Microprocssor Based Design for Biomedical Applications for BME

(Fourth Year)

2010-2011

Assistant Prof \
Fadhl M. Alakwaa

Course Description

- Introduction to microcontrollers.

Microprocessor registers, memory, and programmable input/output devices. Interrupts. Single chip controllers. Design and testing of software for microcontrollers. Hardware/software design tradeoffs and issues. Individual design projects.

Our goals for this term:

- **Practical usage of Microcontrollers in the Biomedical Context**

- **See examples of ongoing research in BME**

- **Implementation of project ideas**

At the end of this course the students could:

(1) Concepts and usage of microcontrollers ?

(2) Atmel microcontrollers + Tools ?

(3) Breadboard – circuits, Soldering, SMD ?

(4) Analog electronics (OpAmps, Filtering) ?

(5) Sampling and A/D Conversion ?

Query the given skills

(6) Assembly & C-Programming, Keil ?

(7) Event-based firmware programming, interrupts ?

(8) Data Transmission using UART/RS232 ?

(9) Interfacing uC-firmware and PC (host-) software ?

(10) Design of PCBs using a CAD-Tool ?

(11) Usage of the Eagle-CAD Layout Editor ?

Query the given skills

(12) Soldering and building up electronic circuits

(13) Reading datasheets, studying new parts

(14) Understand the PowerPC processor architecture

(15) Be able to program in assembly & C.

(16) Be able to understand how assembly is converted to machine code

Query the given skills

(17) Do basic hardware and software debugging

(18) Be able to work with, program, and design basic embedded systems.

What are your ideas / expectations for this course ?

Books

- The 8051 Microcontroller and Embedded Systems Using Assembly and C-2nd-ed BY Mazidi
- The 8051 Microcontroller 3rd Edition Mackenzie
- Introduction to Microprocessor &Microcontroller
- Embedded systems design 2ed
- Analog Interfacing to Embedded Microprocessors

Course Lab

Adobe Acrobat Professional - [uni_ds3_manual.pdf]
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Open
Note Tool
Text Edits
Show
Create PDF
Review & Comment
Secure
Sign
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Select Text
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Bookmarks
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SOFTWARE AND HARDWARE SOLUTIONS FOR THE EMBEDDED WORLD
MikroElektronika
Development tools - Books - Compilers
UNI-DS3
User's Manual
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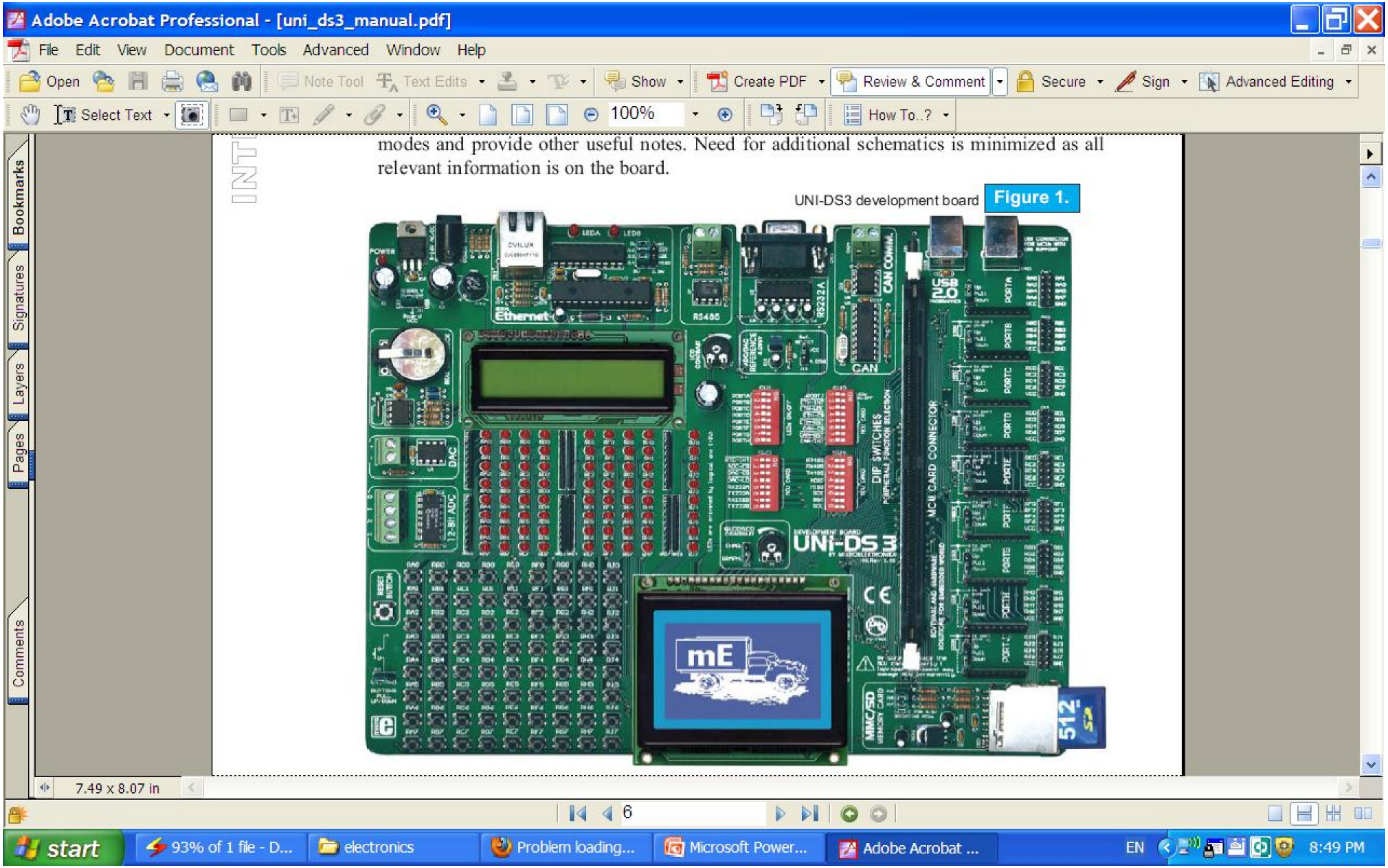
Course Lab



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modes and provide other useful notes. Need for additional schematics is minimized as all relevant information is on the board.
UNI-DS3 development board
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Course Lab

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PLACING MCU CAR
Figure 42. Placing MCU Card
UNI-DS3 development board supports a broad range of MCU families. Each MCU family has it's own MCU Card which can be connected to UNI-DS3 development board via 168-pin connector.
All you have to do in order to switch between different MCU Cards is to remove the exist-
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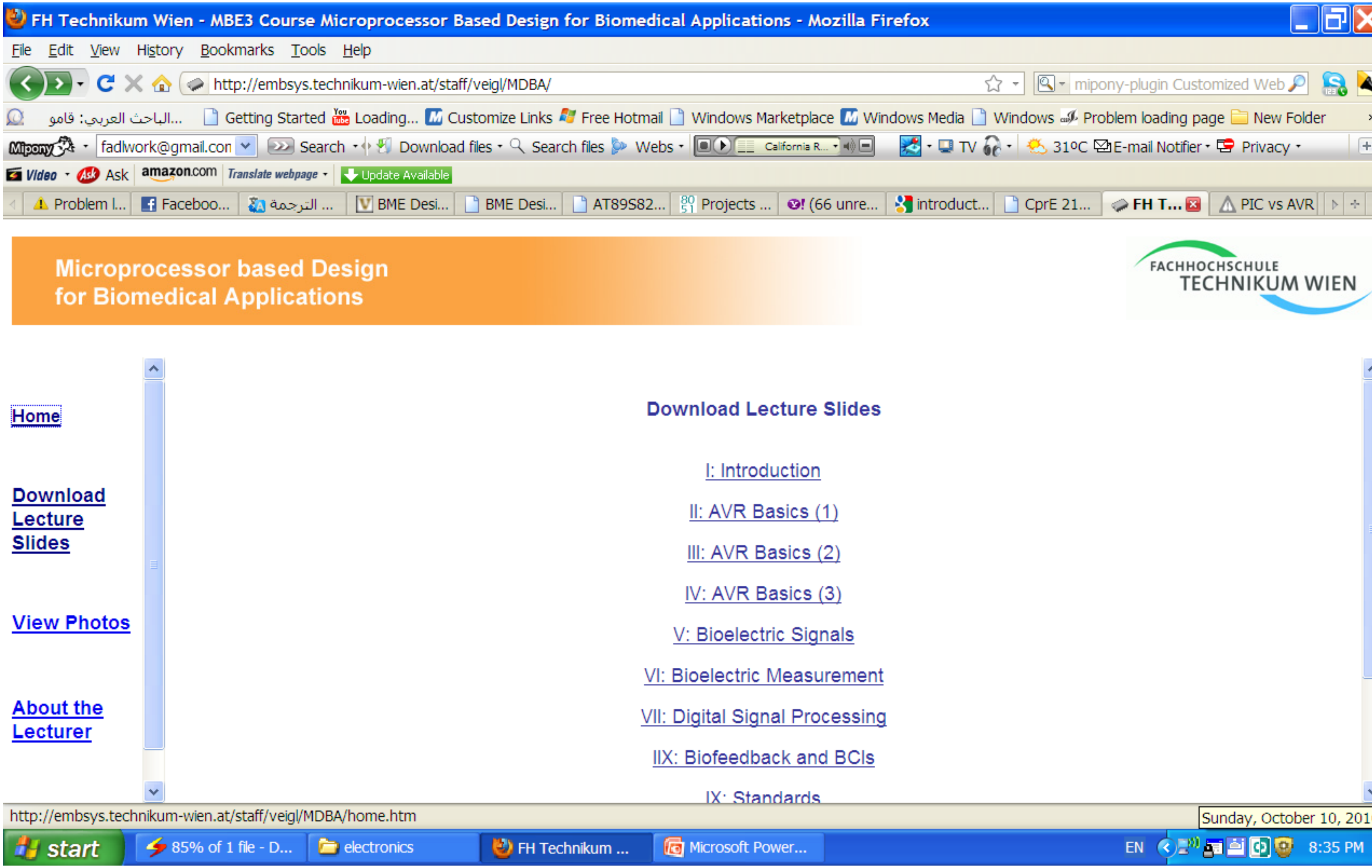
FH Technikum Wien - MBE3 Course Microprocessor Based Design for Biomedical Applications - Mozilla Firefox
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http://embsys.technikum-wien.at/staff/veigl/MDBA/
Microprocessor based Design
for Biomedical Applications
FACHHOCHSCHULE
TECHNIKUM WIEN
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I: Introduction
II: AVR Basics (1)
III: AVR Basics (2)
IV: AVR Basics (3)
V: Bioelectric Signals
VI: Bioelectric Measurement
VII: Digital Signal Processing
IIX: Biofeedback and BCIs
IX: Standards
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CprE 211 Web Site - Mozilla Firefox

http://class.ee.iastate.edu/cpre211/

CprE 211 - Microcontrollers and Digital Systems Design

Department of Electrical & Computer Engineering
Iowa State University

Spring 2007 (under construction)

