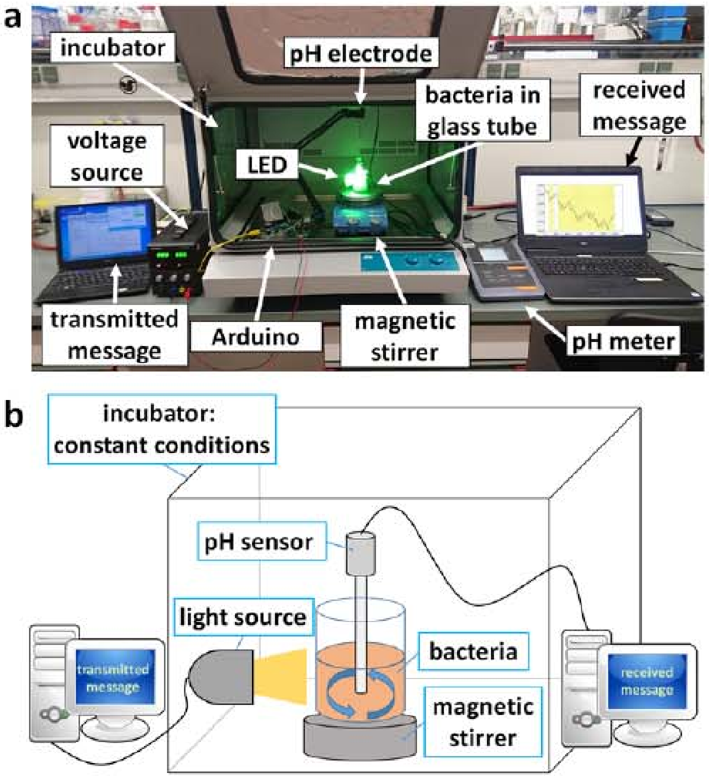


Figure 1: Biological modulator model. (a) Benchtop experimental setup; (b) Schematic illustration.

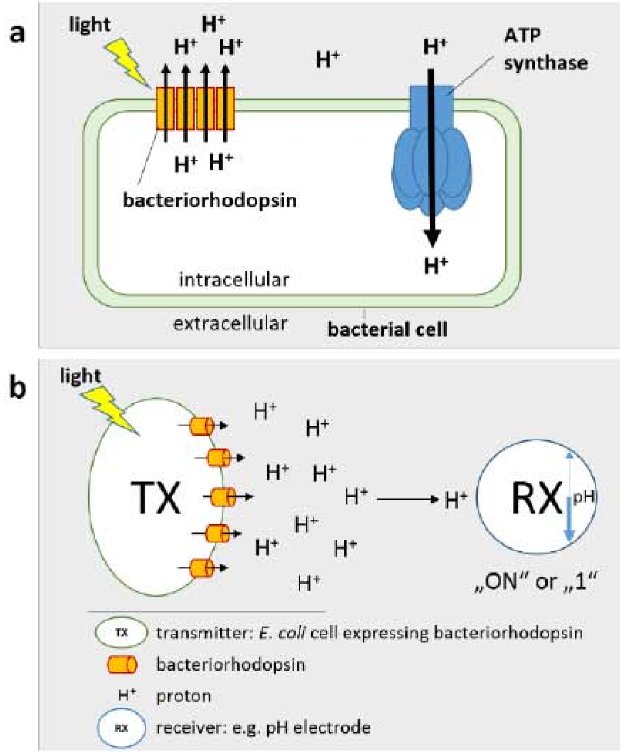


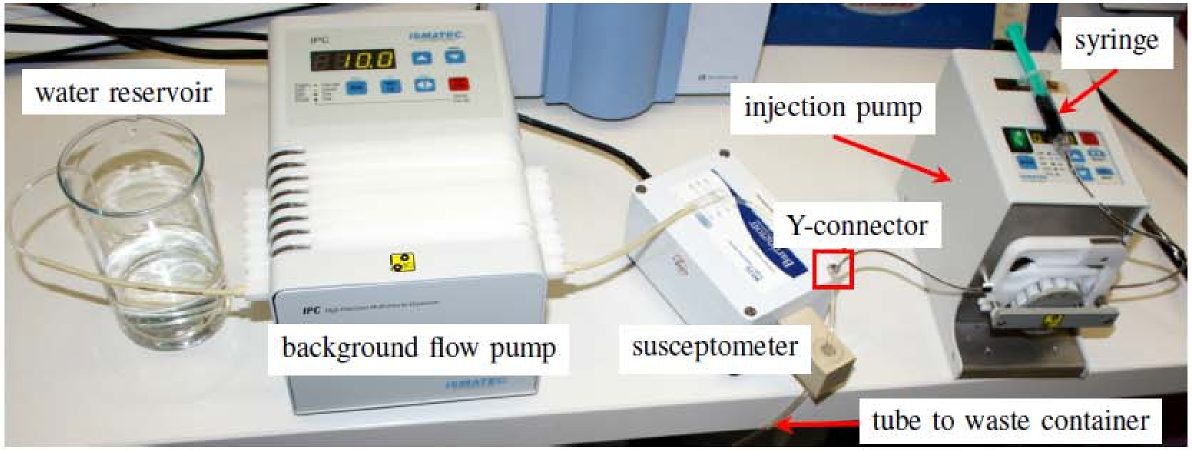
Figure 2: The light-driven proton pump bacteriorhodopsin. (a) Biological function of bacteriorhodopsin in a native cell; (b) Schematic transmission model.