Course Information:

- Syllabus
- Current Semester's Plan
- Grading Policy
- WebCT
- Announcements
- Distance Education

Contact Information:

- Instructor and TAs

Online Information:

- Lectures
- Notes
- Homework
- Labs
- Frequently Asked Questions
- Useful Links and Resources
- Feedback Forms

Other Information:

http://class.ee.iastate.edu/cpre211/lectures.html


JeffLamoon.Com - A1 Educational Series - Fast revision for English, A Maths, E Maths, Physics, Chemistry and Science - Mozilla Firefox
http://www.jefflamoon.com/others for teenagers.htm
Computer Networks Chapter 10 : Planning and Cabling Networks
Computer Networks Chapter 11 : Configuring and Testing Your Network
The 8051 Microcontroller : INTRODUCTION TO COMPUTING
The 8051 Microcontroller : 8051 MICROCONTROLLERS
The 8051 Microcontroller : ASSEMBLY LANGUAGE PROGRAMMING
The 8051 Microcontroller : JUMP, LOOP, AND CALL INSTRUCTIONS
The 8051 Microcontroller : I/O PORT PROGRAMMING
The 8051 Microcontroller : ADDRESSING MODES
The 8051 Microcontroller : ARITHMETIC, LOGIC INSTRUCTIONS, AND PROGRAMS
The 8051 Microcontroller : HARDWARE CONNECTION AND INTEL HEX FILE
The 8051 Microcontroller : TIMER PROGRAMMING IN ASSEMBLY
The 8051 Microcontroller : SERIAL PORT PROGRAMMING IN ASSEMBLY
The 8051 Microcontroller : INTERRUPTS PROGRAMMING IN ASSEMBLY
The 8051 Microcontroller : INTERFACING TO EXTERNAL MEMORY
Stepper Motor Laboratory
Stepper Motor Video
Electronics - Semiconductors (Read Only File)
Electronics - Diodes (Read Only File)
Electronics - AC Signals and Applications of Diodes (Read Only File)
Electronics - Bipolar Junction Transistor (Read Only File)
Electronics - Transistor Amplifier (Read Only File)
Electronics - Field Effect Transistor (Read Only File)
Pressure - Flow
Industrial Quality -
DIY Prices
gekgasifier.pbworks.com/G
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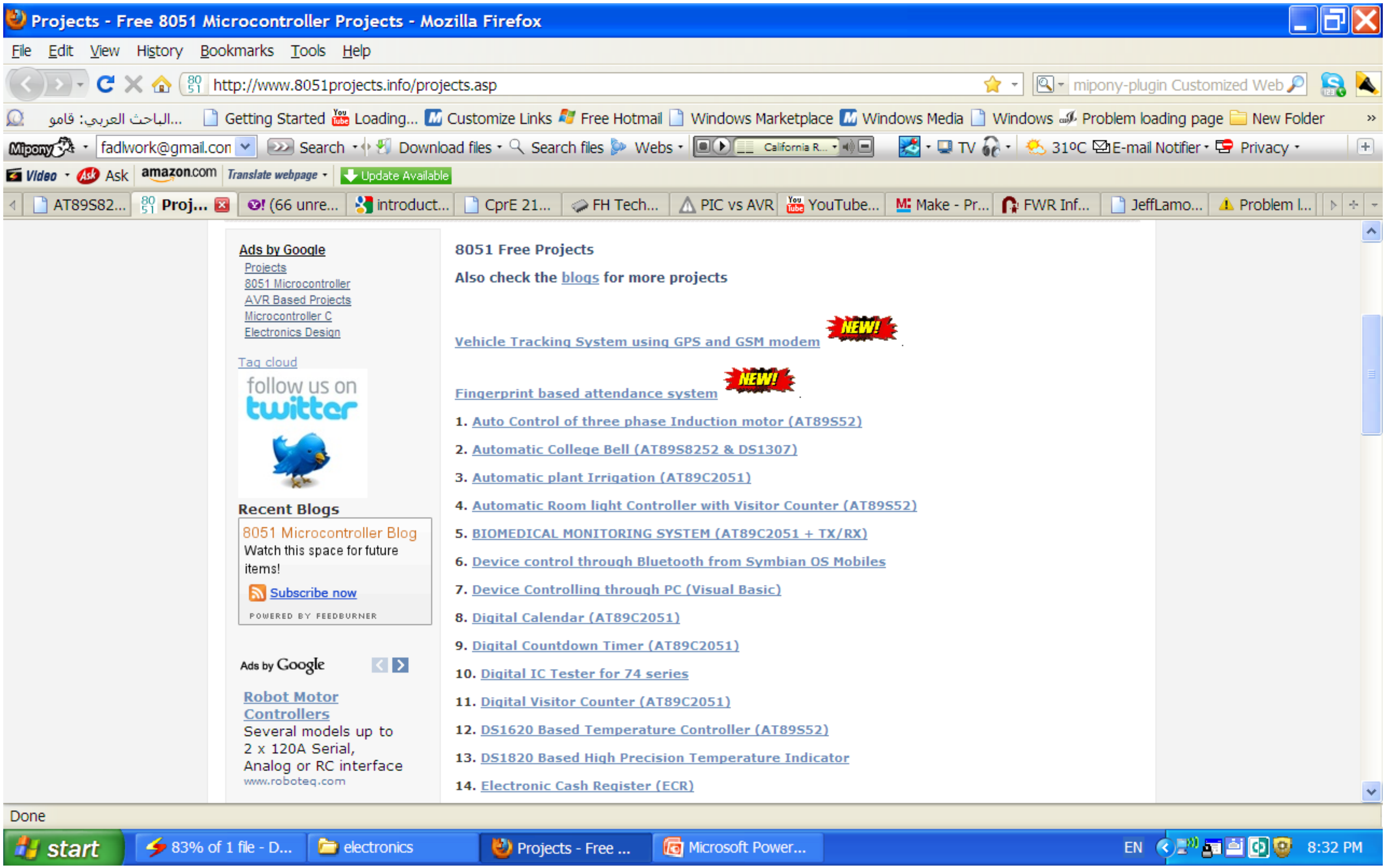
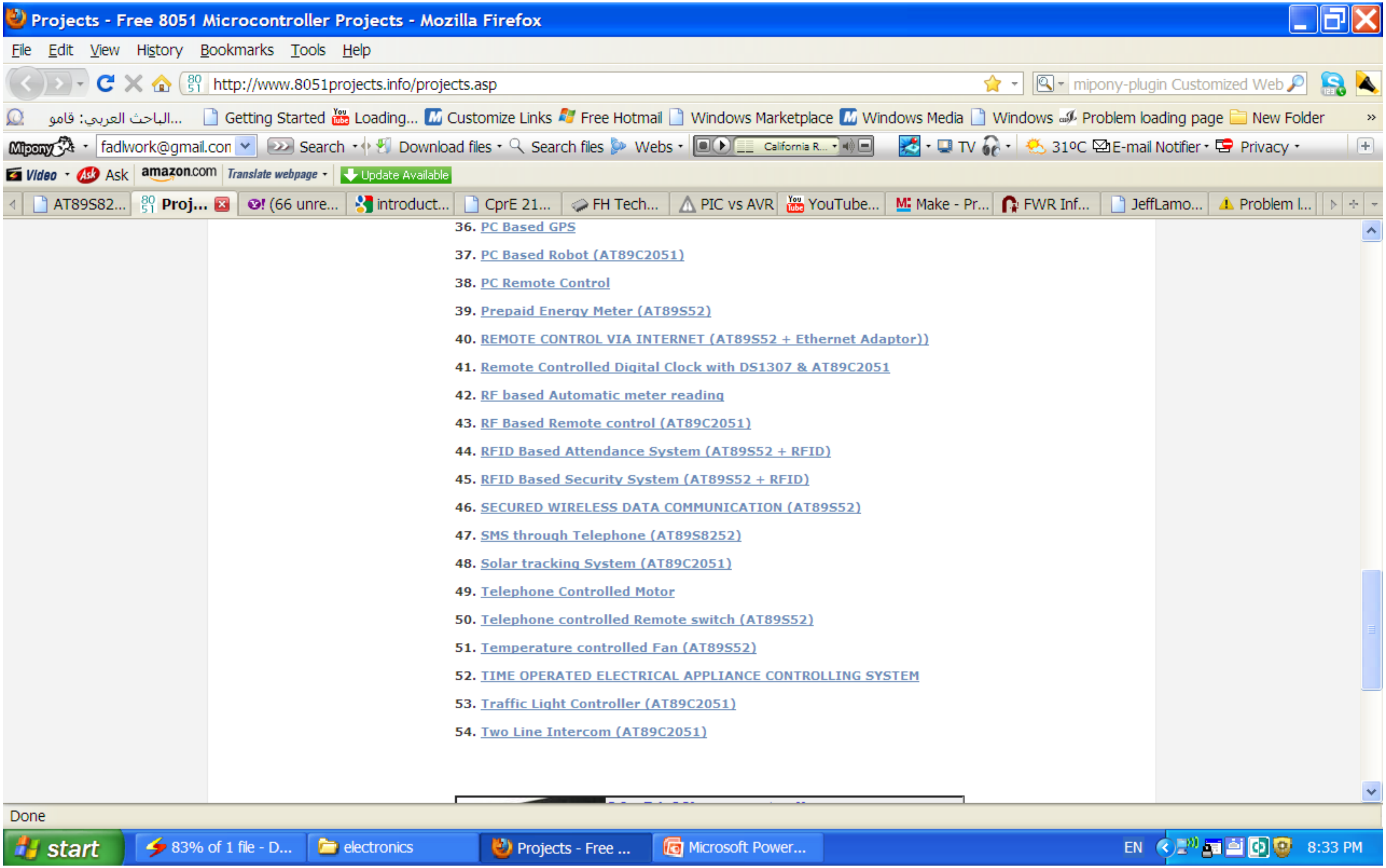
Course Evaluation