Research: Molecular communications

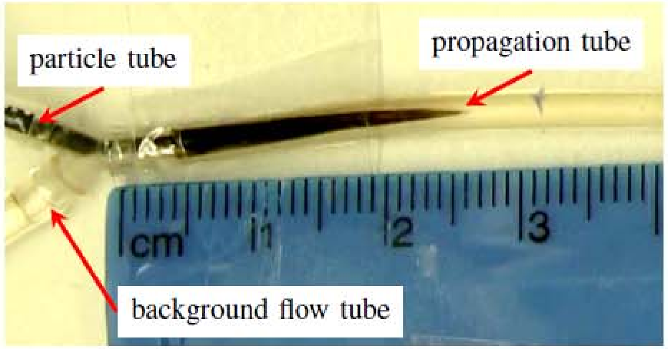
Testbed realization – magnetic nano particles

Testbed

- Superparamagnetic particles used as information molecules



(a)



(b)

Fig. 1. (a) Photograph of the testbed showing the water reservoir, the background flow pump, the susceptometer, the pump used for injection, the syringe holding the suspension of SPIONs, and flexible plastic tubes connecting the components. The waste container below the table is not shown. (b) Photograph of the Y-connector with elongated particle suspension right after injection for a slow background flow of $Q_b = 1\,\mathrm{mL/min}$. Ruler with cm scale for reference.

9. Research: Glucose Sensing

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Research: Glucose Sensing
Diabetes – Test strips

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Sensor today
- Invasive method
- Prick into finger, Lancette creates pain

Measurement principle
- A small amount of blood is taken from finger
- Drop it onto test strip
- Enzymatic reaction
- Put test strip into reader
- Electrical resistance changes with glucose level
- Make a DC measurement
- Calibration data stored on test strip

Error sources
- Non washed hands
- Wet fingers
- Too less blood on strip
- Wrong storage of test strips
- Touching of test strip
- Exchange of calibration data between strip and device erroneous
- Temperature variations

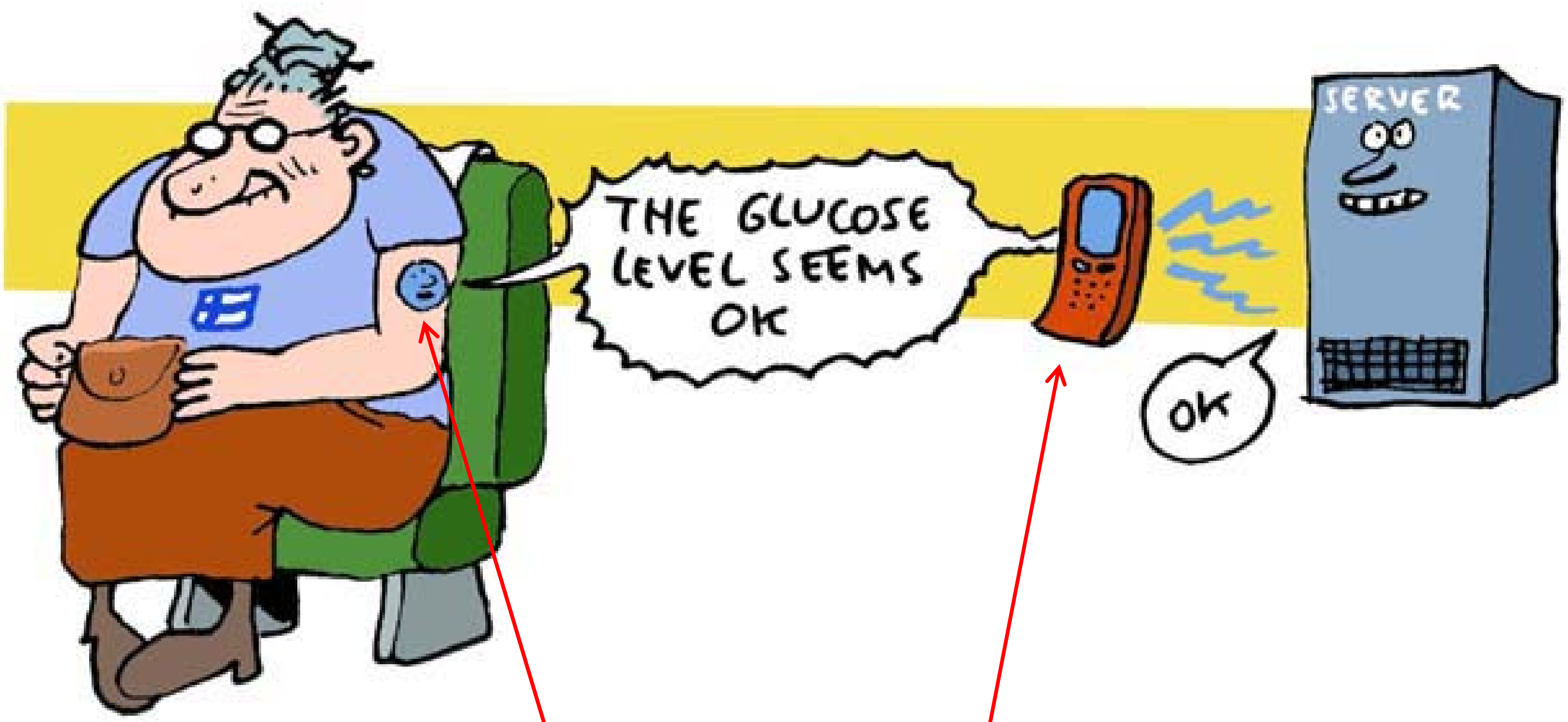
Preparation of skin

Lancet aid

Test Stripes

Source: Accu Chek, Roche

Research: Glucose Sensing
Diabetes – Microsystem RFID sensor?



RFID

Mobile Phone

Source: EU FP7 Mimosa, Deliverable report – WP1 / D1.5

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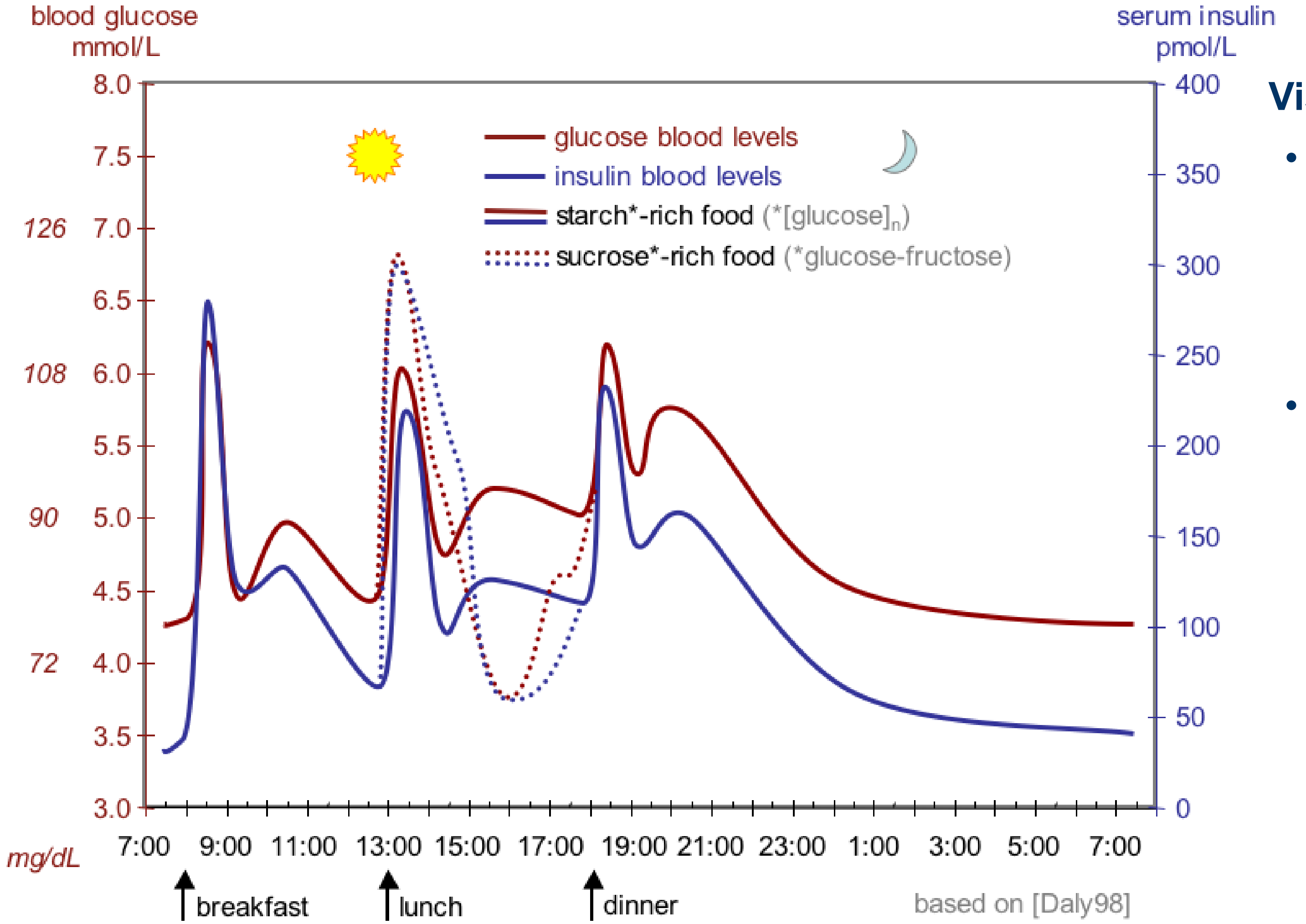
Fluctuation over the day



Vision

- It would be desirable to measure the glucose level 24/7
- See later Chapter Microwave metabolism sensors

Source: Jakob Suckale, Michele Solimena

Research: Glucose Sensing
Non-Invasive glucose monitoring

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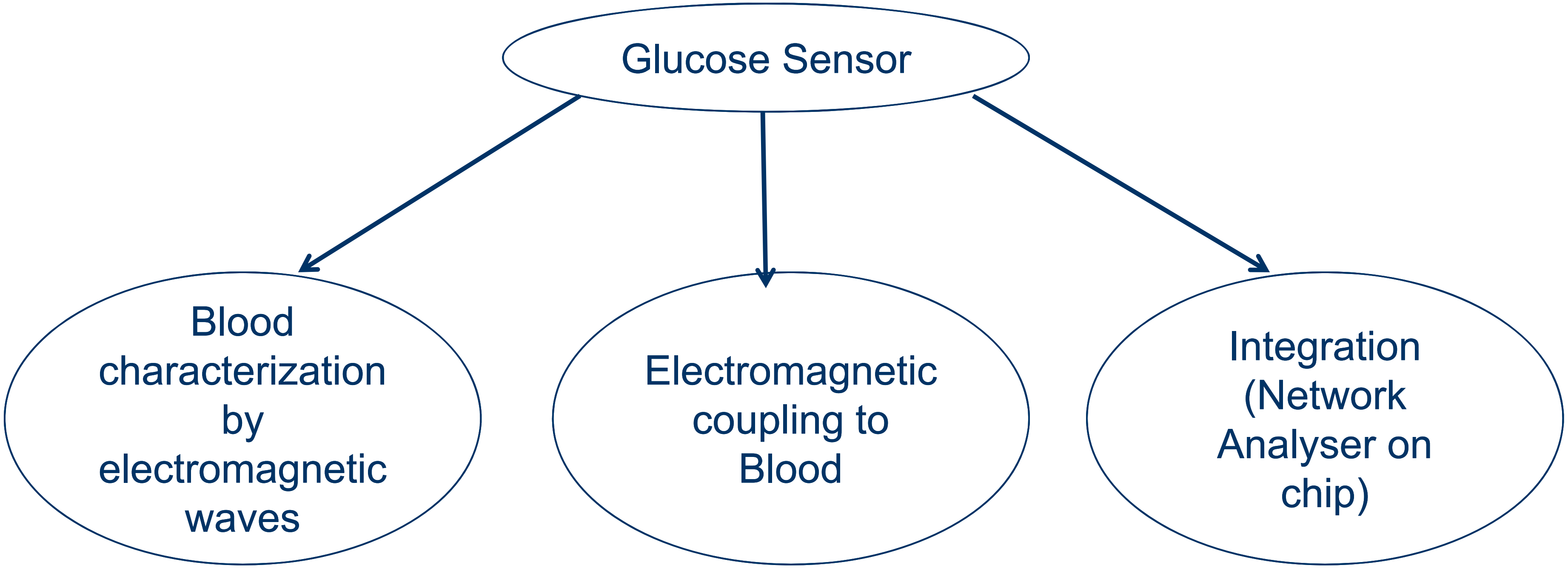
Breaking the problem down