Project
Midterm
Attendance
Quiz
Lab
Presentation

Course Projects: Project



Course Projects: Project



Course Presentation

Choose one topics from the below and do a power point presentation:

1
2
3
4
5
6
7
8
9
10
11
12
13

Important comments from the previous course

- Not Excuses
- Not degree explanation (fair assessment)
- In time policy (one day late=one degree loss)
- Join a group (mandatory)
- Update your attendance and results daily.

Group Activity: BME_UST

http://www.facebook.com/search/?q=BME_UST&init=quick#!/group.php?gid=325135515239&ref=search&sid=1096082202.1772363120..1

Microcontrollers in embedded biomedical Applications

Microcontrollers in embedded biomedical Applications:

We want to have systems that :

- **are reliable**
- **are small and lightweight**
- **have a low power consumption**

These issues are critical when we deal with body implants

I: Introduction – Microcontrollers

Some features / advantages of microcontrollers:

- **they are small and flexible**
- **easy to use (most of the time ..)**
- **few external components and wires needed**
- **low and ultra low power designs possible (-> PSoC, ASIC)**
- **wide range of different uCs available (memory, I/O, speed, busses, A/Ds)**
- **data interchange using standard bus systems; -> various peripheral hardware accessible**
- **IDEs and toolchains for firmware programming /**
- **Simulation and high level languages**

-> **90% of the manufactured CPUs** are not found in desktop PCs but in embedded systems, with growing areas of application: RFID, hidden "ubiquitous" computing, wearables, "smart environments", MEMS (micro electro-mechanical systems)

I: Introduction – Microcontrollers

Some examples for uC-based biomed devices / applications:

- various sensors or meters:
  Body temperature, Blood Pressure,
  Blood Sugar Level, …
- Implants and prostetics
- Pacer makers (for heart, breathing, ...)
- functional Electrostimulation
- Orthesis and artificial limbs
- Biosignal acquisition equipment

Adam blood glucose meter

www.heartratemonitor.co.uk

I: Introduction – Microcontrollers

Some examples for uC-based biomed devices / applications:

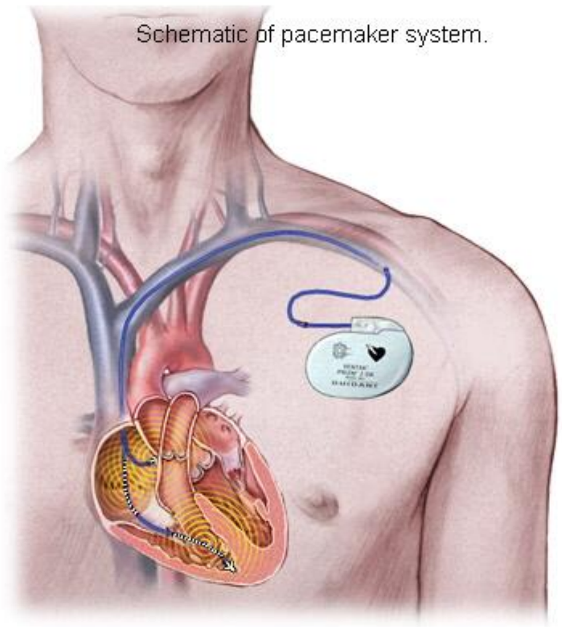
- portable emergency equipment (defibrillator, ..)
- Sports medicine
- Patient monitoring
- “Smart Homes", service robotics
- support of Communication for disabled persons
- wireless sensor networks / Body Area Network (BAN)
- Sensors and Actuators for stationary medical equipment

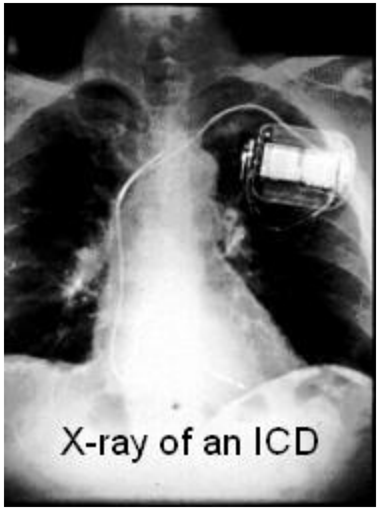
Life-point defibrillator
Spo2 Module

Microcontroller In Research

Pace Makers and Functional Electro-Stimulation

http://www.hgcardio.com/HRhythm/Treatments/a_pacemaker_schematic.jpg

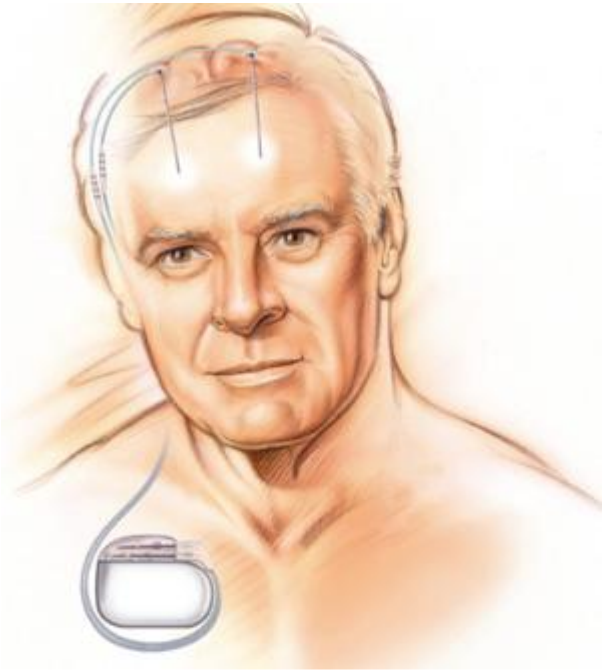


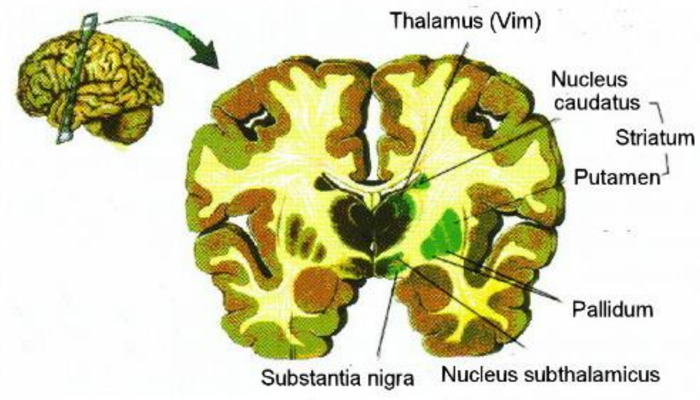


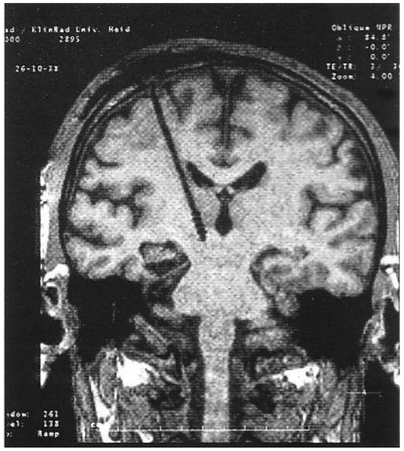
- current pacemakers have 5-7 yrs. battery lifetime
- feedback loops -> adapt to physical needs
- multichannel stimulation and measurement electrodes

Parkinson relief from deep brain stimulation

http://www.firstscience.com/SITE/IMAGES/ARTICLES/dbs/man_pacemaker.jpg
http://www.parkinson-club-u40.de/Hirnschrittmacher.htm



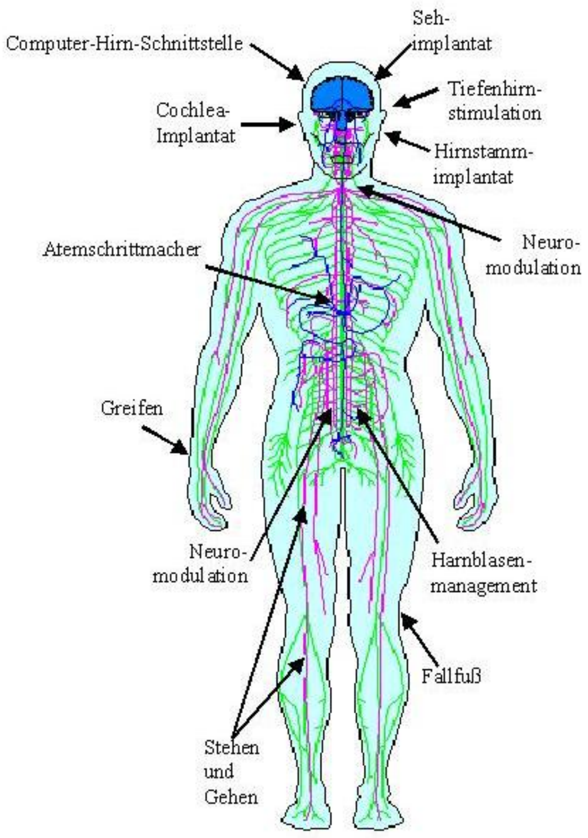




- lack of dopanine in substantia nigra
- hyper-activity of nerve cells
- pacemaker „inactivates“ those cells