- Blood Dielectric properties
- Frequency dependence
- Temperature dependence
- Side effects
- Blood is a complex matter

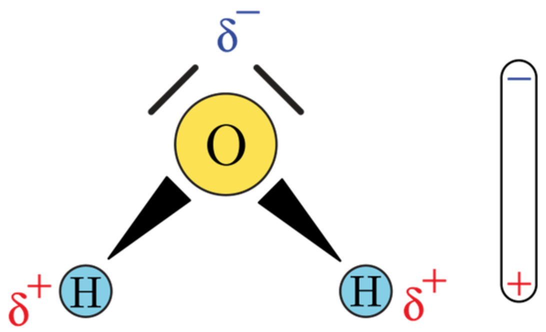
- We only want to see blood, not a mixture of fat and bones
- What is the best location?
- Electromagnetic field propagation mainly into blood

- Microelectronics allow for high density integration
- High frequencies can be managed at low cost (see Car Radar)

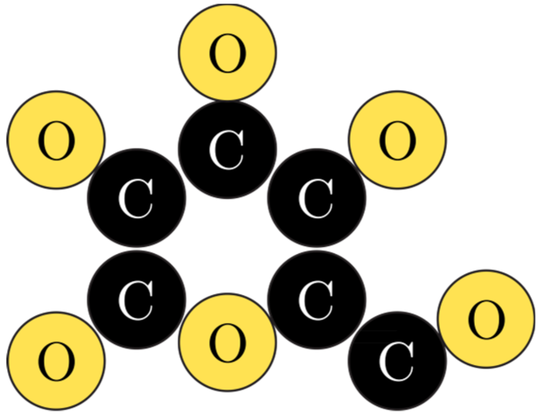
Research: Glucose Sensing
Non-Invasive glucose monitoring

Molecule dipole moment

Water



D-Glucose



Frequency range considerations

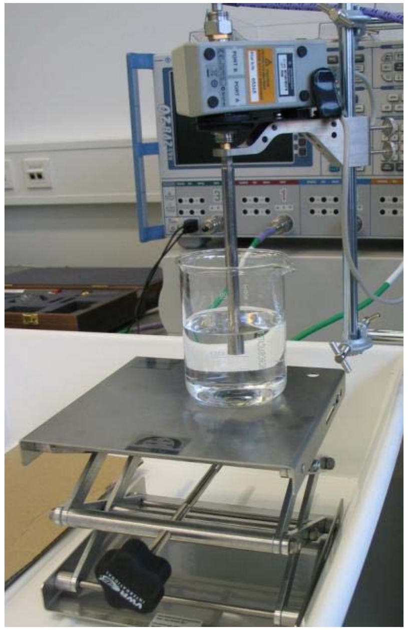
- Water molecules strongly polar -> high permittivity
- D-Glucose molecules less polar und larger -> low permittivity
- Total permittivity of a solution decreasing for increasing glucose concentration

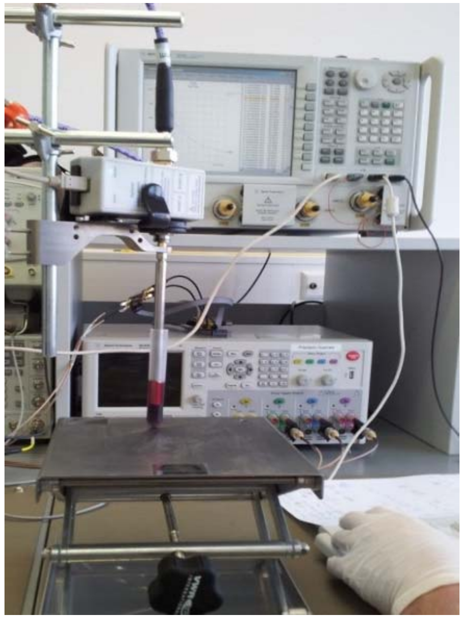
Measurement approach

- Not look for the molecule signature itself
- Look how the water signature of human body is altered
- Look at multiple water signatures at different frequencies -> broadband view

Research: Glucose Sensing
Non-Invasive glucose monitoring

Lab experiments





Problems

- An Electronics Lab is not suited for Medical Matter: Blood, Urine, Stool, Meat, ...
- Set-up of RF lab with its measurement equipment extremely costly (60 GHz Lab)
- High Risk, as measurement equipment is exposed to Liquids!