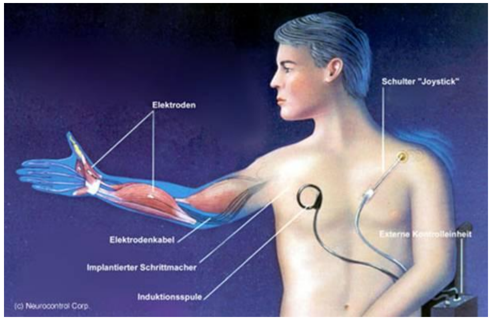
Other Areas for FES - Implants / Pacer Makers

http://www.bio-pro.de/imperia/md/content/bioregionen/freiburg/neuropro.jpg
http://www.altenpflegeschueler.de/krankheiten/querschnittslaehmung.php



Some examples:

- **muscle activation / support**
- **gastrointestinal support**
- **breathing support**
- **chronic pain relief**



Wireless sensor networks

http://www.eecs.harvard.edu

WeC (1999)

Rene (2000)

Dot (2001)

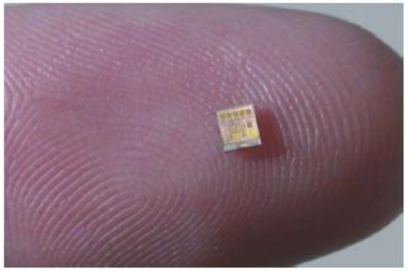
Exciting emerging domain of deeply networked systems

- Low-power, wireless "motes" with tiny amount of CPU/memory
- Large federated networks for high-resolution sensing of environment

Drive towards miniaturization and low power

- Eventual goal - complete systems in 1 mm^3, MEMS sensors
- Family of Berkeley motes as COTS experimental platform

MICA (2002)



Speck (2003)

Wireless sensor networks

http://www.eecs.harvard.edu

Real-time, continuous patient monitoring

- Pre-hospital, in-hospital, and ambulatory monitoring possible
- Replace expensive and cumbersome wired telemetry systems

Home monitoring for chronic and elderly patients

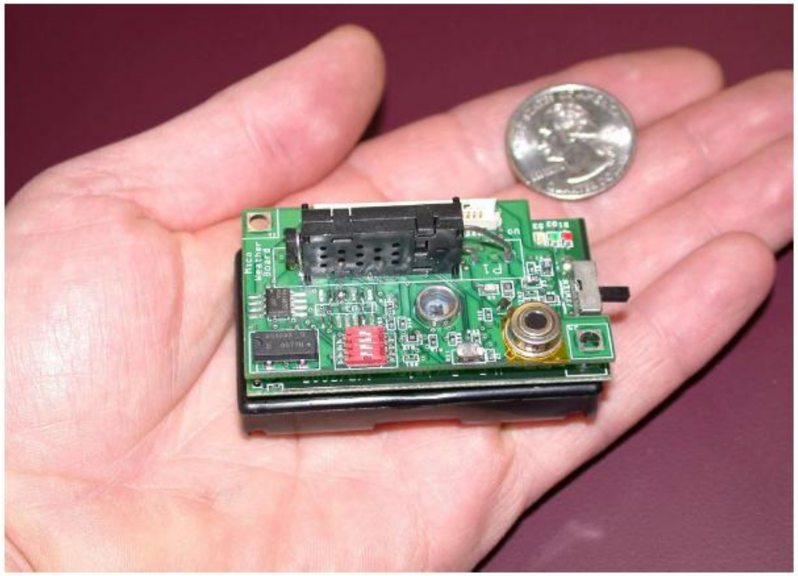
- Collect periodic or continuous data and upload to physician
- Allows long-term care and trend analysis
- Reduce length of hospital stay

Collection of long-term databases of clinical data

- Correlation of biosensor readings with other patient information
- Longitudinal studies across populations
- Study effects of interventions and data mining

Berkeley Mica motes

http://www.eecs.harvard.edu



- ATMEGA 128L (7.3 Mhz 8-bit CPU)
- 128 KB code, 4 KB data SRAM
- 512 KB flash for logging
- 433 or 916 Mhz, 76.8 Kbps radio (100m max)
- Sandwich-on sensor boards
- Powered by 2AA batteries

Several thousand produced, used by 100s of research groups

- Get yours at www.xbow.com, about $150 a pop

Great platform for experimentation (though not particularly small)

- Easy to integrate new sensors & actuators
- 15-20 mA active (5-6 days on 2 AAs)
- 15 µA sleeping (21 years, but limited by shelf life of battery!)

Sensor Net Challenges

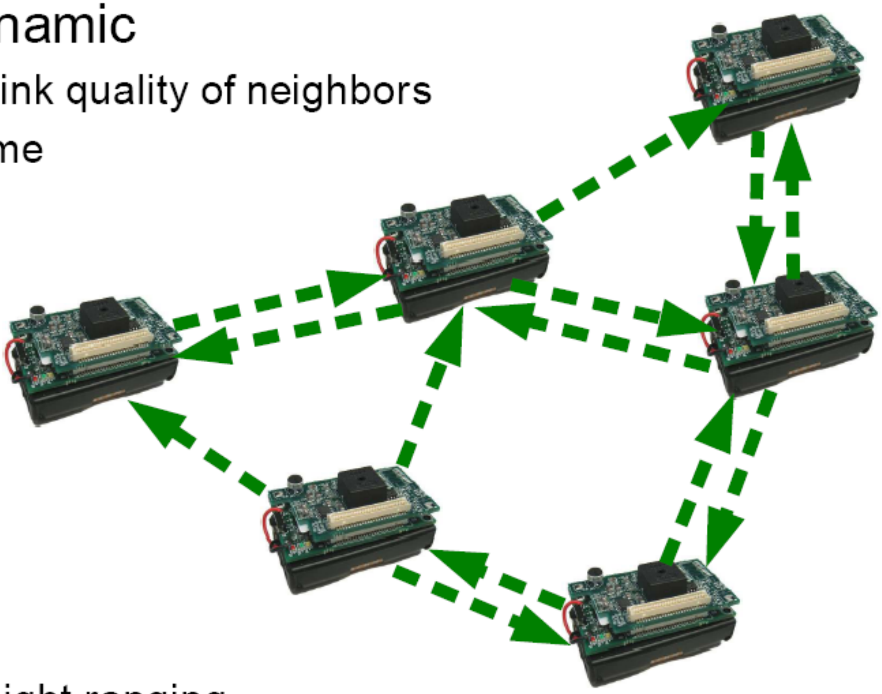
http://www.eecs.harvard.edu

Multihop routing is extremely dynamic

- Nodes must continuously evaluate link quality of neighbors
- Collect packet loss statistics over time
- Periodically broadcast “link report”

Time synchronization

- Complex link dynamics make this difficult
- Scaling and overhead of time sync traffic is an issue



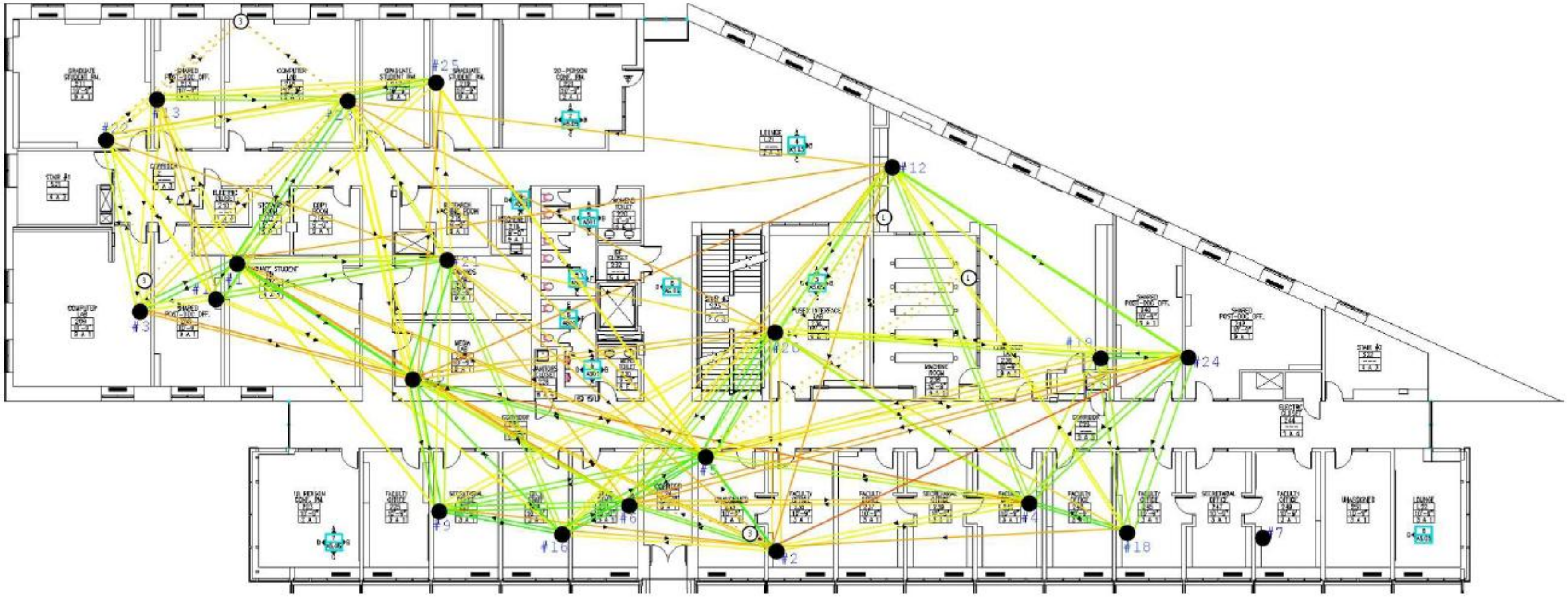
Localization

- Commonly use ultrasound time-of-flight ranging
- Send RF and ultrasound pulse simultaneously
- Lots of difficulties arise due to lack of receiver calibration
- RF-signature based localization achieves indoor accuracy of 2-3 meters

Sensor Net Challenges

Radio connectivity is highly volatile!

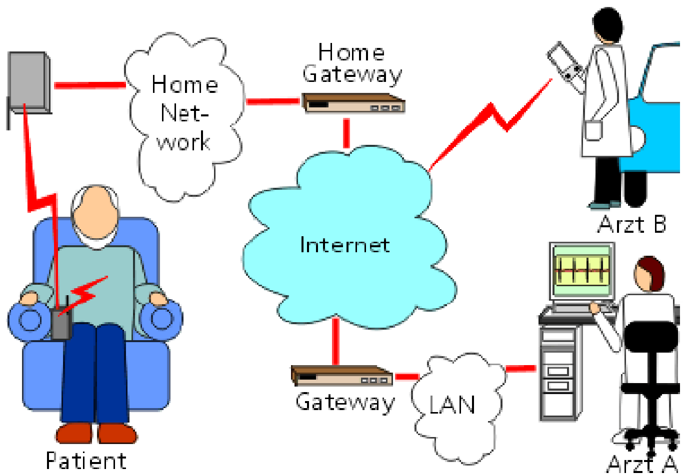
- Packet loss not well correlated with distance
- Affected by receiver sensitivity, wall attenuation, antenna orientation, etc.
- Many links are asymmetric!

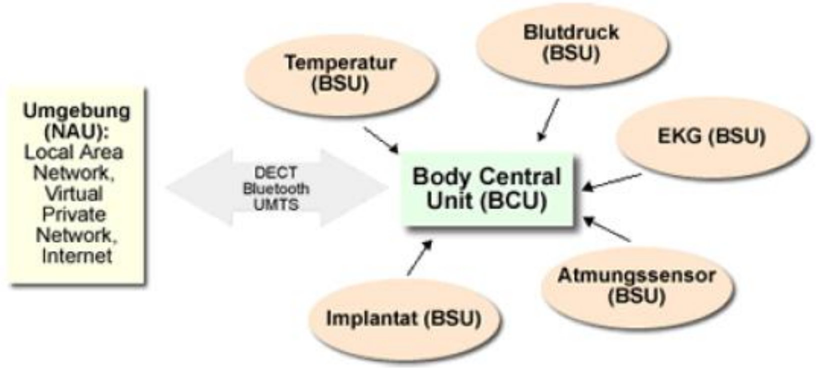


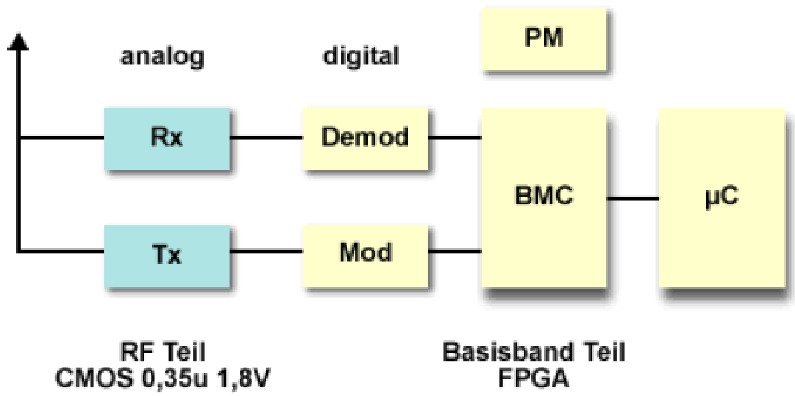
motelab.eecs.harvard.edu

BAN: Body Area Networks

- wireless low power transmission of biological parameters to a base station (internet gateway)
- Harmonization with Standards for biomedical Data exchange: DICOM / HL7 / IEEE11073
- HomeCare and Clinical use







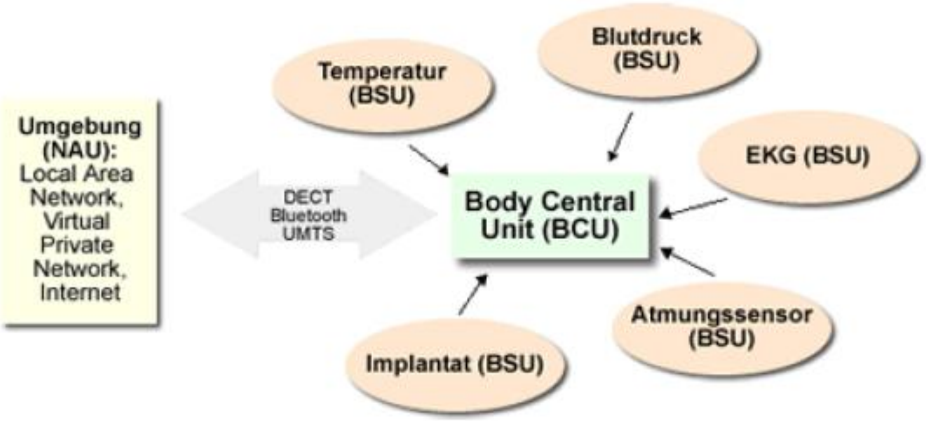
BAN: Body Area Networks

- 400-MHz radio link
  low transmission ranges and low power

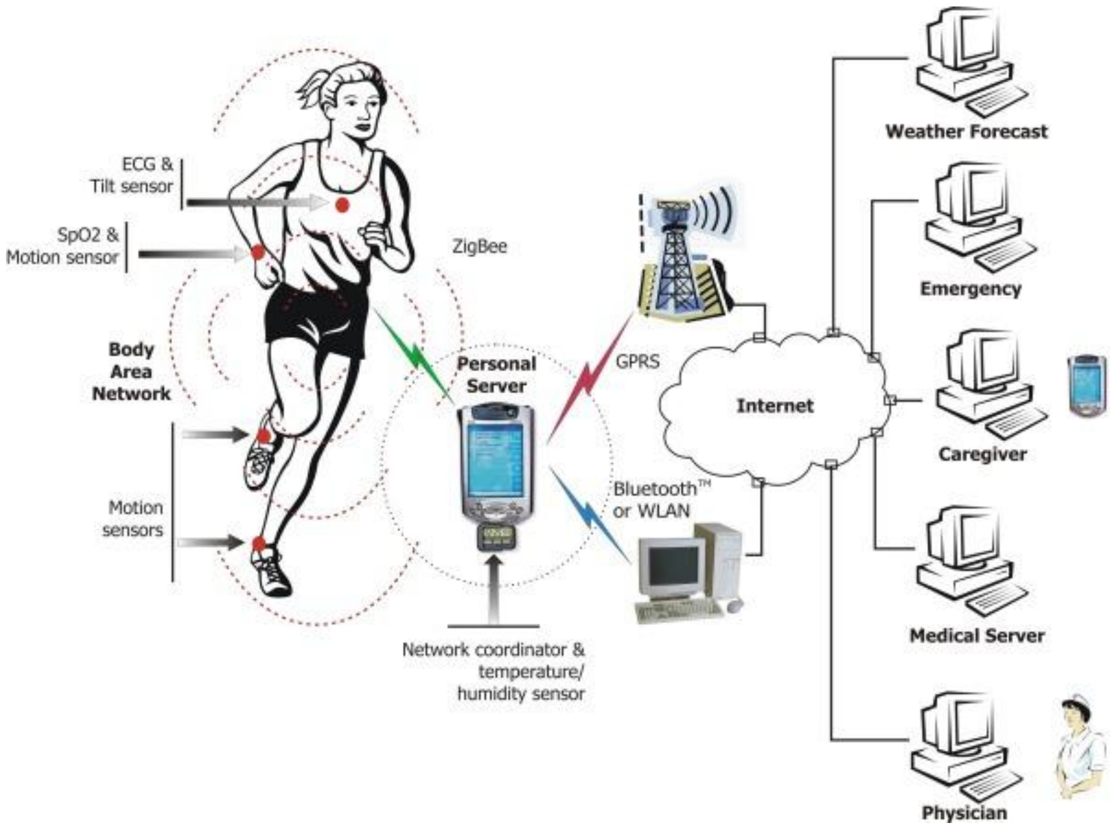
- Integration of Implants and wireless
  technologies: Zigbee, Bluetooth,..