Research: Glucose Sensing
Non-Invasive glucose monitoring

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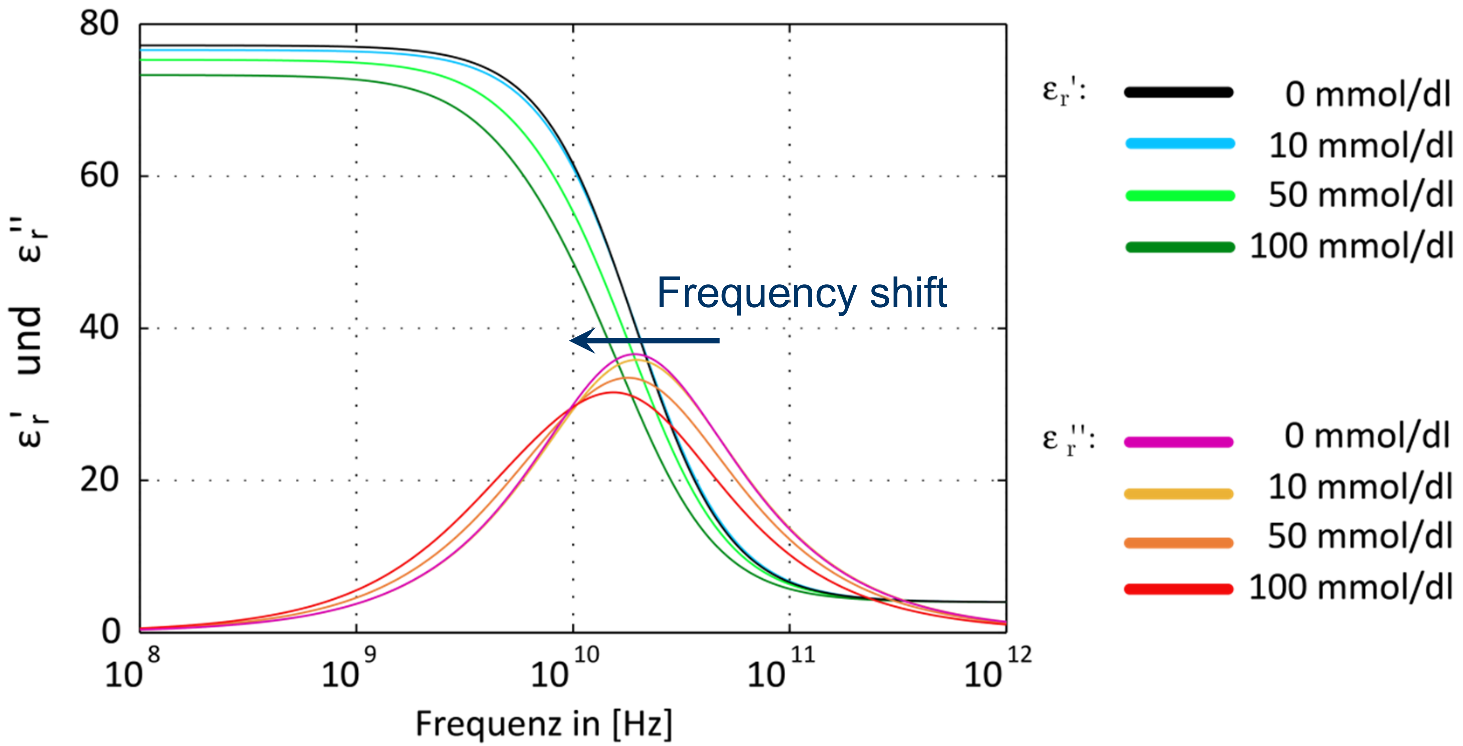
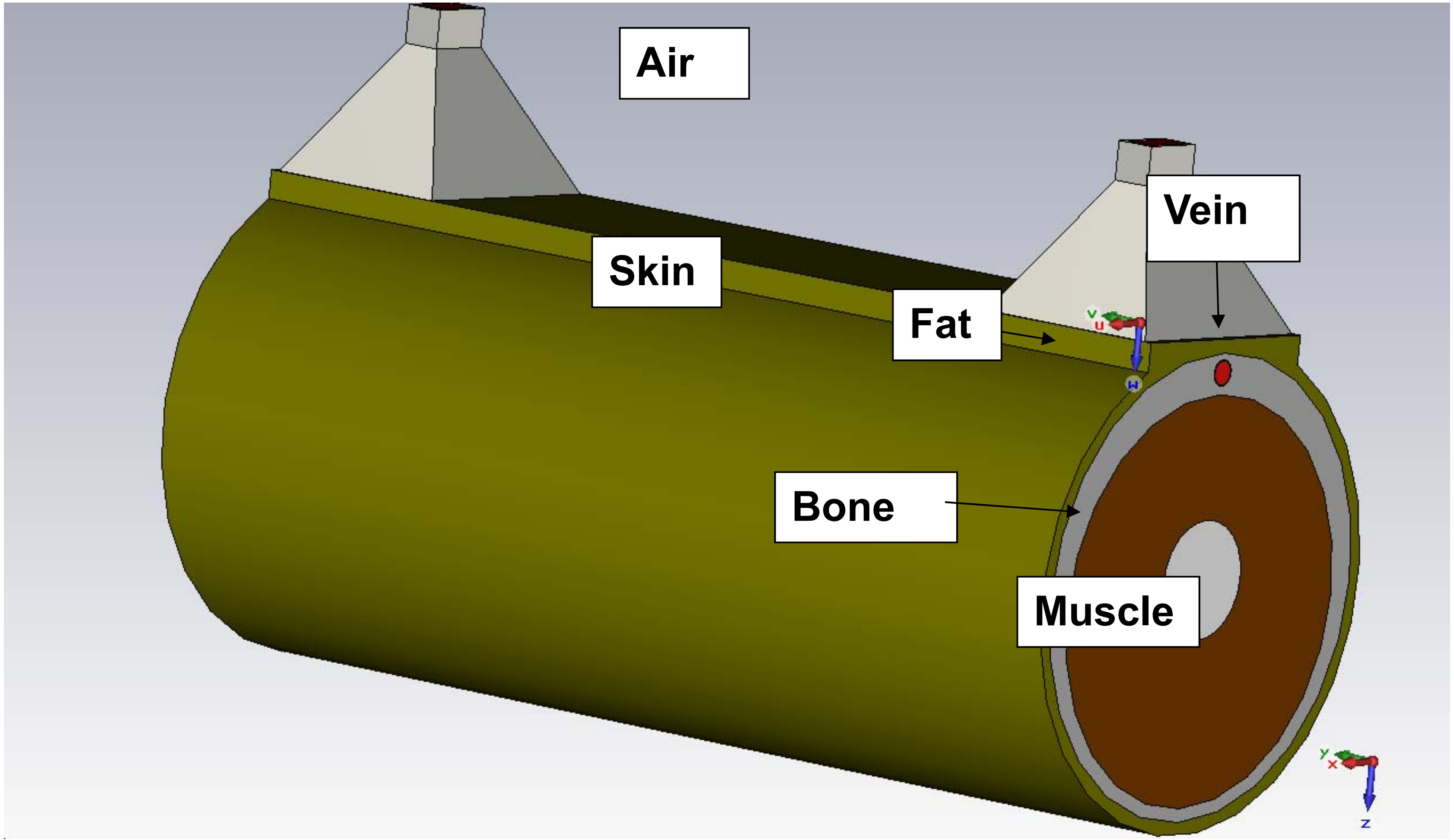
Frequency shift of relaxation due to glucose variation