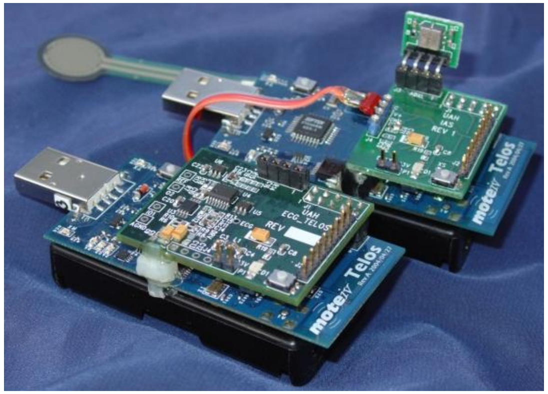
- early detection of critical states, wireless
  integration of sensors and effectors inside or
  worn on the body

- challenges: reliability / safety, interoperability,
  privacy, size, low-power operation, …



BAN: Body Area Networks



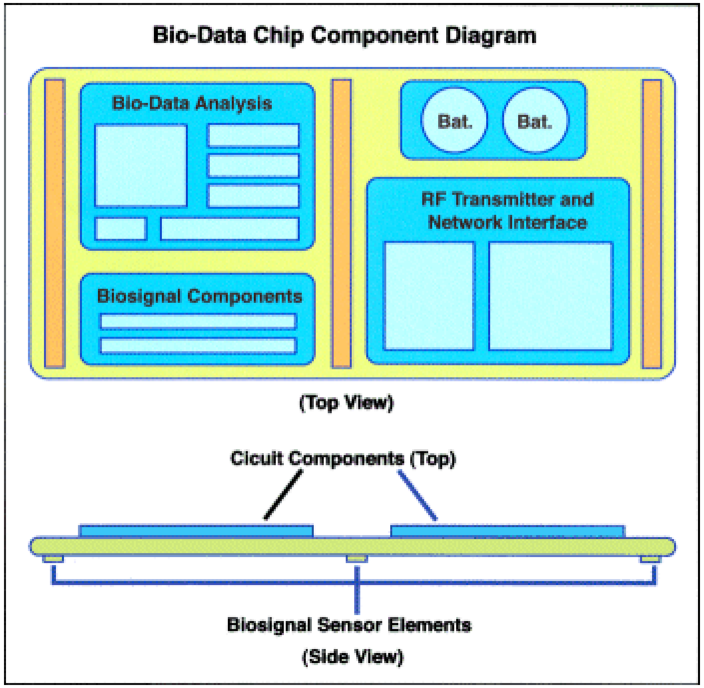


WHMS: Wearable Health Monitoring Systems, University of Alabama
http://www.ece.uah.edu/~jovanov

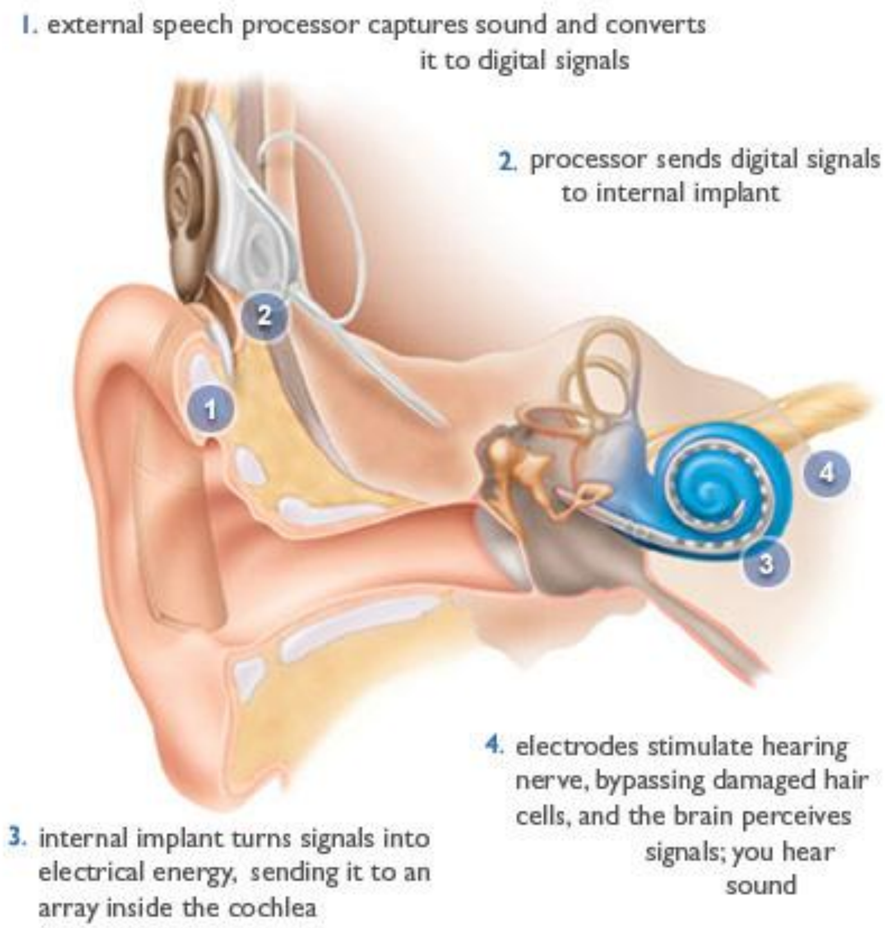
„Bio-DataChip“

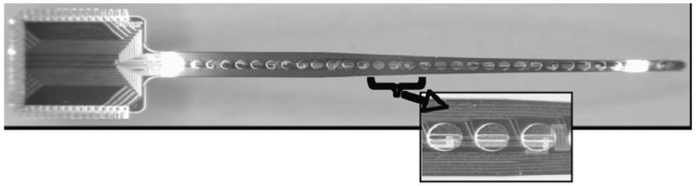
- „Dry" sensor - requires no electrolytes
- processor and firmware (downloadable)
- RF transmitter with network software
- basic layout size = 10 X 25 mm

http://www.biocontrol.com



Cochlear Implants



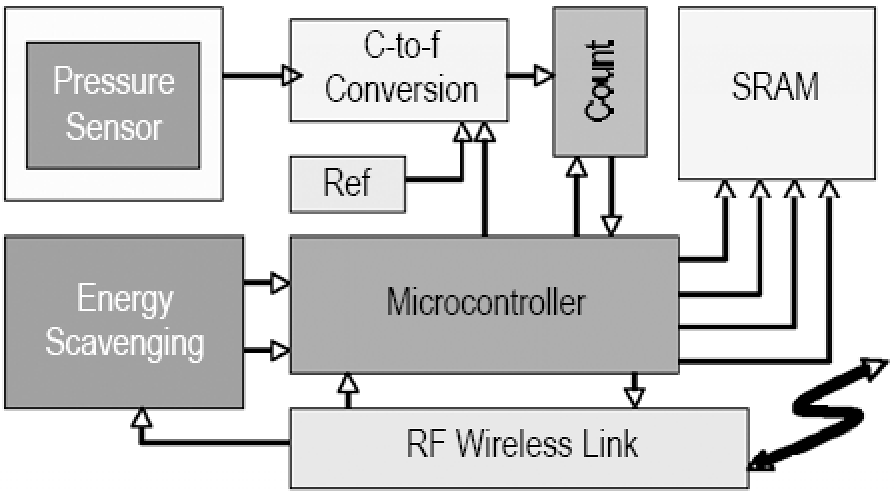


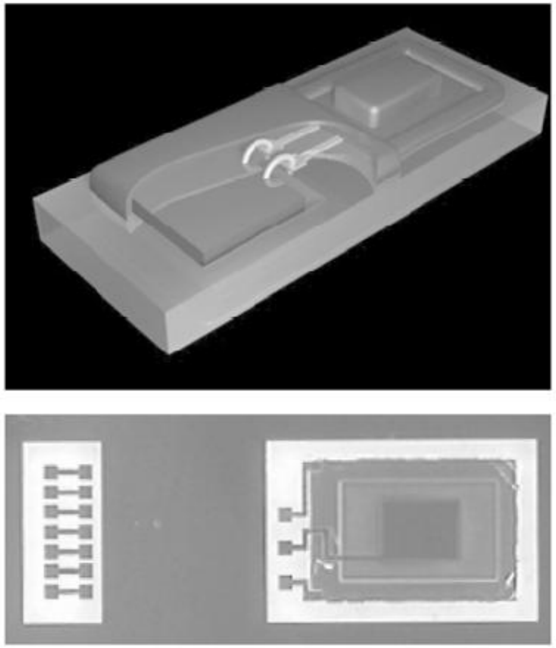
128-site-16-channel elecrode array

http://www.theuniversityhospital.com/cochlearweb

http://www.wimserc.org

Micropower intra-ocular pressure sensor

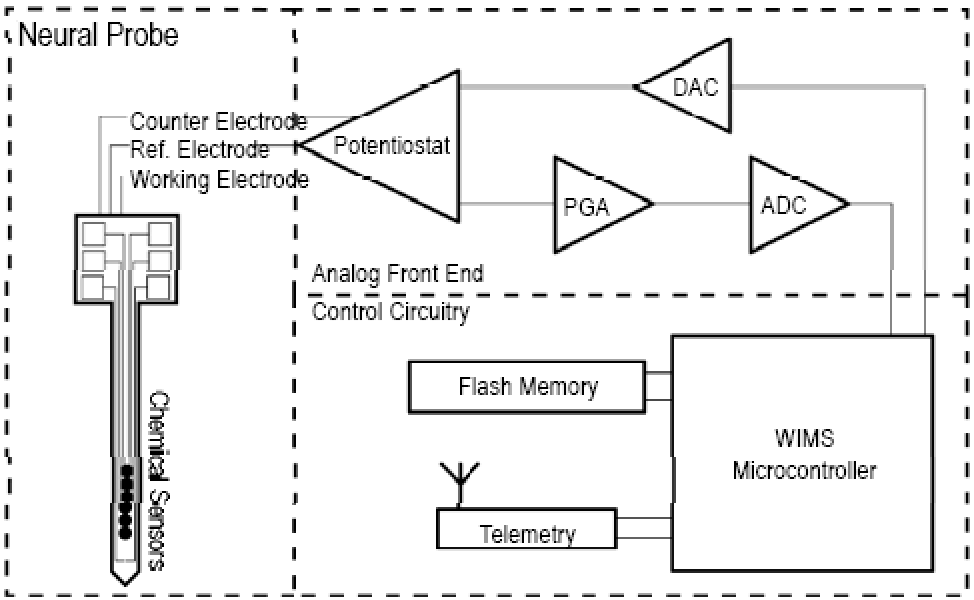




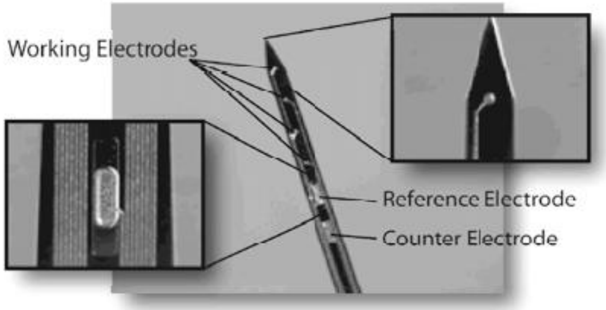
Drawing of the intraocular sensor together with a top view of the pressure sensor (below).

http://www.wimserc.org

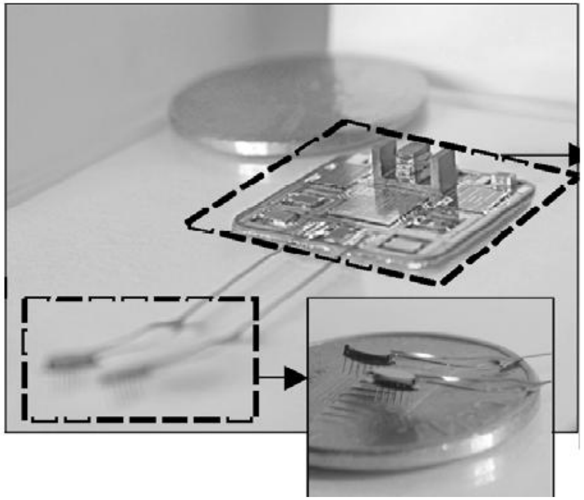
Implantable neurochemical sensing system



Conceptual Neurochemical Sensing System.

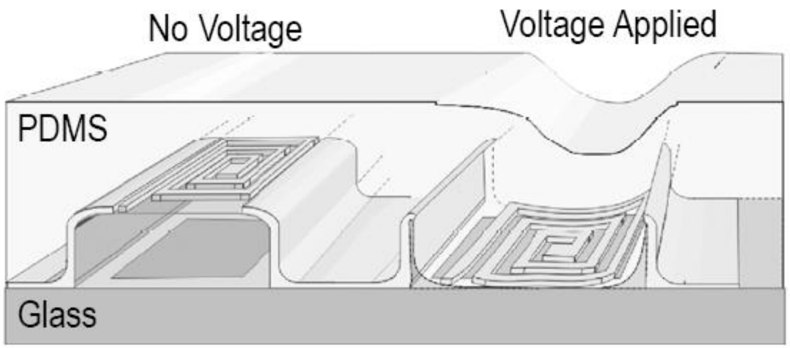


Fabricated neural probe with on-chip reference, counter, and working electrodes.

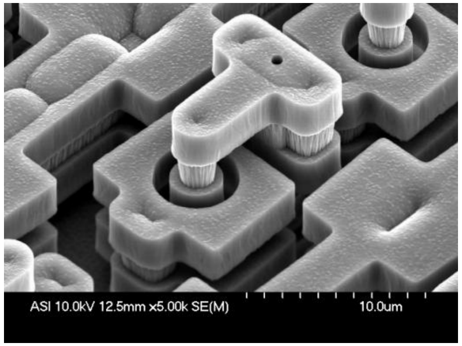


http://www.wimserc.org

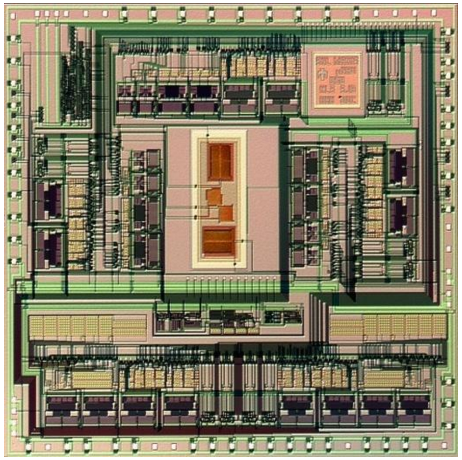
MEMS: Micro Electro Mechanical Systems



Electrostatic Actuator for chronic drug dosing



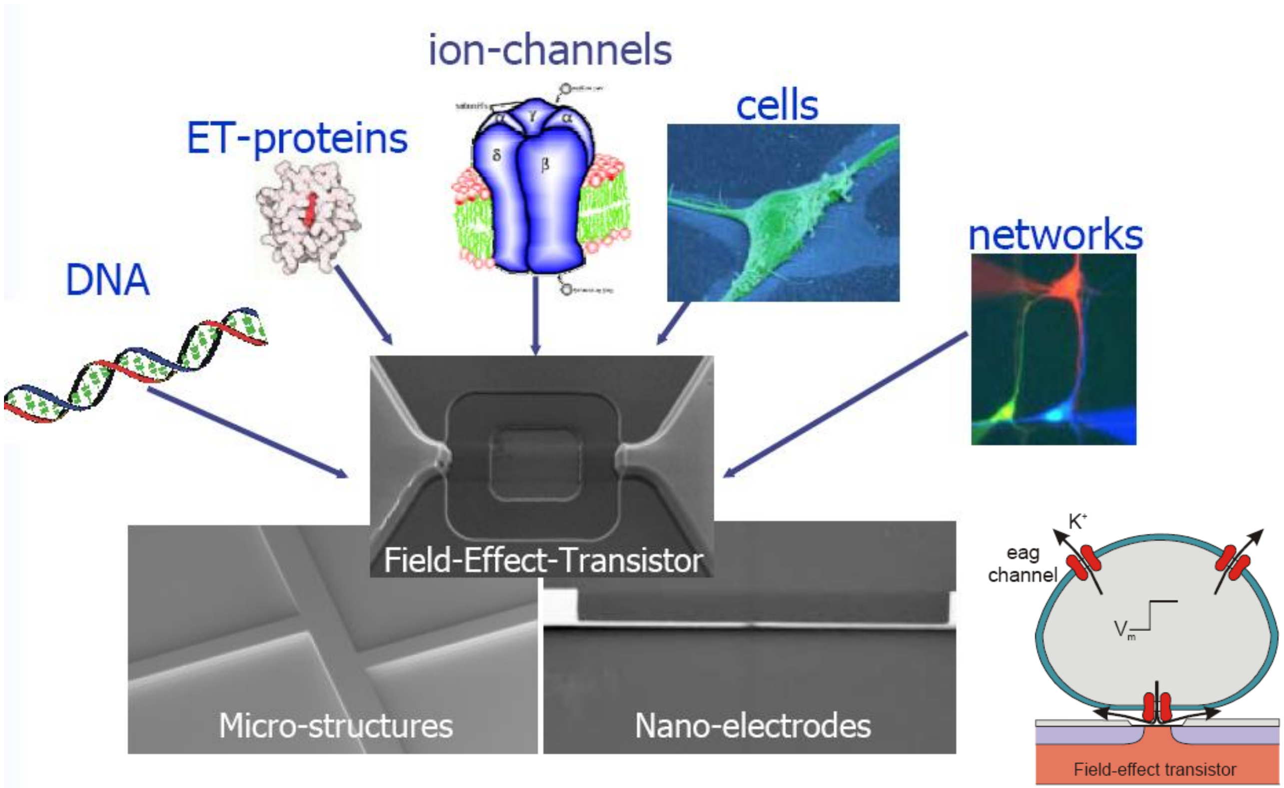
Mechanic actuator

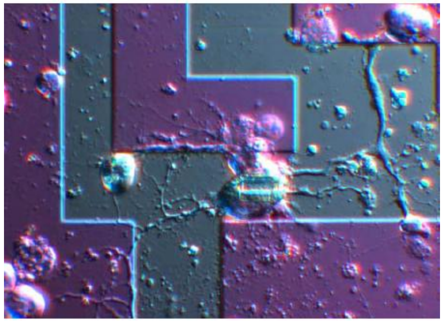


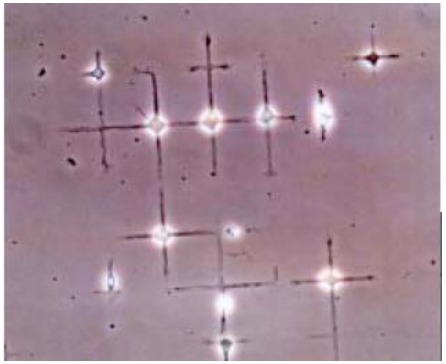
Accelerometer

http://www.wimserc.org
http:// www.memx.com
http://mems.sandia.gov/about/electro-mechanical.html

Bioelectronic hybrids, cellular lithography







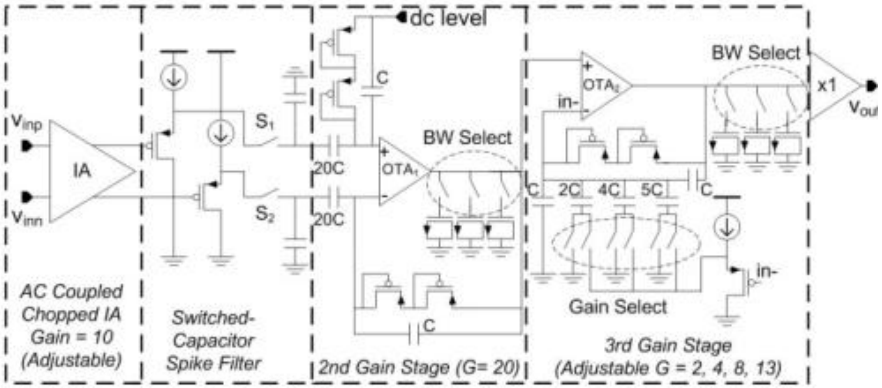
Forschungszentrum Jülich, http://www.fz-juelich.de/isg