- High difference of relative permittivity required
- Strongest changes around 20 GHz

Research: Glucose Sensing
Non-Invasive glucose monitoring

Vein guiding EM waves



$$\varepsilon_{Blood} > \varepsilon_{Muscle} > \varepsilon_{SkinWet} > \varepsilon_{Vein} > \varepsilon_{Bone} > \varepsilon_{Fat}$$

Research: Glucose Sensing
Non-Invasive glucose monitoring

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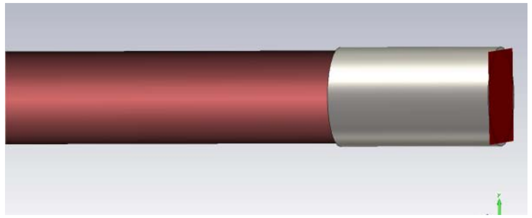
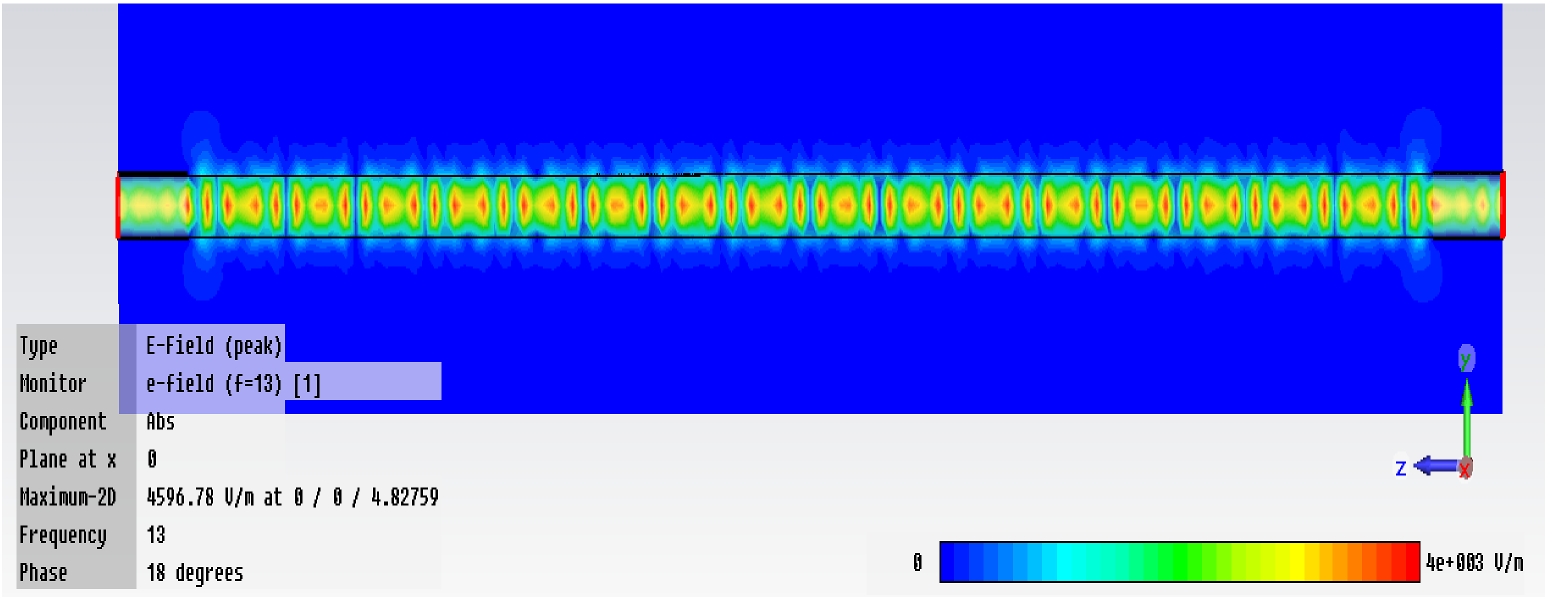
Characterizing only blood

- Guide the EM wave through veins
- Verified by electromagnetic field simulation



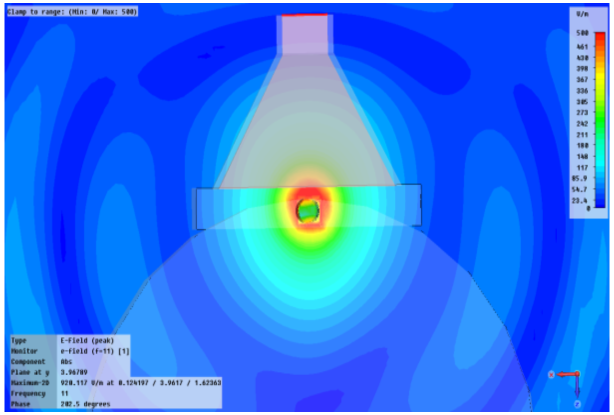


The vein can guide electromagnetic waves similar to gals fibres!

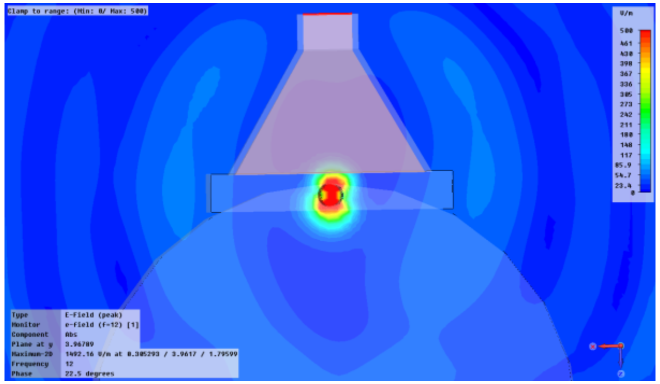
Research: Glucose Sensing
Non-Invasive glucose monitoring

Field distribution – concentration in vein

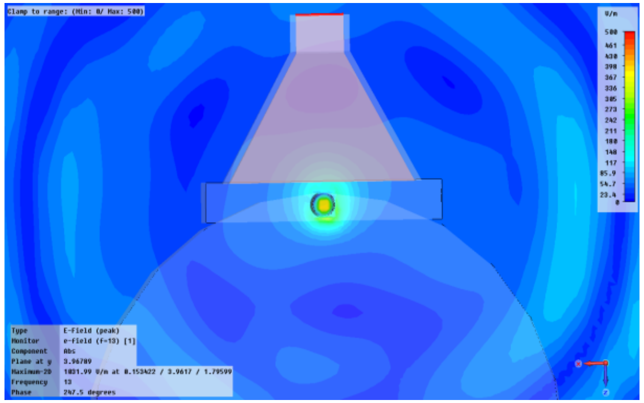
E-Field **H-Field**



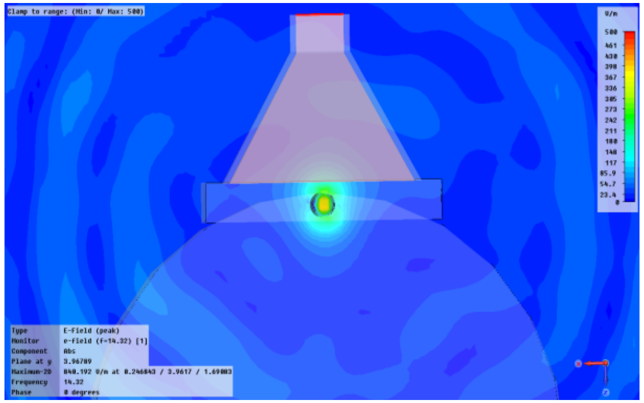
11GHz



12GHz



13 GHz



14 GHz

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Chip integration

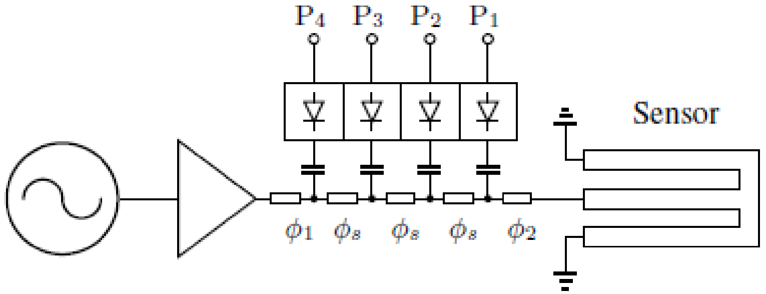


Fig. 2. Schematic view of the 125-GHz multiprobe reflectometer and dielectric sensor consisting of a VCO, frequency dividers, buffer, four power

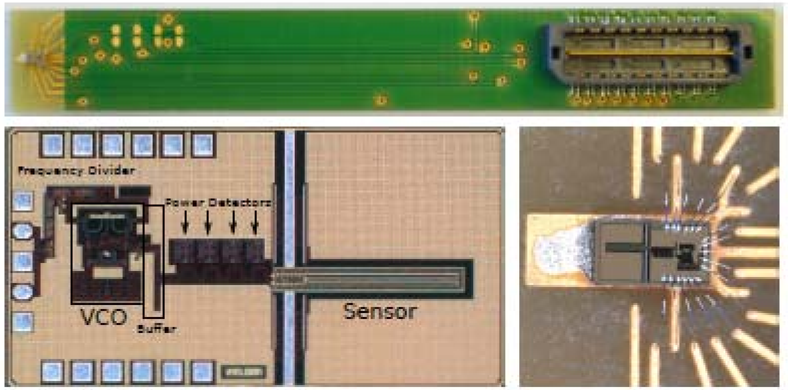


Fig. 4. Chipmicrograph of the 125 GHz fabricated dielectric sensor with read-out circuit (bottom, left), micrograph of the wire-bonded chip (bottom, right), and photo of the sensing board (top).