Ultra-low-power biopotential measurement front-end ASIC

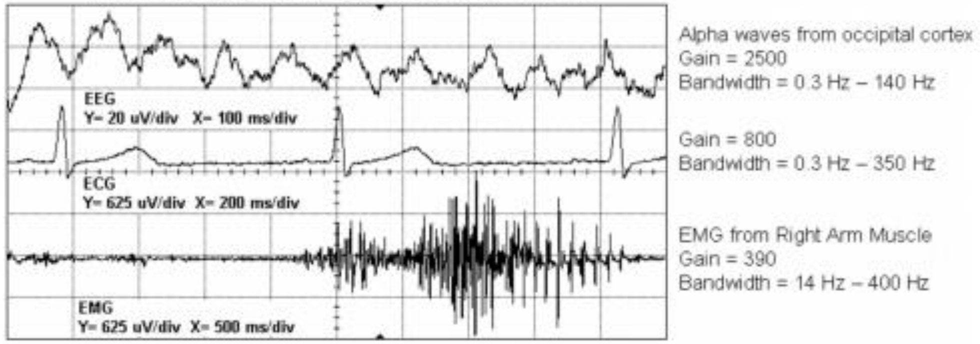
www.imec.be

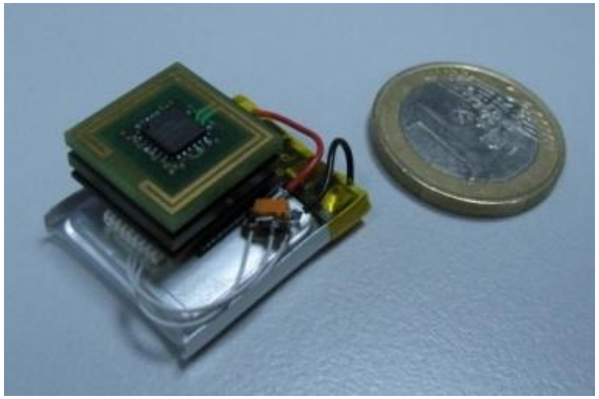
EEG, ECG, and EMG signals (single channel)

- **Circuit consumption 20µA from 3V,**
- **CMRR > 110dB,**
- **50mV DC electrode offset**
- **3D stack technology: 1cm3**



Extracted Biopotential Signals (Input Referred)





Current Consumption of Channel Blocks

Building Blocks of Front-End	Current Cons.
Chopped IA	11.1 µA
Spike Filter	800 nA
Second Gain Stage	1.4 µA
Third Gain Stage	750 nA
Channel Buffer	2.4 µA
Bias Buffer Opamps	2*0.6 µA
Bias Circuit	2.4 µA
Total Current Consump.	**20 µA**
Total Power Dissipation	**60 µW**

Measured Characteristics of the Front-End

Voltage Supply	3 V
Current Consumption	20 µA
Electronic Gain Selection	390, 800, 1450, 2500
Continuous Gain Adjustment	via R_2
Equivalent Input Referred Noise	$60\,nV/\sqrt{Hz}$
CMRR (0 mv Electrode Offset)	>120 dB
CMRR (50 mV Electrode Offset)	> 110 dB
Low cut-off frequency	Adjustable via external capacitance
High cut-off frequency	Electronically selectable

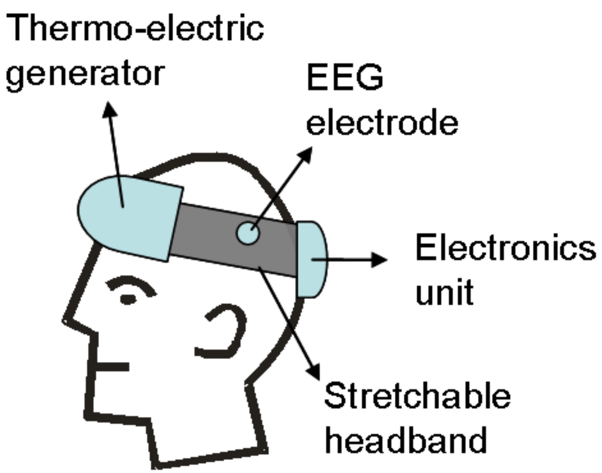
EEG system powered by body heat

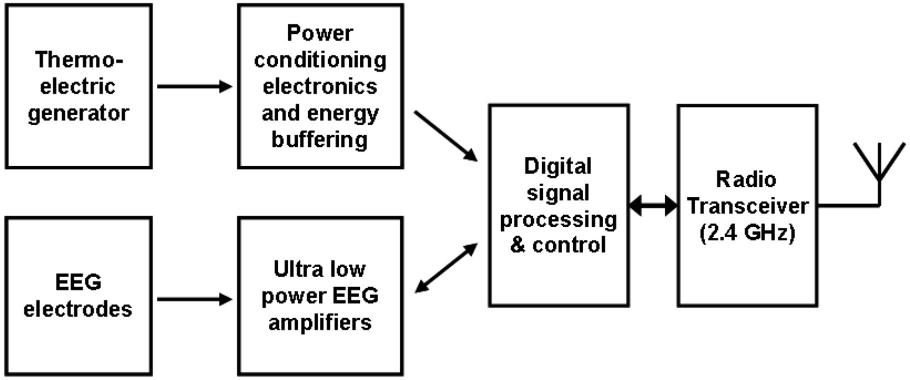
www.imec.be, www.holstcenter.com

- 2 chn EEG unit, 2,4Ghz wireless transceiver
  Circuit consumption: 0.8 mW

- Thermoelectric generator converts
  heat flow between skin and air
  2-2,5mW at room temperature

- Operational in < one minute





In a medical Context:

Dependability and Fault Tolerance are major issues.

- **Failsafe: safe state after failure**
- **Fault recovery: normal operation can be restored**
- **Gracefully Degradation:**
  system continues (restricted) work

MTBF Mean Time Between Failure
Environment conditions / Materials

Redundant Hardware / Software makes sense here !

System Design and Integration:

- Hardware Selection for Development / Production
- Hardware and Software Co - Development
- System Modelling and Simulation, UML

The earlier a design bug is found, the better !

History of Microprocessors

- 1950s - The beginning of the digital era and electronic computing
- 1969 – Intel is a small startup company in Santa Clara with 12 employees
  - Fairchild, Motorola are large semiconductor companies; HP and Busicom make calculators
- 1971 – Intel makes first microprocessor the 4-bit 4004 series for Busicom calculators
- 1972 – Intel makes the 8008 series, an 8-bit microprocessor,
  - ATARI is a startup company
  - Creates a gaming console and releases PONG

History of Microprocessors

- 1974 – the first real useful 8-bit microprocessor is released by Intel – the 8080
  - Motorola introduces the 6800 series
  - Zilog has the Z80
- 1975 – GM and Ford begin to put microcontrollers in cars
  - Many cars today have over 100 microcontrollers
  - TI gets into the microprocessor business with calculators and digital watches
- 1977 – Apple II is released using MOS 6502 (similar to motorola 6800). Apple II dominated from 1977 to 1983
- 1978 – Intel introduces the first 16-bit processor, the 8086
  - Motorola follows with the 68000 which is ultimately used in the first Apple Macintosh

History of Microprocessors

- 1981 – IBM enters the PC making market and uses the Intel 8088 – proliferation of the home computer
- 1982-1985 – Intel introduces the 32-bit 80286 and 80386
- 1989 – 80486 is being used in PC's, able to run Microsoft Windows
- 1992 – Apple, IBM and Motorola begin to make PowerMac and PowerPC's using Motorola chips
- 1993 – Pentium chip is released
- The rest is history

Discussion

- What are some components of a computer?
- What is a Microprocessor?
- A Microcontroller?
- An Embedded System?

Components of a Computer

- Central Processing Unit
  - Interprets and carries out all the instructions contained in software
- Memory
  - Used to store instructions and data
  - Random Access Memory (RAM)
  - Read Only Memory (ROM)
- Input/Output
  - Used to communicate with the outside world

Microprocessor

- A single chip that contains a whole CPU
  - Has the ability to fetch and execute instructions stored in memory
  - Has the ability to access external memory, external I/O and other peripherals
- Examples:
  - Intel P4 or AMD Athlon in desktops/notebooks
  - ARM processor in Apple iPod

Microcontroller

- Essentially a microprocessor with on-chip memories and I/O devices
- Designed for specific functions
- All in one solution - Reduction in chip count
  - Reduced cost, power, physical size, etc.
- Examples
  - MC68332, MC68HC11, PPC555
- More details of components later
  - A/D converters, temperature sensors, communications, timing circuits, many others

Embedded System

- Special purpose computer system usually completely inside the device it controls
- Has specific requirements and performs pre-defined tasks
- Cost reduction compared to general purpose processor
- Different design criteria
  - Performance
  - Reliability
  - Availability
  - Safety

Why Study Microcontroller

The course may serve several purposes:

- Build useful applications
- Practice programming and debugging skills
- Understand the inside of computer

It paves the way to learning computer design, operating systems, compilers, embedded systems, security and other topics.

- Microcontrollers have everything in a typical computer: CPU, memory and I/O.

The 8051 Microcontroller and Embedded Systems

CHAPTER 0

INTRODUCTION TO COMPUTING

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CHAPTER 1

THE 8051 MICROCONTROLLERS

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CHAPTER 2

8051 ASSEMBLY LANGUAGE PROGRAMMING

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CHAPTER 4

I/O PORT PROGRAMMING

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CHAPTER 5

8051 ADDRESSING MODES

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CHAPTER 6

ARITHMETIC, LOGIC INSTRUCTIONS, AND PROGRAMS

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CHAPTER 8

8051 HARDWARE CONNECTION AND INTEL HEX FILE

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8051 HARDWARE CONNECTION AND INTEL HEX FILE

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CHAPTER 9

8051 TIMER PROGRAMMING IN ASSEMBLY

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8051 TIMER PROGRAMMING IN ASSEMBLY

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CHAPTER 10

8051 SERIAL PORT PROGRAMMING IN ASSEMBLY

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CHAPTER 11

INTERRUPTS PROGRAMMING IN ASSEMBLY