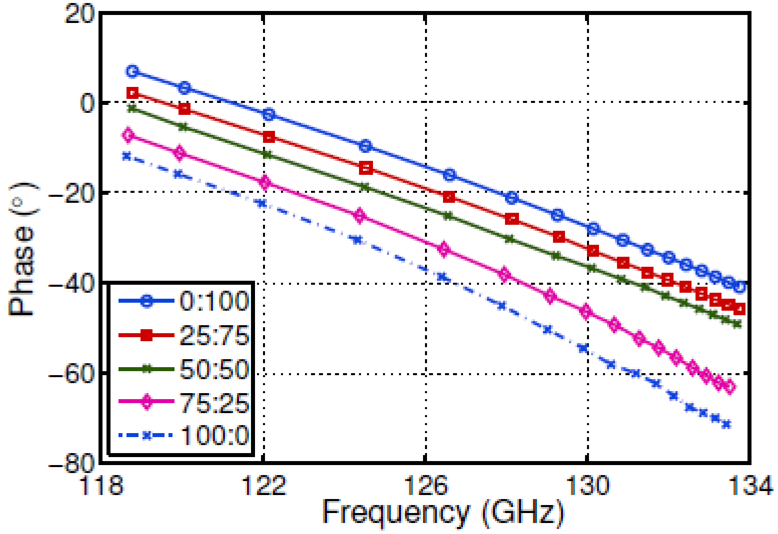
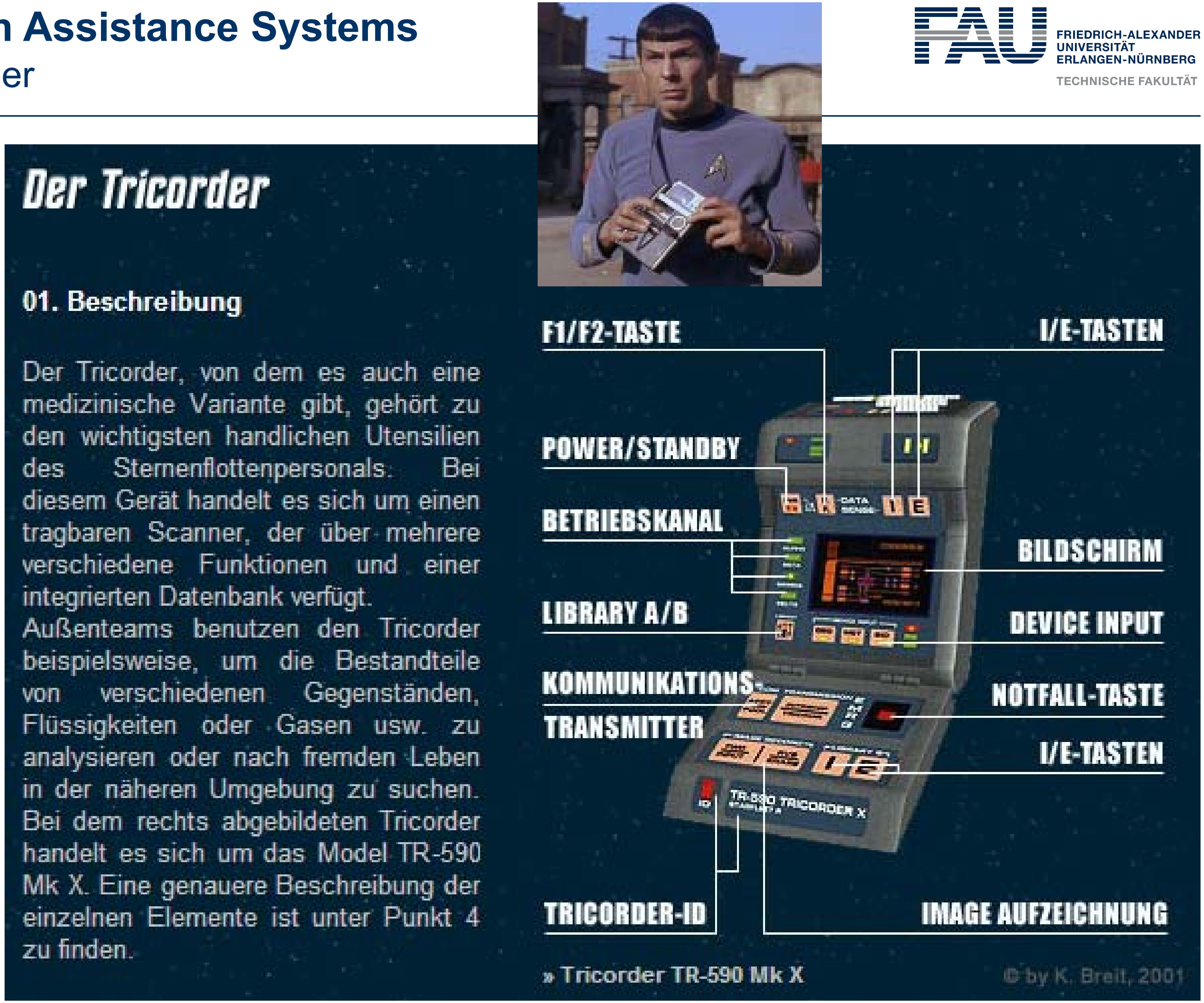


Fig. 5. Measured phase of the sensor's reflection coefficient immersed in binary methanol:ethanol mixture (concentration in percent by volume).

Source:
Benjamin Laemmle, Klaus Schmalz, Christoph Scheytt, Robert Weigel and Dietmar Kissinger,
An Integrated 125GHz Sensor with Read-Out Circuit for Permittivity Measurement of Liquids, Microwave Symposium Digest (MTT), 2012 IEEE MTT-S International

Health Assistance Systems

Tricorder



Der Tricorder

01. Beschreibung

Der Tricorder, von dem es auch eine medizinische Variante gibt, gehört zu den wichtigsten handlichen Utensilien des Sternenflottenpersonals. Bei diesem Gerät handelt es sich um einen tragbaren Scanner, der über mehrere verschiedene Funktionen und einer integrierten Datenbank verfügt.
Außenteams benutzen den Tricorder beispielsweise, um die Bestandteile von verschiedenen Gegenständen, Flüssigkeiten oder Gasen usw. zu analysieren oder nach fremden Leben in der näheren Umgebung zu suchen.
Bei dem rechts abgebildeten Tricorder handelt es sich um das Model TR-590 Mk X. Eine genauere Beschreibung der einzelnen Elemente ist unter Punkt 4 zu finden.

Source: StarTrek